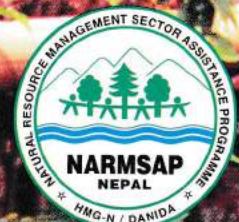


Soil Conservation and Watershed Management Measures and Low Cost Techniques



**Soil Conservation and Watershed
Management Component
(NARMSAP)
Department of Soil Conservation and
Watershed Management
2004**



Preface

Many works have been done in the low cost soil conservation. However, the works have been scattered in many publications. Its compilation in appropriate formats for the mid-level technicians working in the Department of Soil Conservation and Watershed Management has been a need to promote low cost soil conservation measures. Here an attempt is made to compile information on soil conservation and watershed management measures and low cost techniques related with the scope and mandate of the Department of Soil Conservation and Watershed Management. Pragmatic aspects of the techniques and steps have been emphasized while preparing the material. For in-depth knowledge and information it is recommended to consult with respective specialist and references. To keep the material simple, no citation is made in the text. However, references used for each section are listed at the end of the chapter in brief and the details are given in the references.

Promotion of the soil conservation and watershed management measures and low cost techniques to the farmers / communities is one major issue, which needs to be dealt in the conservation extension training. This book basically deals with the technical aspects of the low cost soil conservation and watershed management measures and techniques.

Soil Conservation and Watershed Management Component (SCWMC) of the Natural Resource Management Sector Assistance Programme (NARMSAP) has also prepared training materials and conducted training on Conservation Extension and Bioengineering and Survey Design and Estimation. This material could be considered as complementary to those prepared for the Conservation Extension and Bioengineering and Survey Design and Estimation.

The material is tested in the "Trainers' Training" on the subject given to the officers working in the District Soil Conservation Offices, Regional Training Centers and NARMSAP Regional Support Units. And appropriate improvement on the material has been made.

Field practitioners are advised to make notes on: **Observed in the Field** (If anything similar technique / activity is observed in the field, describe including impact), **Drawbacks observed, Recommendations to solve the drawbacks, and Recommended Survey / Design / Practical Tips or Considerations** as given in Annex 3 for the future improvement of their own.

The material is recommended for use as handout for the training as well. Use of this material for the training varies depending on the level of the trainees and resource person. Therefore, it is recommended to design session plan and training schedule to suit the target group and resource person. However, the training schedule used during the Trainers' Training and piloting of the training are given in the Annex 4.

Mr. Keshar Man Sthapit, Senior Programme Officer from Soil Conservation and Watershed Management Component, Mr. Yashu Nath Yogi, Programme Officer from NARMSAP Regional Programme Office-Far-western Region, Mr. Krishna Prasad Poudel, District Soil Conservation Officer from Lamjung District and Mr. Kamal Prasad Gautam, District Soil Conservation Officer from Rasuwa District, Mr. Chandra Man Shrestha, Horticulture Officer from District Agriculture Development Office, Lamjung are involved in the compilation of this material.

Preparation of this material is by no means complete. Its continuous improvement by adding technical information, case studies and design tips is highly desirable.

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2. What is Low Cost Soil Conservation Measures ?

Low cost soil conservation measures are characterized by:-

- **Affordability**: The cost of the techniques must be sufficiently low so that the farmers along with the supporting agency could afford it.
- **Use of Local Material**: Technique must use local materials, so that farmer could implement the activity using the materials available in the locality. It will help in mobilizing local resource.
- **Easy to Use**: Technique must be simple, so that target group could implement the activity with minimum backstopping from the technicians.
- **Easy to Maintain**: Maintenance of the activity must be easy and simple, so that farmer can maintain using local materials and with minimum support from the technicians.
- **Stability (Long-term)**: As time passes, the activity develops its stability. For example: as the vegetation grows in the gully, its roots will firmly be grounded in the soil making the gully treatment more stable. Similarly, in the clay pond as time passes the clay will reduce the seepage loss.
- **Environment Friendly**: Techniques should incorporate more vegetative activities, so that with the time lapse the area will be covered with greenery. Similarly, it must not create adverse effects on the environment. It must not disturb the natural water flow, and existing vegetation such as haphazard dumping of the cut soil.

As an Example of the Low Cost Soil Conservation Activity, Kumpur Sub-watershed Dhading



- High Cost Raised Conservation Pond with Cement-Stone Mortar Wall and Concrete Floor. Requires external project support to construct. Total cost = NRs. 85,445.
- Needs engineering design and intense technical supervision.
- Needs skilled labor and construction materials such as stone, sand, etc. which may not be available locally and relatively costly.
- Needs cement to be procured from outside flowing major cost outside the community.
- Normally for single use such as storing water for irrigation.
- Maintenance needs external support to procure cement.
- No vegetation is integrated. Looks exotic.
- Difficult to replicate by the community.

- Low cost conservation pond made by the farmer with mud wall covered with vegetation and clay floor.
- Does not need engineering design and supervision. Farmers could do.
- Needs unskilled labor and uses all local materials. Normally labor intensive and construction cost remains in the local community.
- Normally for multiple uses i.e. storing water for irrigation, fish farming, drinking and bathing for livestock, etc.
- Farmers could maintain themselves without any external assistance.
- Looks indigenous and homely.
- Easy to replicate by the community.

Introduction to Low Cost Soil Conservation Measures

1. What is Soil Conservation ?

Soil Conservation is defined as “the use, regulation, and treatment of water and land resource to maintain and / or improve soil productivity and prevent land degradation”. Application of soil conservation considering watershed as working unit is known as watershed management.

Some important principles for promoting soil conservation work may be described as follows:-

- **Soil Conservation Begins with Proper Land Use.** Proper land use in most cases can prevent erosion which is more economic and feasible than rehabilitating the land after severe erosion.
- **Soil Conservation is More than Erosion Control.** Although, land degradation control is a major and important task in soil conservation, production function of the conservation work should also be equally emphasized.

Land degradation includes soil erosion, acidification and water logging. Maintenance and /or improvement of soil fertility measures include maintenance of organic matter, soil physical properties and nutrients and avoidance of toxicity in addition to soil erosion.

- **Soil Conservation should Benefit the Land, Farmer, as well as the Nation.** Benefiting one without others may have adverse effects and should not be considered as sound, fair or proper.
- **Soil Conservation Work Needs to be Integrated into Farming Systems.** If soil conservation work can be integrated into the local farming systems, it will be automatically or easily adopted by farmers.
- **Farmers' Participation is the Key to the Success of Soil Conservation Work.** Any such programme needs to involve farmers' participation starting from planning, implementation, maintenance and benefit sharing through extension and education. Incentives/ subsidies may be provided as required.
- **Soil Conservation Techniques are Field Specific and Farmers Should have the Right to Choose.** Soil conservation techniques should be designed to suit the local conditions and should also offer a series of alternatives for farmers to choose from according to their individual interest, resource and land use plan. To impose any measure without considering the needs of the site and farmers is destined to fail.
- **Good Coordination and Integrated Approach are Necessary.** Soil conservation is an inter-disciplinary work. Good co-ordination among related agencies and an integrated approach are both necessary.

Soil erosion in Nepal is an integral part of the country's steep topography integrated with the heavy and intense monsoon rain, and unstable and weak geologic formation. Land degradation problem in the country, which is further exacerbated due to the over exploitation of land and water in Nepal, is huge. Whereas the resource available to encounter the land degradation problems and to maintain and / or improve the soil fertility is very small compared to the scale of the problem. There are many farmers seeking assistance to implement many activities with limited resources at their disposal. Therefore, low cost soil conservation measures for the agriculture based developing country like Nepal is very important.

3. Why Not Fully Adopted?

Despite full acceptance of its need and importance of the low cost soil conservation, its' wide application in the projects and programme is still not satisfactory. Following may be described as some of the major constraints or hindrances.

3.1. Inadequate Technical Confidence/Competency

Field staff facilitating the community in the implementation of soil conservation measures must have wide range of knowledge on the low cost measures to recommend different alternatives to address the community's needs. Simply knowing the techniques is not sufficient to a facilitator. Understanding oneself and making others understand is more complicated. S/he has to be able to convince the community that proposed techniques fulfill the community's needs and is more beneficial. S/he must have conceptual clarity so that community could be fully convinced. Community may have different confusions or queries regarding the recommended low cost activities. The facilitator must be able to answer those.

3.2. Looked as Problem Not as Process (Activity Considered as Solution Rather A Process)

Generally, the technician looks at the community's need as a problem and recommends a measure to address the need. Rather it is more important that the technician analyses the community's need from the process point of view. The technician should understand different inter-linked cause and effects of the issue and recommend a complete package solution to the need. Convincing the community the rationales of the package recommendation is very crucial for its acceptance and adoption.

3.3. Dominated by Immediate Needs Than Long Term Solution

Although the application of proper soil conservation measures will result in both protection of the lands and increase in crop production, most small farmers may only be interested in the immediate return from the land. As the resource poor farmers will be looking for their pressing basic daily needs i.e. producing more foods immediately rather than long term prosperity of the life i.e. improve the soil fertility and conserve soil for future. This is more serious in terms of adopting land husbandry or using land according to its capability or suitability. Pressing needs for their daily requirements for living force them to immediate harvest of more soil nutrients in the form of foods from the agriculture land with the minimum inputs to it. There are 45 % of the country's farmer population holding insufficient land for subsistence living, therefore will be seeking more land for cultivation in order to sustain their food and other living expenditure (Assuming a farmer in Terai and Hill requires 0.5 hectare and Mountain needs upto 1 hectare of agriculture land for subsistence). As a result, soil fertility will be depleted thereby degrading the land's capability. Famous proverb "Prevention is Better Than Cure" fails in this situation.

3.4. Perception / Understanding of Stakeholders

Farmers' belief and confidence have emphasized demands on the hard structures (Cement and Gabion) and high cost oriented conservation measures. Prominent structures become not only a matter of pride to the communities but also for the technician as well as for the implementing agency. Equitable distribution of the benefits for covering more area by the low cost conservation measures has still not been fully adopted. Also, empowering of the community in the planning processes has played the role in pressuring the technicians to design structure oriented conservation measures.

Implementing hard structures is easy for expending resource. With the same man-power one can expend huge resource in implementing hard structures, whereas only small amount of the same resource could be expended in implementing low cost soil conservation and watershed management measures. Therefore, it has been a general tendency of the line agencies to get attracted towards hard structure.

4. Soil Conservation Techniques

Soil erosion is the process of detachment of the soil particles from the land's surface at one place and its transportation to another place for deposition. Therefore, soil erosion involves three distinct processes; viz :- **a. Detachment, b. Transportation, and c. Deposition.** Many physical conditions of a watershed may contribute to soil erosion, such as steep slopes, heavy and intense rainfall, erodibility of the soil, unstable bedrock and weak geological formation.

The basic principle of soil erosion control is either to reduce detachment and transportation capacity of the eroding agents (water and wind) or both through different farming practices, vegetative and engineering measures generally known as conservation techniques. Among all of factors contributing to soil erosion, slope is probably the only one that can be modified to reduce erosion. In many instances, a combination of minimum slope modification such as simple terracing, maximum crop canopy and water management for controlling detachment prove very cost effective.

We need to demonstrate that conservation give better production and protection. Many people think that soil conservation is necessary only when the land is severely eroded. It is always much cheaper, easier and more effective to prevent erosion than to treat. Production and protection are like two hands of a person: one without the other will cause people to suffer. We need to help the farmers on every aspect of farming, production and marketing, as much as possible.

Some of the generally used conservation techniques may be listed as follows: -

- Fascine
- Palisades
- Wattling
- Bamboo planting
- Grass Sowing
- Conservation plantation
- Hedge Row / Bio-terracing
- Live fence
- Mulching
- Retaining wall
- Checkdam
- Brush Layering
- Riprap
- Grass Waterways
- Water harvesting (Conservation Pond)
- Agro-forestry
- Nitrogen fixing
- Conservation Farming
 - Compost / Farm Yard Manure
 - Conservation Tillage
 - Crop Rotation
 - Multiple Cropping
 - Cover crop

5. Soil Conservation Activities

In continuing endeavor to mitigate land degradation and improve productivity through the mobilization of national and local resources, the Department of Soil Conservation and Watershed Management has been implementing the following sub-programmes:-

Land Use Planning

To prepare land use development and improvement plans based upon scientifically assessed land capability. This includes: Soil conservation and Watershed management plans / Operational plans / SCWM consulting services.

Land Productivity Conservation

To improve and develop land based upon land capability to reduce the loss of land productivity. This includes: On-farm conservation, fruit tree planting, fodder / grass plantation, conservation ponds and nursery operation.

Development Infrastructure Protection

To protect and lengthen the economic lives of development infrastructures such as roads, irrigation, dams, reservoirs, lakes etc. This includes: Road slope stabilization, irrigation canal protection, trail improvement, shelter belt and buffer strips

Natural Hazard Prevention

To protect lives and properties from natural (Soil and water erosion) hazards. This includes: Gully treatment, landslide treatment, torrent control, stream bank protection and degraded land rehabilitation

Community Soil Conservation Extension Programme

To develop people's knowledge and skills to raise the level of community awareness and participation in conservation activities. This includes: Micro-watershed conservation demonstration, conservation education / extension / training / study tours / exhibitions / essay and poster drawing competitions.

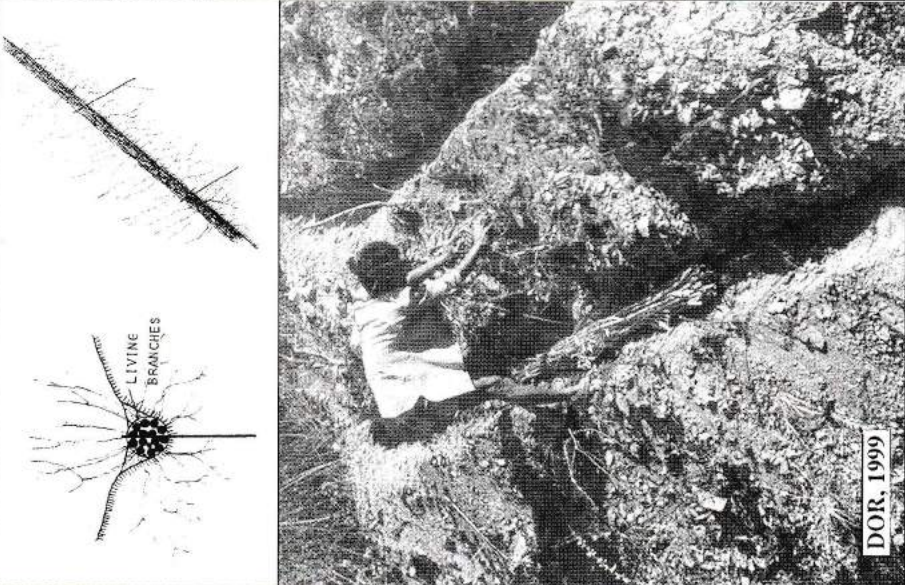
DSCWM has defined and explained the objective, working strategy, scope, and working unit in Soil Conservation and Watershed Management Activities (Definition, Objective, Scope And Working Strategy) generally known as "White Book". However, further emphasis is required to practices implementation according to its essence. Conceptual unclarity, inadequate motivation of the field staff are some of the major reasons of its ineffective implementation. Inadequate resources availability for the implementation has also played a major role on it. The "White Book" may also be revised to address the low cost soil conservation measures adequately and implementation considering multi facets of the activities widening the scope of the department.

6. Objectives: -

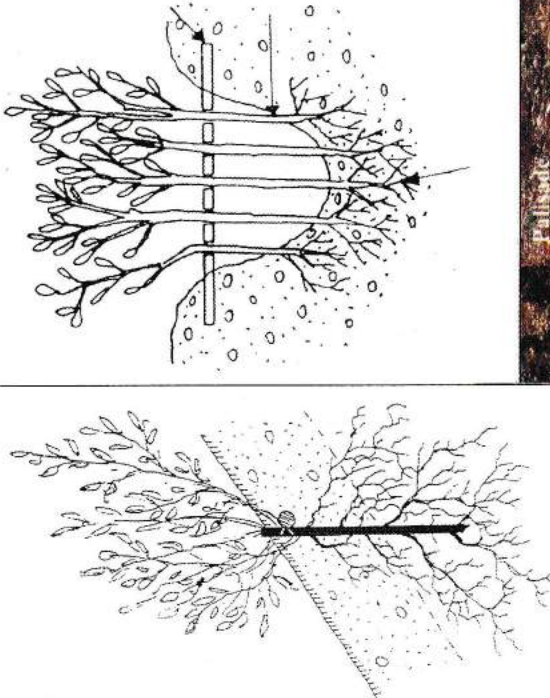
At the end of the training, the participants will be able to: -

- Explain major reasons because of which the farmers have not fully adopted the low cost soil conservation techniques.
- Explain commonly used low cost soil conservation techniques and activities and their importance,
- Design different conservation activities as a package,
- List and apply different extension methods in the promotion of the low cost soil conservation techniques, and
- List, select and explain the importance, uses and propagation techniques of various vegetative species used for conservation independently or integration with other activities.

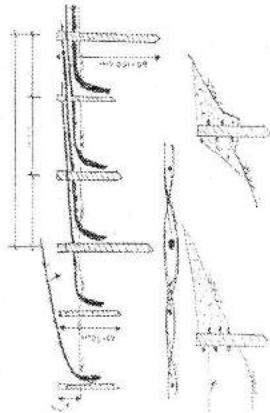
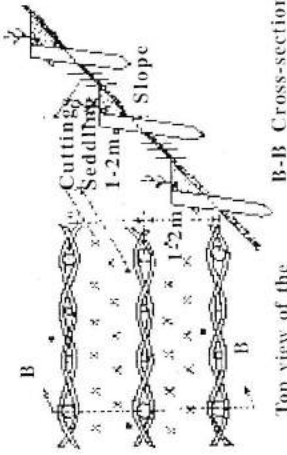
References:- Anonymous, 1994. DSC, 1992. CBS, 1994.

Title: Fascine Sketch		What is it? Bundle of live branches lay in shallow trenches. Function: • Catch debris. • Reinforce the slope, • Increase infiltration, • On slopes, fascine provides sub-surface drainage. Advantage: • Put out roots and shoots forming a strong line of vegetation. Construction Steps • Prepare the site well in advance of planting. Clear all loose material and protrusion and firmly infill depression. • Mark the line, where fascines are to be installed. Ensure that the lines follow the contour or desired angle or rills. • Always construct fascines from the bottom of the slope, and work upwards. • Dig about 5 meters long trench at a time and lay the cuttings together with their ends overlapped and fill the trench. This ensures that the soil in the trench is exposed only for short period thereby minimizing the loss of soil moisture. • The fascine can be bound as they are installed across the trench and then tying it when the cuttings are in place. • Backfill the trench as soon as possible, lightly covering the cuttings, and tamp the soil down firmly around it. • If the slope angle is more than 25°, you should peg the fascine. Use two pegs per meter. Materials • Branches of rooting plants of different species 6 to 18 months old of 3 to 5 cm diameter and 50 cm 100 cm long. • Sprouting Wooden pegs (3-6 cm diameter and 50-100 cm long). Species Tree: Assuro, Bainsh, Dabdbe, Phaledo, Kavro, Khirro, Saruwa / Bihaya, Simali, etc. Tools • Hessian and water to keep the cutting moist until planting • Tools to dig trench • (Optional) Jute or coir string or wire to bind the fascine as it is laid. Specification • Spacing between fascines depends on the steepness of the slope. 4 m interval for less than 30° slope and 2 m interval for 30° - 45° slope for contour fascine. • The trench should be about 10 cm deep and 20 cm wide. • If fascines are used on the rills or small gullies, spacing depends on the frequency of the rills / gullies. • For each fascines, there should be at least four but not more than eight cuttings. Construction Period • During dormant season if the site is moist. • Just before monsoon if the site is dry (Baisakh, Jestha)	Precautions • The butt end of the branches should always point in the same direction. • Trench should not be deeper than 30 - 40 cm. If so fill the trench with gravel. • Care should be taken to ensure that water cannot run under the bundle and scour them out. • Fascine drain must connect to nearest suitable drainage system. Scope (Site for Application) • Fascines are effective on the shallow gullies or deep rills lines. • Best used on consolidated debris or soft cut slopes. • On well drained material, contour fascines are used; on poorly drained materials, a herringbone pattern of fascines is used to improve drainage.
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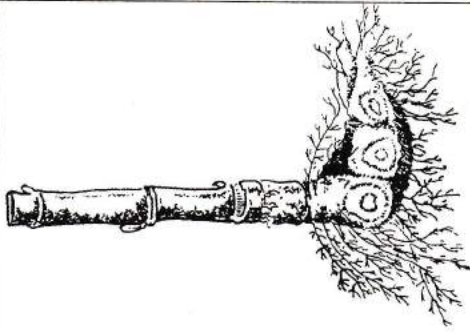
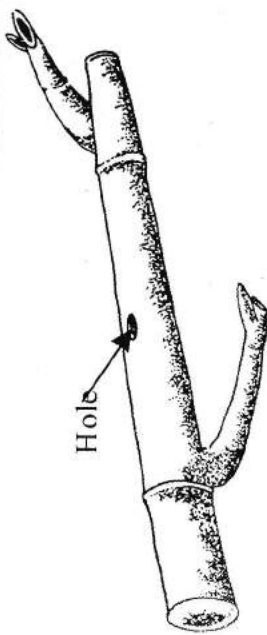
References: DOR, 1999, FAO, 1985.

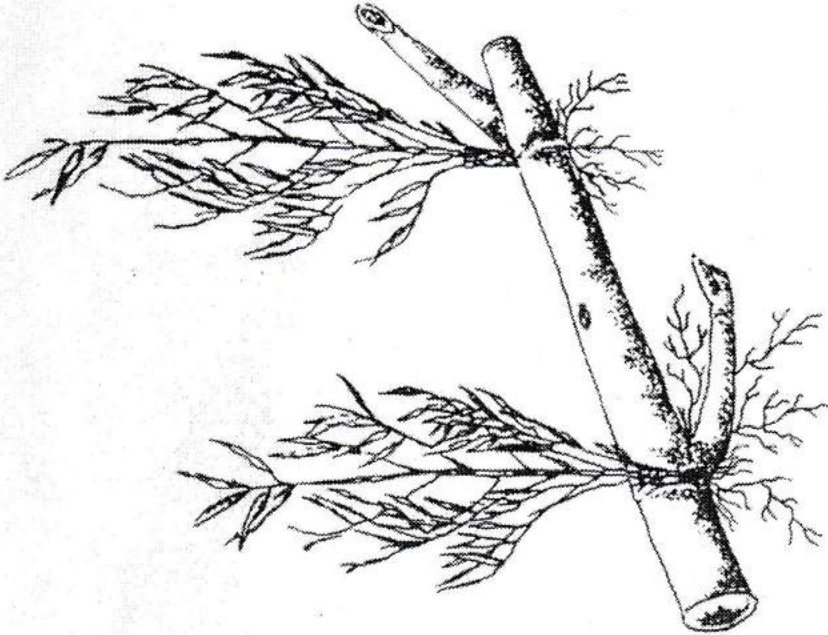
Title: Palisade		What is it? Woody cuttings planted in line across the slope, usually following the contour.			
Sketch			Function:	Limitation	
			- Reinforces the slope. - Increases infiltration. - Catches debris moving down the slope.	Weak to support big volume of debris.	
			Advantage:	Disadvantages	
			- Fast construction, immediate effect. - Forms a strong low cost barrier built with the minimum disturbance to the slope. - Living checkdam for gullies with periodic floods. Good means against gully erosion helps to repair and fill the gullies.	Only for small, narrow gullies	
			Construction Steps		
		- Always start at the top of the slope and work downward. - Using pointed bar or crowbar, make a hole that is bigger than the cutting and deep enough to take at least two-third of its length. - Cut the branches at right angle at top and at 45° at bottom. If possible, take the cutting the same day that they are to be planted. - Carefully place the cutting side by side in the hole, so that about 15 cm is above ground. Firm the soil around it, taking care not to damage the bark. (Ideally, only one node of the cutting should protrude from the soil. On steep, unstable sites, however, a greater protrusion helps to raise the delicate new shoots above the zone of moving debris, and to catch more debris.) - Stakes are tied with branches or gabion wire to a cross beam which is anchored in the sides of the gully and protected by the pegs on either ends. - On steep rills and gullies, palisade is supported with stone and soil from lower side.			
		Materials	Species	Tools	
		- Branches of rooting plants of different species 6 to 18 months old of 3 to 5 cm diameter and 30 to 50 cm long. - Gabion wire.	Tree: Assuro, Bainsh, Dabdabe, Phaledo, Golaichi, Lahare Pipal, Kavro, Khirro, Saruwa bihaya, Simali, etc.	- Hessian and water to keep the cutting moist until planting. - Pointed planting bars or crowbars to make holes for planting.	
		Specification	Construction Period		
		- Spacing between palisades depends on the steepness of the slope: 2 m interval for slope less than 30° and 1 m interval for 30° - 45° slope. - Within the palisades lines, spacing between the cutting is 2 to 3 cm.	- During dormant (November-January) season if the site is moist. - Just before monsoon if the site is dry (May-June)		
		Precautions	Scope (Site for Application)		
		- Site with poorly drained material subject to high rates of small scale slumping should be avoided. - Make sure cuttings are not allowed to dry in the sun.	- Can be used on a wide range of sites up to about 60° slope. It is particularly effective on steep landslide debris slope. - Good for steep, narrow gullies.		
Maintenance		- Because the spacing of plants in palisades is very dense, there is unlikely to be a need for replacing failures. - Inspect the area during the first rainy season. Any exposure or breaks of the stakes should be repaired and strengthened to allow vegetation to take place. - Some thinning may be required after few years.			

References:- DOI, 1992. DOR, 1999. FAO, 1985, ITECO, 1990.

Title: Wattling Sketch   Top view of the B-B Cross-section 	What is it? Wattling is rows of fence made out of vegetative materials (preferably live cuttings) placed across the slope. <table border="1"> <tr> <th>Function:</th><th>Limitation</th></tr> <tr> <td> • Catches debris moving down the slope. • Reinforcement. • Slope modification. </td><td> • Applicable only in slope with limited volume of debris flow. • Danger of breaking because of falling rocks. </td></tr> <tr> <th>Advantage:</th><th>Disadvantages</th></tr> <tr> <td> • Fast and simple protection. • Establishes a micro-site for other plants. </td><td> • Labor and material intensive. • Driving stakes loosens the soil. </td></tr> <tr> <th>Construction Steps</th><td> • Prepare the site well in advance of planting. Clear all loose material and protrusion, and firmly infill depression. • Mark on the slope the lines where wattling fences are to be installed to ensure that the lines follow the contour. • Dig a hole for placing stakes with crowbar or auger. Place 100 cm long stakes at intervals of about 100 cm along the lines; and place two 50 cm long stakes in between the long stakes. Stakes should protrude about 20 - 30 cm. • Dig out a groove along the contour between the stakes; it should be at least 15 cm deep. • Place the cuttings with their lower ends in the groove, bending them down along the line of the fence. Weave them in and out between the stakes. Firm the soil back into the groove. • The end result should have the cuttings almost horizontally above each other, but with the ends firmly planted in the soil. • Soil must be filled behind the wattles if the planting of tree and grass seedling and cuttings are to be carried out. </td></tr> <tr> <th>Materials</th><th>Species</th></tr> <tr> <td> • Stakes 100 cm long 4 - 6 cm diameter and 50 cm long 3 - 4 cm diameter. All stakes are sharpened at the bottom. • Woody cutting of long and flexible plants which root easily (more than 150 cm long and 2 - 3 cm diameter) • If sprouting materials are not available material like bamboo could also be used. • Jute or coir string or wire to bind </td><td> Live stack for anchoring stakes: Phaledo, Bains, Dabdabe, Lahare pipal, Golainchi, Kavro, Khirro, etc. Bushes, Shrubs: Asuro, Nilkanda, Bihaya, Sajiwan, Simali, etc. </td></tr> <tr> <th>Specification</th><th>Construction Period</th></tr> <tr> <td> • Spacing between long stakes 100 cm. • Average horizontal distance between wattling is 100 to 200 cm. on steep slope. </td><td> • During Dormant season if the site is moist. • Just before monsoon if the site is dry (May, June) </td></tr> <tr> <th>Maintenance</th><th>Precautions</th></tr> <tr> <td> • Because the spacing of plants in wattling fences is very dense, there is unlikely to be a need for replacing failures. However, regular protection from the grazing and human interference is needed. • Inspect the area during the first rainy season. Any breaks of the stakes should be repaired and strengthened to allow vegetation to take place. • Some thinning of shrubs may be required after few years. </td><td> Scope (Site for Application) • Useful in the small shallow short length slides. • In combination with other measures useful for bank protection. </td></tr> </table>	Function:	Limitation	• Catches debris moving down the slope. • Reinforcement. • Slope modification.	• Applicable only in slope with limited volume of debris flow. • Danger of breaking because of falling rocks.	Advantage:	Disadvantages	• Fast and simple protection. • Establishes a micro-site for other plants.	• Labor and material intensive. • Driving stakes loosens the soil.	Construction Steps	• Prepare the site well in advance of planting. Clear all loose material and protrusion, and firmly infill depression. • Mark on the slope the lines where wattling fences are to be installed to ensure that the lines follow the contour. • Dig a hole for placing stakes with crowbar or auger. Place 100 cm long stakes at intervals of about 100 cm along the lines; and place two 50 cm long stakes in between the long stakes. Stakes should protrude about 20 - 30 cm. • Dig out a groove along the contour between the stakes; it should be at least 15 cm deep. • Place the cuttings with their lower ends in the groove, bending them down along the line of the fence. Weave them in and out between the stakes. Firm the soil back into the groove. • The end result should have the cuttings almost horizontally above each other, but with the ends firmly planted in the soil. • Soil must be filled behind the wattles if the planting of tree and grass seedling and cuttings are to be carried out.	Materials	Species	• Stakes 100 cm long 4 - 6 cm diameter and 50 cm long 3 - 4 cm diameter. All stakes are sharpened at the bottom. • Woody cutting of long and flexible plants which root easily (more than 150 cm long and 2 - 3 cm diameter) • If sprouting materials are not available material like bamboo could also be used. • Jute or coir string or wire to bind	Live stack for anchoring stakes: Phaledo, Bains, Dabdabe, Lahare pipal, Golainchi, Kavro, Khirro, etc. Bushes, Shrubs: Asuro, Nilkanda, Bihaya, Sajiwan, Simali, etc.	Specification	Construction Period	• Spacing between long stakes 100 cm. • Average horizontal distance between wattling is 100 to 200 cm. on steep slope.	• During Dormant season if the site is moist. • Just before monsoon if the site is dry (May, June)	Maintenance	Precautions	• Because the spacing of plants in wattling fences is very dense, there is unlikely to be a need for replacing failures. However, regular protection from the grazing and human interference is needed. • Inspect the area during the first rainy season. Any breaks of the stakes should be repaired and strengthened to allow vegetation to take place. • Some thinning of shrubs may be required after few years.	Scope (Site for Application) • Useful in the small shallow short length slides. • In combination with other measures useful for bank protection.
Function:	Limitation																						
• Catches debris moving down the slope. • Reinforcement. • Slope modification.	• Applicable only in slope with limited volume of debris flow. • Danger of breaking because of falling rocks.																						
Advantage:	Disadvantages																						
• Fast and simple protection. • Establishes a micro-site for other plants.	• Labor and material intensive. • Driving stakes loosens the soil.																						
Construction Steps	• Prepare the site well in advance of planting. Clear all loose material and protrusion, and firmly infill depression. • Mark on the slope the lines where wattling fences are to be installed to ensure that the lines follow the contour. • Dig a hole for placing stakes with crowbar or auger. Place 100 cm long stakes at intervals of about 100 cm along the lines; and place two 50 cm long stakes in between the long stakes. Stakes should protrude about 20 - 30 cm. • Dig out a groove along the contour between the stakes; it should be at least 15 cm deep. • Place the cuttings with their lower ends in the groove, bending them down along the line of the fence. Weave them in and out between the stakes. Firm the soil back into the groove. • The end result should have the cuttings almost horizontally above each other, but with the ends firmly planted in the soil. • Soil must be filled behind the wattles if the planting of tree and grass seedling and cuttings are to be carried out.																						
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Maintenance	Precautions																						
• Because the spacing of plants in wattling fences is very dense, there is unlikely to be a need for replacing failures. However, regular protection from the grazing and human interference is needed. • Inspect the area during the first rainy season. Any breaks of the stakes should be repaired and strengthened to allow vegetation to take place. • Some thinning of shrubs may be required after few years.	Scope (Site for Application) • Useful in the small shallow short length slides. • In combination with other measures useful for bank protection.																						

References: DOI, 1992, DOR, 1999, DSCWM, 1983, FAO, 1985.

Title: Bamboo Planting Sketch	What is it? Planting of bamboo for soil conservation and watershed management.
 Clump Stump (Ready for Planting)	Function: - Bamboo reinforces soil against erosion. - It provides excellent support to the slope if planted at the base / toe slope. - It reduces the velocity of run-off water. - It traps soil eroded from up slope. - It works as a fence. Advantage: - Fodder available for animals (Kalo, Mal and Ghopi bans). - Materials for baskets, Doko, Mats etc. (Ghopi, Kalo) - Poles and bamboo straps useful for house construction. (Kalo Nigalo, Taru and Mal Bans) - Edible shoots (Tama Bans) - Provide opportunities for IGA - Large clumping nature Limitation - Nothing else can grow close to tall bamboo, mainly due to nutrients and moisture competition. - Bamboo seeds are rarely set, seeds may not be available during need for seedling production. Disadvantages - Bamboo casts shade to nearby plants - Habitat for pests - Whole plant dies after seedling - Growth from the seed is very slow
 Cut the culms into double node cuttings using a hand saw or a hack saw	Propagation Steps Bamboo Propagation - Vegetative propagation by Clump cutting - Off-cut stems with a portion of rhizome with bud from 1-1.5m of 1 year old culm is separated and can be transplanted directly to a field site or to a nursery for the use as mother stool. This method is simple and used for those species that form clump. - Vegetative Propagation from Nodal cutting - Select the 6-10 month old culm, - Fell the bamboo below the first node with a bud, - Trim back all the main side branches to their first node with a bud. - Trim off all other smaller branches (preferably with a secature / saw). - Cut the culm into pieces (preferably with saw) with two-nodes. Species with large branches like Taru Bans single node cutting is recommended. - Keep all prepared segments in the shade and under moist jute sack or wet paper right until they are planted. - Transport them to the nursery as soon as possible after preparation. - Fill the hollow space of the cuttings with wet mud and place cuttings horizontally in trenches in the nursery beds and buried 2.5-15 cm below the surface of the soil immediately. In two-node cuttings, a hole can be made in the central internodes and filled with water. If there is termite problem, treat soil with appropriate pesticide. - Prepare the soil of the nursery bed in advance (best mix is 3:1:1, soil, sand, compost). - Construct the shade cover stand at 80 cm high. - The bud or branch should face upwards in single-node cuttings and sideways in double node cuttings. - The nursery bed should be watered immediately and kept moist. Flood irrigation prevents termite attack. - Lift nodal cuttings when new shoots grow to about 1 m tall. Thus prepared nodal plants can be planted in just before or during monsoon.
 Double node cutting with hole for watering.	

Sketch		Propagation Steps - This method is suitable for the larger, clump forming species that grow adventitious roots from nodal buds fairly easily. However this technique needs considerable care in the nursery. - Packing for transportation: Cut double-node cuttings into separate plants. Old parent inter-node materials should be trimmed off close to the node. If transportation distance is long, wrap with wet newspaper or jute sack. The seedlings should be planted immediately after their arrival and irrigate them just after planting. - The rate of survival in the field will be more than 85% if they receive water regularly and are well looked after ➤ Propagation by seed: ~ Seeds are collected in late spring. Sound seeds can be separated by floating off dead seeds and unwanted materials in a bucket of water. (25000-35000 seeds per kg). Seeds should be sown as soon as possible after collection. They cannot be stored for a long time (2-3 months after harvesting). ~ Sow seeds directly into prepared seedbed (using a soil mix of 3:1:1 soil, sand & compost). Germination will begin one week after sowing. Keep well watered. Transplant to 4" * 7" polypots when the seedlings are 5 to 10 cm tall. The seedling should be transplanted when they are one year old or about 75-90 cm tall. Materials • Bamboo culm • Seed • Culm with rhizome • Thatching materials Species • Dendrocalamus hamiltonii (Tama): 300-2000 m, grows best in moist and shady sites, not good in south face below 1200 m Large leaves, thin culm, heavy branching, culm split easily • D. hookeri (Kalo): 1200-2500 m, Heavy branching and brown hair • Bambusa balcooa (Dhanu): Terai to 1600m, large clumping, thin and heavy branching • B. nutans / cupalata (Mal): Terai to 1500 m, Strong and straight culm • Ampelocalamus patellaris (Ghopi): 1200-2000 m, Smaller bluish culm • B. nutans (Taru): Terai to 1500 m, strong straight culm Tools • Digging tools • Saw • Sharp tool for cutting • Water can • Doko • Sack
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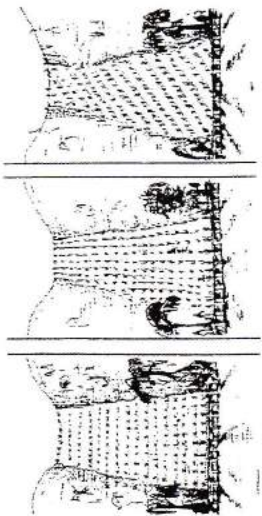
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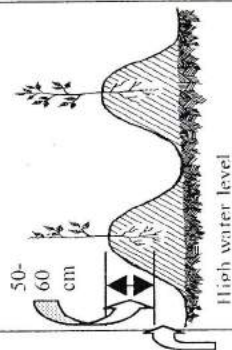
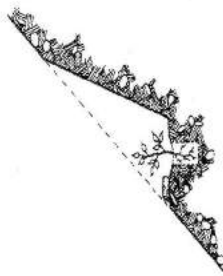
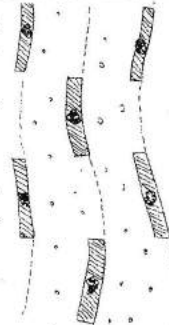
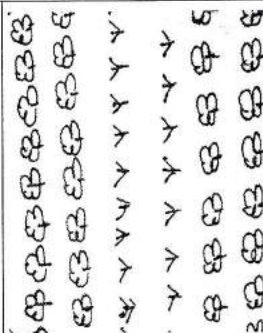
- 5 * 5 m

Planting Period

- During spring (February - May) season.
- Just before monsoon (June) if the site is dry

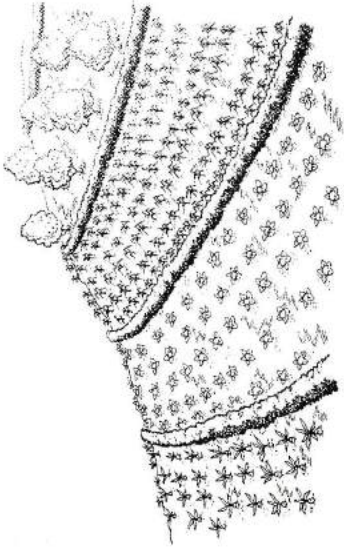
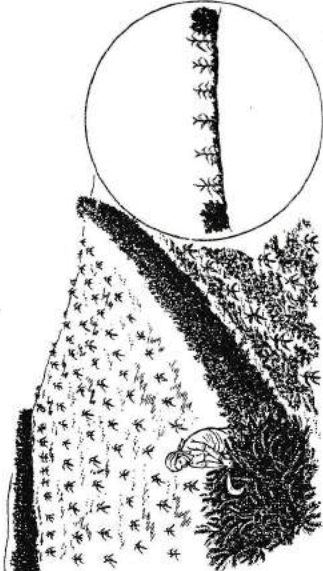
References: McCracken, I. J. (ed.), 1992.

Title:Grass Planting		What is it? Planting of grass (seed, clump, rhizome, cuttings). Planted in contour, vertical and diagonal																			
Sketch		Function:		Limitation																	
 DOR, 1991		• Armour (Protects surface from raindrops by providing ground cover). • Improves infiltration thus reducing runoff. • Catches soil material and reinforce slopes.		• Labor intensive. • Only good for shallow small land slips. • Some species may spread as weed.																	
		Type	Contour	Vertical	Diagonal																
		Advantage:	Increases infiltration and catches soil material. Produces forage.	Channel runoff and minimize infiltration. Produces forage.	Combines the best features of both contour and vertical. Produces forage.																
		Disadvantage:	Can trigger liquefaction due to increase in infiltration.	Can develop rills down the slopes due to runoff.	Can develop small rills down the slopes on weak material.																
		Some species may spread as weed.																			
		Planting Steps																			
		• Prepare the site well in advance of planting. Clear all loose material and protrusion, and fill in surface irregularities so that there is nowhere for erosion to start. If the site is backfill material, it should be thoroughly compacted, preferably when wet. • Always start grass planting at the top of the slope and work downwards. • Mark out the lines with strings where grass lines are to be installed. Ensure that the lines follow the contour or desired angle (Vertical or diagonal). • Split the grass plants out to give the maximum planting material. Trim off long roots and cut the shoots off at about 10 cm above ground level. Wrap the plants in damp hessian to keep them moist until they are planted. Remember that you will need two slip cuttings per drill (planting hole) if the grass is a fibrous rooting type (e.g. babiyu, kans, khar, phurke, etc.) but only one if it is rhizomatous (e.g. amliso, padang bans, etc.) and only one stem cutting (rooted) or seedling. • With a planting bar, make a hole just big enough for the roots/rhizomes/cuttings. Place the grass into the hole. Fill the soil in around them, firming it gently with your fingers. • If compost or manure is available, scatter a few handfuls around the grasses. This is especially important on very stony sites, where compost or manure can help to improve early growth. You may have to incorporate it into the surface material to prevent it being washed off. • If it looks rather dry and there is no prospect of rain for a day or two, consider watering the plants by hand.																			
		Materials		Tools																	
		• Grass plants (clump, rhizome, cutting)		• Short planting bars • Line string / Tape measure (30 meters) • A means of transporting plants to site • Hessian and water to keep the planting stock moist until planting																	
		Spacing: Within rows: 10 cm apart except padang, amliso and tite nigalo bans, which should be spaced 30-50 cm		Planting Period																	
		Row Spacing: Depends largely on the steepness of the slope		• During Dormant season if the site is moist. • Just before monsoon if the site is dry (May - June)																	
		<table><tr><th></th><th>Contour</th><th>Vertical</th><th>Diagonal</th></tr><tr><td>Slope < 30°</td><td>100 cm</td><td>50 cm</td><td>50 cm</td></tr><tr><td>Slope 30 – 45°</td><td>50 cm</td><td></td><td></td></tr><tr><td>Slope > 45°</td><td>30 cm</td><td></td><td></td></tr></table>			Contour	Vertical	Diagonal	Slope < 30°	100 cm	50 cm	50 cm	Slope 30 – 45°	50 cm			Slope > 45°	30 cm				
	Contour	Vertical	Diagonal																		
Slope < 30°	100 cm	50 cm	50 cm																		
Slope 30 – 45°	50 cm																				
Slope > 45°	30 cm																				
		On agriculture land, a compromise between ease of cultivation and reduction of soil and water movement must be reached. A vertical interval of 2 meters or more is generally adequate.																			
Maintenance		Precautions		Scope (Site for Application)																	
• Involves protection, weeding and cutting for new growth. • Regularly trim the grass planted on riser to prevent them from shading and spreading on farmland.		• Protect area from the fire • Ensure that the roots have not tangled or have curved back to the surface. • Take care to avoid leaving air pocket by the roots during planting.		• Almost any slopes less than 65° . Mostly well drained soils where increase in infiltration is unlikely to cause problems. • Riser of the cultivated fields.																	

Title: Conservation Plantation					What is it? Planting of tree and shrub species with due consideration of soil and moisture conservation to protect land from degradation and to improve the water resource.				
Planting Techniques:	Contour Bunds or on mounds	Horizontal Platform or benches	Plantation on Basin pit	Contour Trenches	Strip Plantation				
Problem	Water logging or very wet condition.	- Creeping of loose materials - Moisture stress.	Dry and harsh soil conditions	Moisture and nutrient constraints	High grass and weeds				
Sketch									
Objective	- To protect seedlings from flooding and improve aeration, - To drain excess water.	To protect seedling from debris, To improve infiltration and soil moisture.	To catch rain water for plants, To improve infiltration rate and soil moisture.	To trap the eroded soil, To catch rainwater and use for plant.	To overcome the problems of high grass and weeds.				
Site preparation	- Mounds or ridges are prepared well in advance by scraping the top soil and piling 60 cm height or above the high water level. - If the soil is saline, add gypsum.	- Prepare horizontal platform 60 – 100 cm wide at staggered pattern, - Spacing between platforms 3 m. - Spacing between the plants preferably 2 m in the platform.	- Small round basins are prepared to catch rainwater in staggered pattern for individual plants, - Spacing between plants: Generally 2 m. However, it could vary to suite the sites.	- Trenches of 1.5 – 3m length, 45-60cm wide and 45cm deep are built in a staggered pattern. 1.5 – 3 m space is needed between the trenches.	3m wide contour strips are prepared, - Planting of large seedling or big size stem cutting are preferred.				
Planting time	- Site preparation should be done well in advance (1 –2 months before), - Dig pit of 45cm x 45 cm x 45cm for planting, - If it is possible, fill the pits with good soil, compost and complete fertilizer (NPK). Adding grass, straw, and organic matter in the pits to retain moisture is recommended.								
Care & Maintenance	- Favorable at the end of rainy season in the waterlogged areas. - Carry out plantation program in the beginning of monsoon rain when soil has sufficient moisture to support the establishment of seedlings. - Winter plantation is preferred for the cutting / stem plantation.								
Other considerations	- Select seedling of optimum size with developed root system. Trim supply shoots and leaves to reduce transpiration. - If moisture is the constraint, put mulch around the newly planted seedlings to reduce evaporation and prevent from crusting of surface soil. - Weeding is done from Shrawan to Ashwin at least for first 3 years. - Eucalyptus, Lagerstroemia, Speciosa, Casuarina glauca, willow species are recommended for swampy sites - Sites with loose and creeping materials, select such plant species which can develop roots from stem (willow, simali, khirro). Such plants can tolerate injury by debris from upslope to some degree. - Take safety measures while working on steep slopes. - In cold and windy place like Mustang, planting of 4-5 feet long and 5-6 inch diameter populus cutting gave good results. - While planting cuttings, the tip of cutting needs to be waxed to avoid from desiccation. - Pot plantation is better than bare root plantation in harsh sites. - On rocky sites, seedlings can be planted on the best available spots instead of regular spacing. - Grow leguminous species along with other species in the reclamation of degraded land. - Prefer local species. - Safe disposal of the poly bags.								

	Function: - Protects surface from raindrops by providing ground cover. - Increases infiltration rate (recharging the ground water) and evapo-transpiration thus reducing runoff. - Reduces runoff velocity through obstruction. - Reinforces slopes - Recycles nutrients from deeper layer of the soil	Limitation - Free grazing can not be allowed. - Fire outbreak may damage the plants. - Risk of disease & pests in monoculture.
	Advantage: - Reduced erosion and improved land quality (physical, chemical and biological properties of soil) - Improved water yield (quality and regime) - Multiple outputs (availability of Fuel wood, fodder, timber & leaf litter etc.) - Improved biological diversity Disadvantages - Roots may open rock joints and create unstable slopes. - Load of the large trees combined with the dynamic forces of the wind can induce slope failure. - Time taking for establishment. - Loss of water through transpiration. - Large water drops falling from the leaves may create erosion.	Planting Steps - Identification of the planting site together with local people. - Selection of suitable species is based on adaptability, multiple use, soil improving quality and preference of the local people. - Site preparation (Site survey, site clearance and alignment of the planting pits and pitting) should be done well in advance (1 -2 months before). - If possible put compost at the bottom of planting hole in poor soils or add a good forest soil, then leave for a few weeks to consolidate the loose soil. - Remove polythene bag from the seedling by cutting from the side carefully. - Planting of seedling into the pit and press the soil firmly around the seedling.
Maintenance - Weeding and soil working to induce favorable growing environment. - Regular thinning and pruning to allow the undergrowth. - Carry out enrichment plantation in following years to fill the gaps. - If possible water the plants at dry period, put mulch to conserve moisture and use manure if soil is very poor.	Materials Seedlings, cuttings, seed etc. based on the propagation method of selected species. Tools Survey: Measuring tape / Rope / Compass / Abney's level / Pegs / Field book / Ranging rod Planting: Tape / Rope / Digging tools Specification - Pit size of 45 cm deep and about 45 cm in diameter. (Deeper the pit is better) - Spacing: 2*2 m for tree and 1*1 m for shrubs - Generally, seedling size must be > 30 cm in height.	Planting Period - Planting pits are prepared some weeks before plantation. - Planting should be carried out with the onset of monsoon. - Winter plantation is preferred for the cutting / stem plantation.
Suitable Species For Improving soil fertility & Organic Matter Asuro, Dhaincha, Khirro, Flemengia, Desmodium, Utis, Sisau, Rahar, Ipil-ipli, Tephrosia	Precautions - Protect the plantation site against grazing, fire hazards and damage by people. - Plantation of mixed species to minimize risk of monoculture. - Selection of species with high survival rate, fast growing, several layers and high crown cover density. - Plantation during the fall of monsoon has low survival rate. - Care during seedling transportation including making sure that planting stock is not allowed to dry in the sun.	Scope (Site for Application) - Kharbari - Grazing lands - Community and public barren lands - Gully and landslide - River bed - Road slopes - Community forest
For dry and stony sites Phaledo, Amala, Chilaune, Ketuki, Khirro	For poor soil conditions Amala, bayer, Ketuki, Khair, Bakaino, Babul, simali, Kalo Siris, Tephrosia, Casuarina, Sisso, Khirro	For moist sites Bains, Utis, Chilaune, Laliguras
For dry and stony sites Phaledo, Amala, Chilaune, Ketuki, Khirro	For fodder Badahar, Ipil Ipil, Dabdabe, Jhingar, Flemingia, Kutmiro, Phaledo, Tanki, Koiralo, Khanyu, Kabro, Dudhilo, Bedulo, Bhimal, Gogan	For easy propagation Dabdabe, Jhingar, simali, Asuro, Phaledo, Khirro, Bains, Saru, Simali

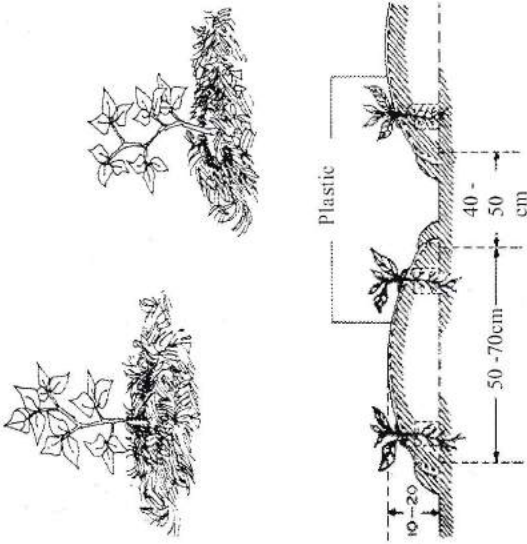
References: Campbell, Gabriel J. and Jeannette Denholm (edt.), 1992. Datta, S. K. 1986. DOR, 1999. Hudson, N. 1981. Saxena N. C. and Vishwa Ballabh -1995. Tingfu, Guo, 1992.

Title: Hedgerow on sloping land	What is it? Planting of trees, shrubs or grasses (preferably nitrogen fixing) closely in paired rows along the contour. Alleys between the paired hedges is used for growing food or cash crops.
Sketch	Function: • Reduces run-off velocity. • Reinforces the slope. • Catches soil materials and creates effective barrier to soil erosion.
	Limitation • Difficult to establish in steep slopes. (>50 degrees)
	Disadvantages • Compete with crops for light, water and nutrients • Occupy part of the crop land(15 - 25%)
Hedgerow cutting will provide green manure for the crop.	Advantage: • Conserves soil moisture • Reduces the steepness of the slope (formation of bio-terrace) • Increases total bio-mass to fulfill short term and long term needs of the farm family (crop, fuel-wood, fodder and organic manure). • Produces leguminous leaves and twigs for mulching and green manuring.
Maintenance • In first year, weeding and pruning is required. • From the second year onwards, trim regularly maintaining height 50 cm to avoid shading effect on agricultural crops. However pruning can be held during the period when the crop is harvested and new crop is not planted. • Place stones, twigs, and crop residues in the space between two lines of paired hedgerows to trap soil.	Planting Steps • Using "A" frame mark the lines to be planted. • Preparation of land for planting • Seed treatment (Seed is soaked in water to enhance germination) • Planting of double line hedgerows (By direct seeding or seedling plantation) • If available, use of compost/manure or fertilizer will be useful for initial growth. • Cultivate agriculture crops in alleys. Crop rotation will be beneficial.
Materials • Planting material:Seed, Seedling, cuttings, slips Criteria for choosing Plant species: • Compatible with agricultural crops. (Complementary function) suitable to local condition fulfilling local needs • Fast growing, deep rooted, nitrogen fixing species • Resistant to regular trimming. Specification • Spacing between plants in the row will not be effective if more than 20 cm for trapping soil. • Generally, 30 - 60 cm spacing between pair of rows is maintained. • Spacing between paired hedgerows varies from 4 m to 6 m depending upon the slope.	Species • <i>Leucaena leucoccephala</i> • <i>Desmodium rensonii</i> (Short life) • <i>Mulberry</i> (Kimbu) • <i>Flemingia macrophylla</i> • <i>Tephrosia candida</i> • <i>Ahimsa nepalensis</i> • <i>Calliandra</i> & <i>Gliricidia</i> in poor soils, • <i>Scabania</i> in moist soils • <i>Dismanthus</i> in alkaline soils.
Tools • 'A' Frame • Measuring tape • String • Digging Hoe or spade	Planting Period • Seed sowing or seedling transplanting should be done with the on-set of monsoon. • Cutting during winter
Precautions • Ensure the lines are drawn on contours, otherwise hedges will not function effectively for erosion control. • Hedges should not shade the crops in alleys.	Scope (Site for Application) This technology works effectively up to 25 degree of farmland. However it has been used in slopes of up to 45 degrees in other places.

References: - BWIMP, 2003. FAO and IIRR, 1995. Ya, Tan -1999, ICIMOD 1998, DOR, 1999, NRRA and IIRR, 1992. ICIMOD, 2001, CSWCS,1987, NAF, 2050 B. S.

Title: Live Fencing		What is it? Planting of shrubs, bushes and trees (preferably thorny plants) along boundaries of land to demarcate and provide protection to farm or fields from the invasion of free grazing animals and people.			
Sketch		Function:		Limitation	
		• Provides protection to the farm / field against invasion of animal and people, • Produces bio-mass for nutrient re-cycling, • Reduces run-off velocity and traps soil eroded from up slope.		• It takes time to establish and difficult to protect in the early stage, • If not planted properly, it is not effective.	
		Advantage:		Disadvantages	
		• Low cost, • Long lasting if properly maintained, • Can be maintained with minimum cost, • Environment friendly, • Foliage useful for green manuring, • Fire wood supply, • Support to income.		• Shading effect to closely grown crops, • May harbor insect pests, • Regular pruning is necessary.	
		Planting Steps			
		• Mark the fence line, • Selection of species is based on adaptability, effectiveness, people's preferences and availability, multiple use, resistant to trimming and non-palatability. • Land preparation: Dig the furrow or pit along the boundary 1-2 months before plantation. • Refill the trench or pits with good soil and if possible use compost. • Planting should be carried out in the beginning of monsoon either by direct seeding or planting seedlings / cuttings. • Planting in two rows in triangular pattern is preferred in order to get thick & dense fence also to obstruct animal.			
		Materials	Species	Tools	
		• Seeds, seedlings, cuttings depending on the propagation method of selected species.	• Agave • Nilkandha, • Ghangharu • Cactus	• Jatropha • Asuro • Simali • Sajiwan • Digging tools • Measuring tape • Pegs • Rope	
		Specification	Planting Period		
		• Size of the furrow should be 30 cm deep and 30-60 cm in width and the pit size 30cm*30cm • Spacing between rows and plants 30-60cm.	• During Dormant season (Cutting) if the site is moist. • Just before monsoon if the site is dry (May - June)		
Maintenance	• 2-3 weeding in the first year will enhance early establishment. • Protection from grazing and human interference. • Gap filling. • Maintain the height at 1.5m to minimize shading effect to closely grown crops. • Use trimmed foliage for green manure or mulch. • Regular maintenance for shaping.	Precautions		Scope (Site for Application)	
		• If agricultural crops are grown close to the live fence, maintain the height at 1.5m, but if the shade does not hamper near by vegetation, then height will not be the limitation for more bio-mass production. • Make a thick live fence in order to ensure its effectiveness. • Dig pits instead of furrow along steep slope.		• Home garden • Farmland • Kharbari • Grazing land • CF • Conservation pond	

References: Udhai Thongmee, et. Al, 1999, Thet Sein et.al., 1999.

Title: Mulching	What is it? Technique of covering soil surface temporarily in order to maintain soil moisture and creating favorable environment for plant growth.		
Sketch	Function:	Limitation	
	- Protects soil from raindrop erosion, heat, frost and wind. - Reduces evaporation thus conserves moisture. - Armors soil temporarily. - Plastic film material increases soil temperature (av. 3°C) - Controls weeds. Advantage: - Increases organic matter, microbial activity, moisture in soil thus increased production. - Decrease in the cost for weeding. - Good for seed germination. Mulching Steps - Prepare the land - Collect and chop mulch materials - Sow or plant the crop then spread the mulch to cover the ground or apply mulch then sow or plant the crop. - Mulching can be done as follows: - - Chopped material is laid across the slope to cover the entire surface of the ground. - Mulch is laid in between crop rows (Furrow or flat system) - It is laid around individual plants strips - In case of Plastic Film (PF,) after spreading plastic sheet, press the edges with wet soil at least 10 cm, (to prevent from being blown off by the wind)	Limitation - Requires huge quantity of mulching material. - Labor intensive. - In case of plastic mulch, run-off water may get accumulated and flash flow could wash out the fertile soil. - Poor farmers may not be able to afford cost (in case of Plastic mulching). Disadvantages - Labor demanding during collection - May increase insects (termite) and pests (rodent) - Risk of fire out break - Higher purchasing cost for plastic sheet.	
Materials	Construction Period	Tools	
- Mulching material: Plant residues (Straws, Stack, Husk, Stubbles), Leaf litters, Sawdust/ash, Weeds etc. - Plastic Film (PF)	Specification Slope > 30° cover mulch with wide mesh jute netting (150*500 mm mesh) to hold mulch.	- Spreading Rake - Doko (Bamboo basket) - Sickle	
Maintenance	Precautions	Scope (Site for Application)	
Proper drainage for the safe disposal of accumulated water from the plastic mulch.	- Don't use plant parts carrying seeds (as this may become a weeding problem) - Prevent from fire / wind and control rodents. - Collect used plastic film and retrieve or destroy.	- For high value crops (Fruit orchards, vegetables, spices, MAPs etc.) - Up to 45° slopes and well drained soils - Harsh areas (Red soil, Dry and frost prone area) - Nursery	

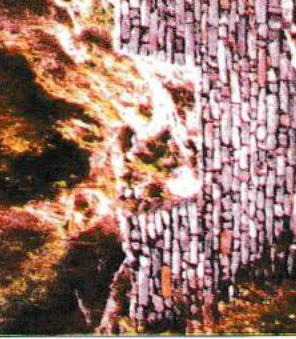
References: DOR, 1999, FAO and IIRR, 1995, Rongsen, Lu, 1994.

What is it? A retaining wall is a wall built to resist the pressure of earth filling or backing, deposited behind it after it is built					
Function:		• Supports the slope. • Prevents the toe cutting. • Prevents bank erosion.			
Type:	Crib wall (Bamboo/Wooden)	Loose stone	Gabion	Masonry / Concrete	
General characteristics	- o Made of wooden pole / bamboo and brush. - o They are cheap and can be made with locally available materials.	- o Made of loose stone. - o Stability and strength depends on the size of stones and the quality of construction. - o Commonly used in the slope stabilization works in Nepal.	- o Made with large rectangular wire crates (Gabion Boxes) filled with stones. Preferable where flat big stone are not available. - o Commonly used in the slope stabilization works in Nepal.	- o Made of cement mortar or concrete. - o Permanent structures. - o Generally not used in Nepal, except to protect important infra-structures such as road, building.	
					
Advantages:	• Uses local materials, simple and low cost. • Once put out roots and shoots form a long-term barrier.	• Uses local materials, simple and low cost. • Well drained; flexible; relatively low cost; low strength threshold	• Well drained; flexible and relatively low cost for strength. • Suitable, where whole land mass is moving.	• Permanent structure • Looks good.	
Disadvantage/ Limitation:	• Takes time to root. • Suitable for gentle slope and shorter slope length.	• Not suitable where the land mass is moving. • Suitable - o where good quality (flat and big) stone are available - o for the shorter slope length - o for small mass movement	• Costly • Cost of the gabion does not remain in the community. • Needs skilled labor for construction.	• Costly • Cost of the material (cement, rods) does not remain in the community. • Needs complicated engineering design and skilled labor. Poor drainage cannot tolerate settlement	

Design / Construction Specification											
Crib wall	Loose Stone Retaining Wall	Gabion	Masonry / Concrete								
- The crib wall should not be higher than 4m for pole or 2m for bamboo - Place wooden pole or 3 bamboos tied together in a triangular shape (A) along the front side of the crib wall. - Place a pole / bamboo (B) every 1 to 2m at a distance apart perpendicular to the horizontally placed pole / bamboos in a down sloping angle of 15-30 degree and tie it together with the horizontally placed pole / bamboos. For this use galvanized wire. - In case of bamboo crib wall, drive a living / bamboo pole in front of the crib wall to protect the horizontally placed bamboos. - In case of wooden pole crib wall, the pole placed perpendicular to the horizontally placed poles are grooved at the end, so that the horizontally placed pole can rest on it. Therefore no pegging in front is required. 	- The top width of the retaining wall should not be less than 60 cm for stone masonry and 55 cm for the brick walls. - The foundation should be taken deep enough to safeguard against weather and should be at least h/10+30 cm below the ground level. - The front face should have a batter of at least 1 (H) in 24 (V), with a maximum of 1 in 6. The most common is 1 in 12. - The back should be left rough or built in steps to increase friction between the wall and the backing. - Prevent the water pressure behind the wall through proper back filling and drainage by the use of coarse material and providing the weep wholes. - The backfill should be deposited in 10 cm to 15 cm layers with moderate compaction sloping downward from the wall to reduce lateral pressure.	- The normal width to height ratio is: width = ½ height + 0.5. - Ensure drainage is provided from the lowest point of the foundations. Size of the Gabion Box: Commonly used gabion box in Nepal is 3m x 1.5m x 0.75m made of 8-gauge galvanized wire with 15cm by 15cm mesh. You can design the gabion boxes of your own size. But, for the practical purposes the dimension of the boxes must be multiple of 15cm in case of 8-gauge gabion boxes or 10 by 10cm in case of 10-gauge gabion boxes.	- Same as loose stone retaining wall. - The weep holes are more necessary for masonry walls than for dry rubble retaining walls. - The weep holes should be 4 square inch, be placed at 3 feet apart horizontally and 2 feet apart vertically. They should not be vertically one under the other.								
- Fill the soil material in the opening between the poles or bamboos and press without leaving any voids. - Put branches of sprouting living plants in the open spaces between the poles or bamboos in such a way that not more than ¼ of their length protrudes. - Repeat the steps till the designed height is attained. This time place the horizontally placed bamboos in such a way that a bamboo peg can be driven in a space between horizontally placed bamboo one below and above.	- Tilting the wall towards the hill slope increases the stability of the wall and its effectiveness. Typically, walls may be tilted by 6 to 10 degrees. - For greater height retaining walls, stepping is recommended to increase the stability. - After the construction, ensure that the slopes around the structure are tidied up and treated using appropriate bioengineering measures. All surplus debris must be removed, or it will encourage the development of erosion. - Dry walls co-exist with, and are strengthened by plant roots. Encourage or plant vegetation.										
Material											
Crib wall	Loose Stone Retaining Wall	Gabion	Masonry / Concrete								
- Bamboo or round / square timber / log (10 – 15 cm in diameter) - Live cutting that roots easily, at least 1 m. length with a large number of side branches - Sprouting wooden poles of 8 to 12 cm diameter or bamboo pole and about 100 cm long.	- Gabion box - Good quality stone (Strong, big and flat stones are preferred) - Specification of gabion box: <table><tr><td>Wire size</td><td>10 Gauge (3.251mm Ø)</td><td>8 Gauge (4.064mm Ø)</td></tr><tr><td>Mesh</td><td>10cm x 10cm</td><td>15cm x 15cm</td></tr><tr><td>Mesh shape</td><td>Rectangular or Hexagonal</td><td>Rectangular or Hexagonal</td></tr></table>	Wire size	10 Gauge (3.251mm Ø)	8 Gauge (4.064mm Ø)	Mesh	10cm x 10cm	15cm x 15cm	Mesh shape	Rectangular or Hexagonal	Rectangular or Hexagonal	- Cement - Sand - Good quality stone (Strong, big and flat stones are preferred)
Wire size	10 Gauge (3.251mm Ø)	8 Gauge (4.064mm Ø)									
Mesh	10cm x 10cm	15cm x 15cm									
Mesh shape	Rectangular or Hexagonal	Rectangular or Hexagonal									

Construction Period																			
Crib wall	Loose Stone Retaining Wall	Gabion	Masonry / Concrete																
- During Dormant season if the site is moist. - Just before monsoon if the site is dry (May - June)	- Any time of the year when it is convenient, however dry period is preferable. - Planting of cutting is done just before monsoon. Planting of cutting is preferable during the dormant season.																		
Maintenance																			
Crib wall	Loose Stone Retaining Wall	Gabion	Masonry / Concrete																
- Inspect the crib wall regularly during the monsoon period. Any opening should be repaired before it gets worse. - Replace the dead cuttings. - Some thinning of cutting may be required after few years.	- Carry out the immediate repair of any damage. - Provide the adequate drainage system in the downward side. - Carry out plantation of appropriate species in upward side.																		
Precautions / Practical Considerations																			
Crib wall	Loose Stone Retaining Wall	Gabion	Masonry / Concrete																
- Make sure cuttings are not allowed to dry in the sun. - Avoid splitting of the stakes by placing a piece of strong wood on the top of the stake when it is being driven in. - Avoid using the techniques on poorly drained area subject to medium to large scale slumping.	- Dress all stone (if it is rounded) into rectangular blocks. - Lay stones so that they are tied into the slope, so that only the small ends, not long sides, are at the face of the wall. - Overlap all joints. - Use stones as large as possible. If mainly small stones are available, use large ones at least every one meter to improve the tying. - Use flatter stones for the top layer. Cover the top of the retaining wall with soil or build a bound masonry band along the top to stop it unraveling. Use these dimensions for dry stone retaining walls, depending on slope angle. This table provides a guide to the dimensions of walls on different slopes. <table border="1"> <thead> <tr> <th>Slope</th><th>Wall Height</th><th>Base height</th><th>Top width</th></tr> </thead> <tbody> <tr> <td>30 – 35°</td><td>1.5 – 2.0m</td><td>1.25 – 1.5m</td><td>0.75m</td></tr> <tr> <td>35 – 40°</td><td>2.0 – 2.5m</td><td>1.5 – 2.0m</td><td>0.75 – 1.0m</td></tr> <tr> <td>40 – 45°</td><td>2.5 – 3.0m</td><td>2.0 – 2.3m</td><td>1.0m</td></tr> </tbody> </table> - Use of the above mentioned dimension does not need the stability test against overturning, collapsing and sliding. - For the complicated design needs to consult experts.	Slope	Wall Height	Base height	Top width	30 – 35°	1.5 – 2.0m	1.25 – 1.5m	0.75m	35 – 40°	2.0 – 2.5m	1.5 – 2.0m	0.75 – 1.0m	40 – 45°	2.5 – 3.0m	2.0 – 2.3m	1.0m	- Stones should be tabular and angular. - All stones should be carefully and densely packed. - Ensure that the minimum dimension of all stones is larger than the wire mesh size. - Ensure the quality of the galvanized wire. - Ensure proper sealing of the box using 12 SWG wire. - Wire all gabion boxes together using 12 SWG wire, allowing an additional 5% of wire for binding and tying.	Same as loose stone retaining wall.
Slope	Wall Height	Base height	Top width																
30 – 35°	1.5 – 2.0m	1.25 – 1.5m	0.75m																
35 – 40°	2.0 – 2.5m	1.5 – 2.0m	0.75 – 1.0m																
40 – 45°	2.5 – 3.0m	2.0 – 2.3m	1.0m																

References: FAO, 1985., SCWMC, 2001., Sthapit, K. M., 1998.

Title: Checkdam	What is it? A small, low dam constructed in a gully or other water- course to decrease the velocity of stream flow, to minimize the channel scour and to promote the deposition of eroded material.				
Function:	• Reduces the velocity of water to non-erodible one, thus traps the silt going to the lake or reservoir. • Prevents erosion by not allowing water to run on long slopes. • Reduces the water depth by widening the riverbed. • Raises the bed level to such an extent that it can support the unstable side slopes. • Stores water and increases its infiltration / percolation in the soil. • Collects sufficient soil and water to promote plant growth. • Prevents bank erosion.				
Type:	Brushwood	Loose stone	Boulder	Gabiono	Masonry / Concrete
General characteristics	- o Made of wooden poles and brush. - o Least permanent of all types, but they are cheap and can be made with locally available materials. - o Suitable for small gullies of 1 to 2 meters in depth.	- o Made of loose rocks. - o Stability and strength depends on the size of rocks and the quality of construction. - o Commonly used in the gully control works in Nepal.	o Same as the loose stone checkdams except that, big boulders are used in its' construction.	- o Made with large rectangular wire crates (Gabion Boxes) filled with stones. They are preferable where big boulders are not available. - o Commonly used in the gully control works in Nepal.	- o Made of cement mortar or concrete. - o Generally not used in Nepal, except to protect important infra-structures such as road, building.
					
Advantages:	• Uses local materials, simple and low cost. • Once put out roots and shoots form a long-term barrier.	• Uses local materials, simple and low cost.	• Uses local materials, simple and low cost. • If properly made, they are almost like a permanent structure like the gabions, masonry and concrete structures.	• Flexible, Permeable, and Economical compared to other solid structures. • Suitable, where whole land mass is moving.	• Permanent structure • Looks good
Disadvantage:	• Takes time to root.	• If dams are made with only small stones, the stones will be moved by the large water flow and dams may be quickly damaged.	• Transport of the big boulders is difficult if not located upslope of the site. • Large voids in the dam may create water jets, which could be destructive if directed towards banks.	• Costly • Cost of the gabion does not remain in the community. • Needs skilled labor for construction.	• Costly • Cost of the material (cement, rods) does not remain in the community. • Needs complicated engineering design and skilled labor.

Checkdam	Design Specification																					
Site Selection:	Select the site for the construction of checkdams taking into account the following considerations: a) Wide enough to limit specific run-off b) The best site for foundation and side foundation - To accommodate higher flood run-off in Nepal makes it necessary to select a place, which is wide enough to limit specific run-off (per meter width) "q" and so the scour depth. The spillway has to be big enough with at least 0.5m free board to take flood run-off, otherwise the side foundation of the checkdams will be washed out and the checkdams are by-passed by the river and are destroyed. - The checkdams should be made at a straight and firm stream bank. They should never be made on the curve, junction of two streams and just below it. - It is necessary to build the last checkdam on good foundation base rock as it affects the foundation of the rest of the checkdams above. - The selection of the site is also restricted by the height of the structure. If the elevation difference between two successive sites is too high, one or more sites have to be selected in between so that the structure height will fulfill the conditions.																					
Spacing:	The spacing of the checkdams should be so placed that the bottom of the upper checkdam and the top of the next below give the gradient, which for the kind of soil in the stream will give a non-erosive velocity of flow. It is known as the compensation gradient. For the general practice, the compensation gradient is taken as 3 to 5% slope. The horizontal distance between two successive checkdams is given by the relation: $d = h * 100 / (SO - S_c)$ Where, - d = Spacing between two successive checkdams (horizontal distance) - h = Height of the checkdam (up to notch) - SO = Existing slope of bed in % - S_c = Stabilizing slope of bed in %. In general, it is 3 - 5 %. Number of checkdams is calculated following the formula:- Number of Checkdams = (a-b)/ H Where, - a = The total vertical distance between the first and the last checkdam in that portion of the gully or torrent. - d= The horizontal distance between the first and the last checkdam in that portion of the gully or torrent. - b= The total vertical distance calculated according to the compensation gradient for that portion of the gully. - H = Average height of the checkdams.	Example:- Given:- <table><tr><td>h =</td><td>2m</td></tr><tr><td>So =</td><td>15%</td></tr><tr><td>S_c =</td><td>5%</td></tr><tr><td>d =</td><td>$h*100/(So - S_c) = 2*100/(15-5)=20m$</td></tr></table> Given:- <table><tr><td>a =</td><td>30m</td></tr><tr><td>Se =</td><td>5%</td></tr><tr><td>d =</td><td>200m</td></tr><tr><td>b =</td><td>$Se*d/100 = 10m$</td></tr><tr><td>H =</td><td>2m</td></tr><tr><td>No of Checkdam =</td><td>$(a-b)/H = (30-10)/2=10$</td></tr></table>	h =	2m	So =	15%	S _c =	5%	d =	$h*100/(So - S_c) = 2*100/(15-5)=20m$	a =	30m	Se =	5%	d =	200m	b =	$Se*d/100 = 10m$	H =	2m	No of Checkdam =	$(a-b)/H = (30-10)/2=10$
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Foundation:	- The depth of foundation must be taken below the scour level. - In erodible strata if D is the anticipated maximum depth of scour below the designed highest flood level including that on account of possible concentration of flow, the minimum depth of foundation below the highest flood level should be taken as 1.33 * D. - The scour depth is not to be taken from the present bed level but from one to be expected in the future after siltation of the lower checkdam and after the establishment of new bed gradient due to the reduced bed-load after the erosion control. - Take a 1.0 m foundation as a rule of thumb.																					

Checkdam	Design Specification																									
Scour Depth	Scour occurs when the bed velocity of the stream exceeds the velocity, which can move the particles of the bed material. Velocity varies with the gradient, the hydraulic depth and the characteristics of the bed and banks. When the velocity is retarded, silt is dropped and when the velocity is increased, silt is picked up. Scour is worst when the river is falling. It depends more on the water depth than on the gradient. A river has to adjust its velocity to what its bed and banks can stand by changing its section. The scouring action of the current is not uniform and it is all along the bed width and scouring is deeper at the obstructions and also at bends than normal. Therefore, the maximum scour depth has to be determined. Normal Scour Depth: i). Schocklitch's Formula: $\text{Scour Depth, } D_s = \frac{4.75 * h^{0.2} * q^{0.57}}{d_m^{0.35}}$ Where, D_s = Scour depth (in meter) below water level d_m = Grain diameter (in mm) which divides bed material in a way that 90 % is smaller than d_m h = Water level difference (in meter) above and below the checkdam q = Run-off (in cubic meters / meter width) in the spillway	Example:- Given:- <table><tr><td>d_m</td><td>= 20cm = 200mm</td></tr><tr><td>h</td><td>= 2m</td></tr><tr><td>q</td><td>= 1.25 cumecs / meter</td></tr><tr><td>D_s</td><td>= $(4.75 * h^{0.2} * q^{0.57}) / d_m^{0.35}$</td></tr><tr><td></td><td>= $(4.75 * 2^{0.2} * 1.25^{0.57}) / 200^{0.35}$</td></tr><tr><td></td><td>≈ 7.496/6.39 ≈ 1.17 m</td></tr></table> Breadth of Scour Hole = <table><tr><td>Breadth of Scour Hole</td><td>= 1.5 * Length of the Notch</td></tr><tr><td></td><td>≈ 1.5*4 = 6 meters</td></tr></table> Length of Scour Hole = <table><tr><td>Length of Scour Hole or the Apron</td><td>= $4*(0.467 * q^{0.23})^{1.5} * h^{0.5}$</td></tr><tr><td></td><td>= $4*(0.467 * 1.25^{0.23})^{1.5} * 2^{0.5}$</td></tr><tr><td></td><td>≈ $4*0.399*1.42$</td></tr><tr><td></td><td>≈ 2.26 m.</td></tr></table>	d_m	= 20cm = 200mm	h	= 2m	q	= 1.25 cumecs / meter	D_s	= $(4.75 * h^{0.2} * q^{0.57}) / d_m^{0.35}$		= $(4.75 * 2^{0.2} * 1.25^{0.57}) / 200^{0.35}$		≈ 7.496/6.39 ≈ 1.17 m	Breadth of Scour Hole	= 1.5 * Length of the Notch		≈ 1.5*4 = 6 meters	Length of Scour Hole or the Apron	= $4*(0.467 * q^{0.23})^{1.5} * h^{0.5}$		= $4*(0.467 * 1.25^{0.23})^{1.5} * 2^{0.5}$		≈ $4*0.399*1.42$		≈ 2.26 m.
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Runoff estimation:	The Rational Formula is: $Q = C * I_{Te} * A / 360$ Where, Q = The rate of run-off in cubic meter per second or cumecs = I_{Te} = The intensity, that is the rate of rainfall in millimeters per hour for designed frequency for a duration equal to the time of concentration, T_c A = Area of watershed in hectares C = Dimensionless run-off coefficient Procedure: • Measure the catchment area "A" in hectares by surveying or from topographical map or aerial photographs. • Calculate the Time of concentration (i.e. gathering time) by using the formula: $T_c = L^{1.15} / 15 * H^{0.38}$ Where, T_c = Time of concentration (gathering time) in hours L = Length of the watershed along the main stream from the outlet to the most distant ridge in Kilometers, and H = The difference in elevation between the watershed outlet and the most distant ridge in Kilometers	Example: <table><tr><td>L</td><td>= 700m = 0.7 km</td></tr><tr><td>H</td><td>= 50m = 0.05km</td></tr><tr><td>T_c</td><td>= $L^{1.15} / 15 * H^{0.38}$</td></tr><tr><td></td><td>= $0.6635/(15*0.32)$</td></tr><tr><td></td><td>0.138 hours ≈ 8minutes</td></tr></table>	L	= 700m = 0.7 km	H	= 50m = 0.05km	T_c	= $L^{1.15} / 15 * H^{0.38}$		= $0.6635/(15*0.32)$		0.138 hours ≈ 8minutes														
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Checkdam	Design Specification																								
Runoff estimation continued:	Calculate rainfall intensity for duration equal to time of concentration. Local rainfall records should be used to estimate this if possible. Since, there is no published record of one hour rainfall (mm) for Nepal, for the purpose, we can draw following information from the data prepared for India. Frequency and One Hour Rainfall in mm. <table><tr><th>Frequency</th><th>1 hour rainfall (mm)</th></tr><tr><td>10 Years frequency</td><td></td></tr><tr><td> Eastern and Middle Zone</td><td>100</td></tr><tr><td> Western and Far western Zone</td><td>80</td></tr><tr><td>25 Years frequency</td><td></td></tr><tr><td> Eastern and Middle Zone</td><td>120</td></tr><tr><td> Western and Far western Zone</td><td>100</td></tr><tr><td>50 Years frequency</td><td></td></tr><tr><td> For Whole Nepal</td><td>120</td></tr></table> Convert 1- hour intensity to intensity for duration equal to gathering time for the catchment or the time of concentration i.e. I_{T_c} From the Figure. Example: Given 25 years frequency, Eastern Zone: - <table><tr><td>$I_{hr} =$</td><td>120 mm</td></tr><tr><td>$T_c =$</td><td>8 minutes</td></tr></table> • Project a curve between the 15 minutes and 2 minutes, representing 8 minutes • Draw a horizontal line starting from one hour rainfall intensity of 120 mm/hr till it meets the projected line. • Draw a vertical line from the cross section of the horizontal line and the projected curve • Read the value in the X axis for the Rainfall intensity for the time of concentration <table><tr><td>$I_{T_c} \approx$</td><td>240 mm</td></tr></table>	Frequency	1 hour rainfall (mm)	10 Years frequency		Eastern and Middle Zone	100	Western and Far western Zone	80	25 Years frequency		Eastern and Middle Zone	120	Western and Far western Zone	100	50 Years frequency		For Whole Nepal	120	$I_{hr} =$	120 mm	$T_c =$	8 minutes	$I_{T_c} \approx$	240 mm
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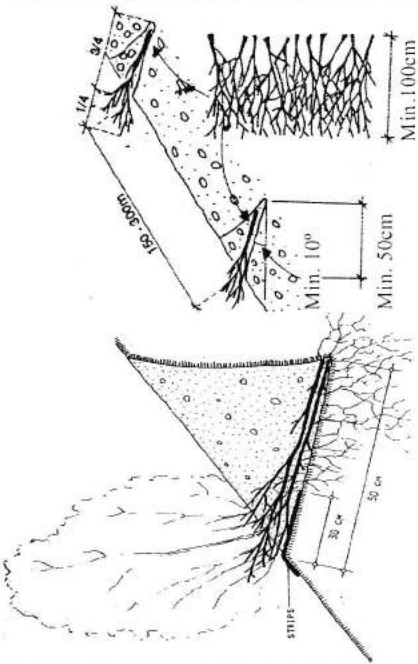
| | Relation of One Hour Rainfall Intensities to Intensities at other Duration (converted and redrawn from G. A. Hataway, Military Air Field - Design of drainage facilities, Trans. Am. Soc. Civil Engineers 110: 700, 1945. Cited by Gupta, et. al. 1973) |

Checkdam	Design Specification																																				
Runoff estimation:	Calculate the constant "C" is a measure of the proportion of the rain, which becomes runoff. Following Table below gives some value of C.	Example:																																			
	<table><tr><th colspan="4">Value of C for Use in Rational Formula</th></tr><tr><th>Soil Type</th><th colspan="3">Landuse type</th></tr><tr><td></td><th>Cultivated</th><th>Pasture</th><th>Forest</th></tr><tr><td>With above average infiltration rate, usually sandy or gravely</td><td>0.29</td><td>0.15</td><td>0.10</td></tr><tr><td>With average infiltration rate no clay pans, loams and similar soil</td><td>0.40</td><td>0.35</td><td>0.30</td></tr><tr><td>With below average infiltration rate, heavy clay soils, or soils with a clay pan near the surface, shallow soils above impervious rock</td><td>0.50</td><td>0.45</td><td>0.40</td></tr></table> Computed weighted "C" for the watershed: $C = (A_1 * C_1 + A_2 * C_2 + A_n * C_n) / (A_1 + A_2 + A_n)$ Where, A_1, A_2, A_n are areas in hectares under various landuse and soil types having corresponding values of C_1, C_2, C_n respectively; and $A = A_1 + A_2 + A_n =$ Total area of the watershed. Limitation: This method is usually suggested for use for a watershed of less than 50 hectares.	Value of C for Use in Rational Formula				Soil Type	Landuse type				Cultivated	Pasture	Forest	With above average infiltration rate, usually sandy or gravely	0.29	0.15	0.10	With average infiltration rate no clay pans, loams and similar soil	0.40	0.35	0.30	With below average infiltration rate, heavy clay soils, or soils with a clay pan near the surface, shallow soils above impervious rock	0.50	0.45	0.40	<table><tr><th>Landuse category</th><th>Area</th><th>Run-off coefficient</th></tr><tr><td>Cultivated</td><td>$A_1 = 10\text{ha}$</td><td>$C1 = 0.29$</td></tr><tr><td>Pasture</td><td>$A_2 = 7.5\text{ha}$</td><td>$C2 = 0.35$</td></tr><tr><td>Forest</td><td>$A_3 = 5\text{ha}$</td><td>$C3 = 0.40$</td></tr></table> $C = (A_1 * C_1 + A_2 * C_2 + A_3 * C_3) / (A_1 + A_2 + A_3)$ $= (10 * 0.29 + 7.5 * 0.35 + 5 * 0.40) / (10 + 7.5 + 5)$ $= 7.525 / 22.5 \approx 0.335$	Landuse category	Area	Run-off coefficient	Cultivated	$A_1 = 10\text{ha}$	$C1 = 0.29$	Pasture	$A_2 = 7.5\text{ha}$	$C2 = 0.35$	Forest	$A_3 = 5\text{ha}$
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Notch design:	The spillway has to accommodate peak runoff, otherwise the side foundation of the checkdam will be washed out and the checkdam will be destroyed. Notch/weir or spillway can be designed by using the following formula. A. Rectangular Notch: Francis's Formula: $Q = 1.84 * B_{sp} * H_{sp}^{1.5}$ Where, Q = Peak run-off, cumecs B_{sp} = Length of Notch, in meters H_{sp} = Height of Notch, in meters For trapezoidal notch, the length of the notch is calculated as the average of top and bottom width of the spillway/notch.	Example: Calculated $Q = 5$ cumecs <table><tr><th colspan="2">Case 1.</th><th colspan="2">Case 2.</th></tr><tr><th>Factor</th><th>Value</th><th>Factor</th><th>Value</th></tr><tr><td>$H_{sp} =$</td><td>0.75m</td><td>$H_{sp} =$</td><td>1m</td></tr><tr><td>$B_{sp} =$</td><td>3m</td><td>$B_{sp} =$</td><td>4m</td></tr></table> Case 1. $Q = 1.84 * B_{sp} * H_{sp}^{1.5} = 1.84 * 3 * 0.75^{1.5}$ $\approx 1.84 * 3 * 0.65 \approx 3.5$ cumecs Since calculated Q is 5 cumecs, the design notch can not accommodate the runoff. Therefore, notch size need to be increased. Case 2. $Q = 1.84 * 4 * 1^{1.5} \approx 7.36$ cumecs > 5 cumecs, OK $q = Q / B_{sp} = 5 / 4 = 1.25$ cumecs / meter	Case 1.		Case 2.		Factor	Value	Factor	Value	$H_{sp} =$	0.75m	$H_{sp} =$	1m	$B_{sp} =$	3m	$B_{sp} =$	4m																			
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Structural:	- Structural design involves the determination of the dimensions of the various components of the checkdam and its strength and stability. - The safety of the checkdams is mostly endangered by scouring. Foundation depth and spillway size and shape have, therefore, to be selected taking scouring depth into consideration. - For complicated design, consult experts.																																				

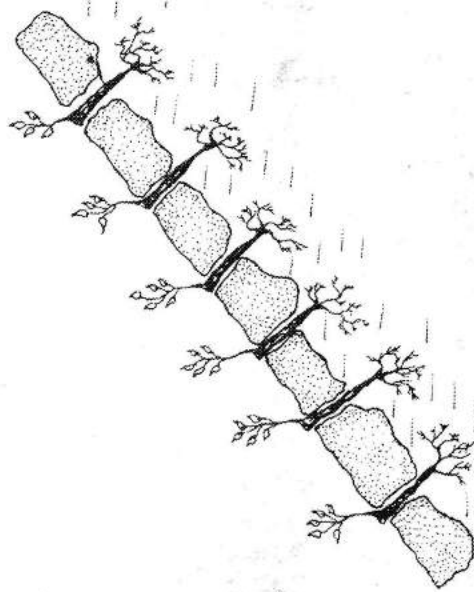
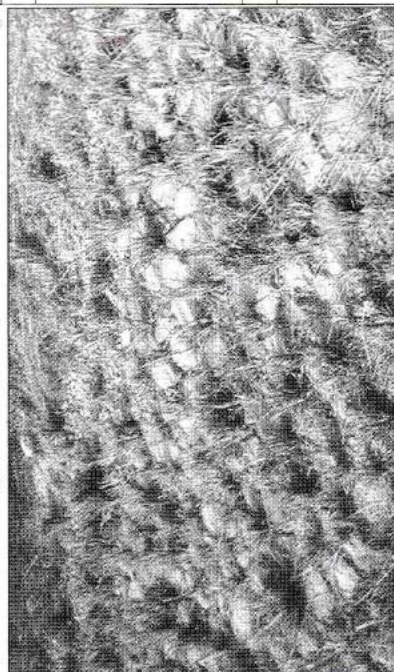
General Specification (After Geyik, 1986)						
Checkdam	Maximum Effective Height	Minimum Foundation Depth	Thickness of Dam at Spillway Level	Slope of Downstream Face of the Dam	Slope of Upstream Face of the Dam	Thickness of the Base of the Dam
Type of Checkdam						
Brushwood:	Maximum height is 1 m from ground level.	Wooden poles are driven to a depth of about 0.75-1 m.				
Loose stone:	1.0 m	0.5 m	0.5 – 0.7 m	20% (1:1/5 Ratio)	Vertical	Calculated accordingly
Boulder:	2.0 m	Half of Effective Height	Preferably 1.0 m	30 % (1 : 0.3 Ratio)	Vertical	Calculated accordingly
Gabion:	May vary (Recommended not more than 5.0 m)	Half of Effective Height	> 1.0 m	20 % Slopped, Stepped or vertical	Stepped or vertical	Calculated accordingly
Remarks:	Use of the above mentioned dimension does not need the stability test against overturning, collapsing and sliding. However, size of the spillway need to be computed according to the maximum discharge of the gully catchment area.					
Construction Specification						
Brushwood			Loose Stone / Boulder		Gabion	
• Clear the site and mark the line of construction using string. • A trench of about 15 cm deep is made across the gully, the wooden poles are driven to a depth of about 1/3 to ½ of the pole length. Spacing of the poles is 30-50 cm. • The tops of the poles in the middle are made lower than the sides to form a notch of the required size to accommodate the maximum runoff. • The flexible branches of tree (salix, poplar, vitex, etc.) and shrub are woven between wooden poles driven into the ground till a dam of required height is obtained. • The ends of inter-linked materials should enter at least 30 cm into the sides of the gully. • The back of the brushwood checkdam must be filled up with soil. • A brushwood apron of about 1.5 - 2 times the height of checkdam is necessary to protect channel from scouring and need to be anchored with galvanized wire. • Provide sidewalls to direct the flow to the weir (center) • Correct the slope of steep gully head.			• Clear the site and mark the line of construction using string. The sides of the gully are cut to a slope of 1: 1. The foundation of the wings should be more than 0.5 meters. The height of the wing wall must be equal to the depth of the spillway. • The foundation of the dam has to be more than the length of the spillway. • For large dams, two wing walls with appropriate foundations are often constructed at the upper side to force the flow into the spillway or notch and prevent it from damaging the banks. • Large flat stones are used on the notch and downstream side of the spillway. The central portion is kept low for the spillway. • When large quantities of run-off are expected, it is advisable to use some concrete in the notch and the crown of the dam, or to cover everything with a wire netting. Below the dam an apron has to be constructed with stones. • The large stones are placed in the bottom of the dam and stones of about 50 cm x 30 cm are used throughout the body of the checkdam. • On the up-stream side, the dam has to get an earth fill for greater strength. • Finally, the structure is supplemented by planting seedlings and cuttings of suitable species with a dense and wide spread root system.		• The structure should enter at least 0.5 m into the side of the gully and should be protected against flash water by wing walls. • The wing walls with appropriate foundations are to be constructed at the upper side to guide the flow into the spillway or notch and prevent it from damaging the banks. The space between the dam and wing the walls should be filled with soil. • The wing walls should enter at least 0.5 m into the side of the gully. • The height of the wing walls must level with the top of the checkdam. • The foundation of the checkdam has to be more than the length of the spillway. • Large flat stones should be put along the sides of the gabion boxes, while smaller ones are filled in the middle. The size of stones used for the construction should be larger than the size of the wire mesh. When debris are expected, it is advisable to protect the spillway and steps in the front part of the dams by a layer of concrete to protect the gabion wire from the falling debris. • The spillway dimensions are computed according to the maximum discharge of the gully catchment. • Below the dam, an apron has to be constructed. • The back of the checkdams must be filled with soil for greater strength. • Finally, the structure is supplemented by planting seedlings and cuttings of suitable species with a dense and wide spread root system on the gully sides. • The gabion boxes need to be laced together very strongly with the 8 gauge wires.	

Material		
Brushwood	Loose Stone / Boulder	Gabion
• Sprouting poles of 8 to 12 cm diameter and 150 to 200 cm long. • Branches of rooting plants of different species 6 to 18 months old of 2 to 4 cm diameter and more than 100 cm long. • Galvanized wire for binding. Species: Pole: Dabdabe, Phaledo, Kavro (Ficus lacer) Jafri: Bains (Salix), Simali (Vitex), Lahare papal, etc.	• Flat stones for loose stone and big boulder for boulder checkdams.	Gabion box and stones: Generally, the gabion boxes are made of either 10 (3.251 mm) or 8 (4.064 mm) gauge galvanized wires. The mesh of the 10-gauge is 10 cm by 10 cm, whereas for the 8-gauge, the mesh of the gabion boxes is 15 cm by 15 cm. The mesh of the gabion boxes may be rectangular or hexagonal. In Nepal mostly used gabion boxes in erosion control works are the rectangular mesh with double knots. The dimension of the most commonly used gabion boxes for erosion control structures in Nepal is 3 m x 1.5 m x 0.75 m made of 8-gauge galvanized wire with 15 cm by 15 cm mesh. You can design the gabion boxes of your own size. But, for the practical purposes the dimension of the boxes must be multiple of 15 cm in case of 8-gauge gabion boxes or 10 by 10 cm in case of 10-gauge gabion boxes.
Maintenance		
Brushwood	Loose Stone / Boulder	Gabion
• Inspect the gully. Any scouring of poles should be repaired before it gets worse. • Close the opening in the jafri (brush).	Checkdam can collapse if: a) Even one stone of the spillway section is washed out. b) The foundation of the checkdam is scoured. c) The water flows from the side foundation of the checkdam. Therefore, continuous monitoring of these incidences is essential and if any damage is seen, maintenance and further control measures should be immediately carried out. Also, to reduce the damage to the checkdams, remove boulders, trees, bushes, and other flow restrictions that would result in the bank cutting or overtopping of the channel.	Same as loose stone / boulder checkdam. Also check the gabion wires are intact. Any loose or broken wire must be repaired in time.
Precautions		
Brushwood	Loose Stone / Boulder	Gabion
• Avoid splitting of the stakes by placing a piece of strong wood on the top of the stake when it is being driven in. • After the structure is built, tramp earth solidly behind and around it to prevent cracking. • The water must go over the structures and not go around them. • The waterways should not be used such as paths.	• Strength of the checkdam depends on the quality of the construction i.e. laying of the stone in the structure. Bonding between the stones within the structure. • Big stone needs to be placed at the spill way and at the foundation.	• Any fall of the stone from the spillway to the structure easily cut the gabion wire. Therefore, the gabion wire of the foundation must be protected from the falling debris by covering with stone. • Gabion box must be properly sealed. Any opening in the gabion box easily washes out the stones.
Construction Period		
Brushwood	Loose Stone / Boulder	Gabion
• During Dormant season if the site is moist. • Just before monsoon if the site is dry (May-June) • Any time if non-sprouting species are used.	• Any time of the year when it is convenient, however dry period is preferable.	• Any time of the year when it is convenient, however dry period is preferable.

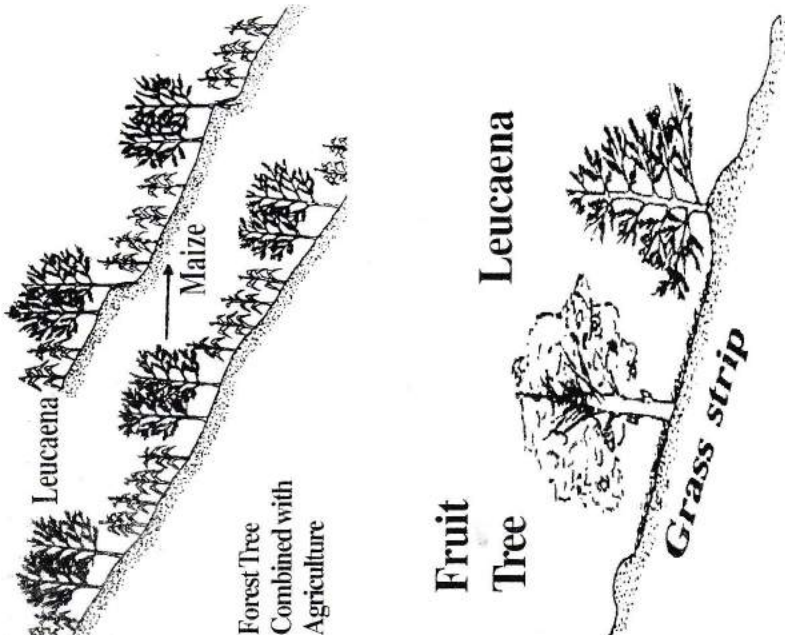
References: Geyik, M. P., 1986., Hiller, B. 1979, Gupta et. al., 1973., 1979, Sthapit, K. M. and L. C. Tennyson, 1991., Fautscher, Otto., 1978/79.

Title: Brush Layering		What is it? A layer of woody cuttings planted in line across the slope, usually following the contour.	
	Function: - Reinforces the slope. - Catches materials moving down the slope, and if angled, it helps to drain out. - Bio-terracing.		Limitation Considerable disturbance to the slope.
	Advantage: - Forms a strong barrier preventing the development of rills, - In long term, a small terrace will form.		Disadvantages Rill erosion between layers if layering is angled
	Planting Steps - Using the string mark the lines to be planted starting 50 cm from the base of the slope. - Make 50 – 100 cm wide terraces with an inclination of at least 10 – 20 % inward. - Lay the cuttings cross-wise, not parallel to each other, one third to one fourth of each branch should extend over the edge of the terrace. Placing the branches crosswise onto the terraces also permits the use of longer branches. - Use branches of different species and of different age and diameter. This allows the roots to penetrate deeper into the soil and greater chances of survival and produces mixed vegetation. - Fill the lower bench with the material excavated from the terrace 1 meter above and compact it reasonably well by gentle foot pressure.		
	Materials - Branches of rooting plants of different species 6 to 18 months old of 2 to 4 cm diameter and 75 to 100 cm long. - Cut the branches at right angle at top and at 45° at bottom. If possible, take the cutting the same day that they are to be planted.	Species Asuro, Bainsh, Dabdade, Kanda phul, Namdi phul, Phaledo, Kimbu, Nilkandha, Sajiwan, Simali, Saruwa/ Bihaya, etc.	Tools - Hessian and water to keep the cutting moist until planting - Shovels and pick axes to make the sloping terraces for planting - Line string - Tape (30 m)
Specification Spacing between brush layer depends on the steepness of the slope: 2 m interval for less than 30° slope and 1 m interval for 30° - 45° slope.		Planting Period - During dormant season if the site is moist. - Just before monsoon if the site is dry (May - June)	
Maintenance - Because the spacing of plants in brush layering is very dense, there is unlikely to be a need for replacing failures. - Inspect the area during the first rainy season. Any breaks of the stakes should be repaired and strengthened to allow vegetation to take place. - Some thinning of shrubs may be required after few years.		Precautions - Ensure the lines run along the contours and do not concentrate runoff. - Make sure that cuttings are not allowed to dry in the sun. - Avoid using the techniques on poorly drained area subject to small scale slumping.	Scope (Site for Application) Suitable for wet slopes or steep and rocky slopes not subject to slumping.

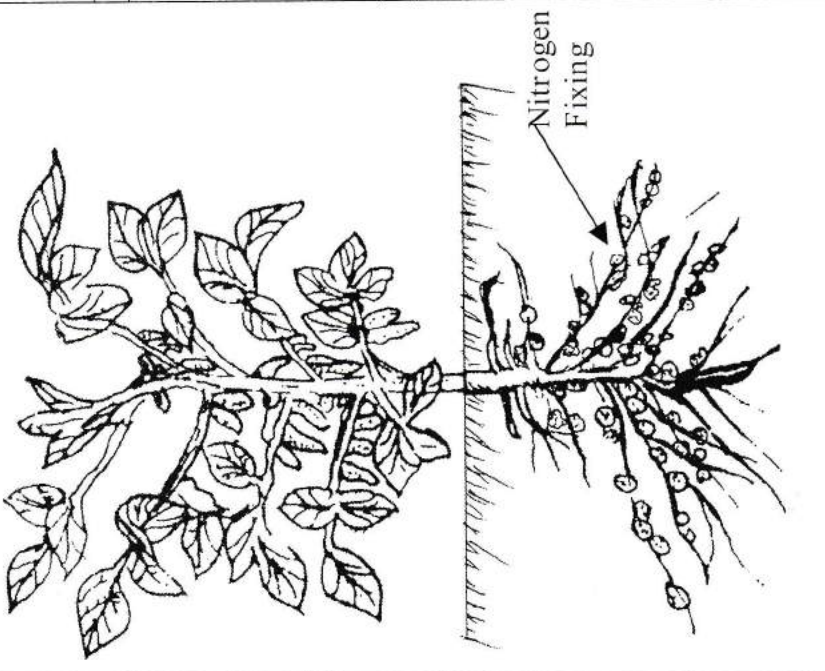
References: DOR, 1999, DOI, 1992, FAO, 1985, ITECO, 1990.

Title: Rip-Rap		What is it? Stone pitching with vegetation inter-planted between the stones.				
		Function:				
		• Reinforces the slope. • Drain through wall by the plants.				
		Limitation				
		• Limited construction height.				
		Disadvantages				
		• Can be used only on short slopes. • Regeneration is obstructed because of stone.				
		Construction Steps				
		• Construct the wall normally, with plenty of soil in the backfill, • After the wall construction, place the cuttings or seeds or grass slips between stones.				
		Gully				
		• Clean the gully floor completely of all debris and excavate as necessary for foundation. • Riprap stones carefully together, always keeping the flattened sides on the surface. Reduce gaps to a minimum and pack all voids with soil. • The stone pitching should have concave shape cross-section for water flow and to prevent scour at the sides, • Cutting / slips (June) or seed (May) should be planted beginning of monsoon rain when soil has sufficient moisture to support the establishment of seedlings.				
Maintenance • Because the spacing of plants in vegetated stone pitching is very dense, there is unlikely to be a need for replacing failures. • Some thinning of shrubs may be required after few years. • Regular cutting of grass would promote root development.	DOR, 1999	Materials		Species	Tools	
		• Stone for construction, • Hardwood cuttings (that could easily roots) or seeds of suitable shrubs, • Grass slips for gully floor. • Cutting should be long enough to reach into soil if portion of the backfill consists of small rocks or gravel.		• Asuro, Nilkandha, Bihaya, Sajiwan, Simali • Acacia pennata, Butea minor, Vitex negundo	• Shovels, hammer and pick axes to pitch stones, • Short planting bars • Hessian and water to keep the planting stock moist until planting	
		Specification		Construction Period		
		• Toe wall upto 2m height and laid back at an angle of about 60°. • Layout of the riprap should be concave to concentrate the water in middle. • If plants can be grown between all stones, it would be beneficial.		• Riprap stone wall can be built at any time, • Planting of cutting during dormant and seedling before monsoon season.		
		Precautions		Scope (Site for Application)		
• Planting should not damage the bark or seed coat.		• Low slope toe walls of upto 2 m in height • Gully floors with a maximum slope of 45° • Gully head after reshaping • Road / trail slopes • Stream bank with medium flow				

References: - DOI, 1992., DOR, 1999, ITECO, 1990, Sthapit, K. M., 1998, Weidlt, H.J. (compiled), 1976.

Title: Agro-forestry	What is it? Integrated practicing of agriculture, forestry and animal husbandry for the benefit of local population and improving soil fertility and environmental.
Sketch 	Function: • Reduces erosion maintaining ground cover • Improves infiltration rate and recharges ground water. Limitation • Generally, small farmers (small holder) cannot afford. • Long-term rotation for tree species. • Inadequate desired planting materials and practical know-how on crop interaction in various combinations Advantage: • Diverse products and continuous source of income. • Nutrient recycling from the deeper soil for crops within the farm • Protects crop from cold, dry and desiccating wind and provides shade to shade loving crops. • Reduces pressure on forest and promotes livestock development. Disadvantages • Tree competes with crops for light, space, moisture, nutrients etc. • Part of cropland is occupied. • Habitat for pests. Implementation Steps • Identification of sites together with local people. • Planning at household level and community level. • Provide suitable options of different combination of cereal, fruit and tree crops (agro-forestry system). • Choice of species is based on multiple-use, climatic adaptability, local need and soil improvement character and relation between the different crops. • Land preparation, pitting, sowing, plantation etc. as per technical prescriptions of different crops. Materials • Planting materials: seeds, saplings, seedlings, cutting, etc. as per needs. Implementation Period • Depends on the different crop combination. Tools • Agricultural implements • Measuring equipment Specification Types of Agro-forestry: • <i>Agri-silviculture:</i> Siris + Tea, Utis + Alainchi / Tea, Sissoo + Coffee, Pakhuri + Black pepper • <i>Silvo-pasture (Livestock + tree / grass)</i> • <i>Agro-silvo-pasture (Crops + Livestock + trees / grasses):</i> Ipil-iril Hedge + Maize / millet, Callocasia + Turmeric / Ginger / grasses Species • <i>Fodder:</i> Badahar, Koiralo, Tanki, Dabdabe, Vimal, Siris, Nimaro, Chuletro, Kutmero, Ipilpil, Kimbu, Kabhro, Rai khanyu, Bhimal • <i>Fire Wood:</i> Utis, Bakino, Siris, Chilaune • <i>Timber:</i> Sissoo, Champ, Chilaune, Bakino, • <i>Multiple Trees:</i> Chyuri, Lapsi, Amala, Kimbu, • <i>Green Manure:</i> Asuro, Khirro, Dhaincha, Simali, Sajiwan, Pati • <i>Live Fence:</i> Simali, Asuro, Phaledo, Nilkada, Bas, Nigalo.
Maintenance • Lopping of fodder trees. • Pruning to obtain bio-mass and prevent shading effect on companion crop. • Grass cutting.	Scope (Site for Application) Spatial Mixed system: Trees on crop land / Plantation of different crop combination / Multistory tree garden Spatial Zoned system: Hedgerow, Alley cropping, Strip cropping, Riser plantation / Boundary plantation / Wind breaks / Tree on marginal lands Silvo-pastoral system: Trees on range or pasture lands / Plantation + pasture / Fodder banks Wood lot management : Timber and land use Aqua-forestry : Trees + Fish Precautions • Consider the nature of crop interaction in various combination of agro-forestry system. • Hedge should not shed the crops in the alley cropping.

References: Gupta J. P. and M.B. Sharma-1997, NAF, 2058 BS. Shankarnarayan, 1984., Young, Anthony 1989.

Name: Use of Nitrogen Fixing Plants (Green Manuring)	What is it? Growing of those plant species, which fix atmospheric Nitrogen in their root nodules through symbiotic process to improve soil fertility and reduce soil erosion.
Sketch 	Function: • Add nitrogen in the soil through symbiotic process. • Plants with deeper roots recycle nutrient from deep sub-soil. • Reinforces the slope. • Improves soil properties and reduces soil erosion. Advantage: • Produce nitrogen rich foliage useful for green manuring, mulching and fodder for animals. • Decaying of roots and nodules add organic matter and other nutrients. • Food legumes provide source of protein. • Tree wood legumes provide firewood and staking materials. • Reduces cost for imported fertilizers. • Nitrogen fixing legumes can grow on marginal and wastelands. Disadvantages • Some N-fixing plants (such as arhar on bund) provide shading effect on crops. • Some land is occupied by legumes Limitation • Some farmers do not accept it. • Some N fixing plants do not provide fodder and fuel. Cultivation Steps • Observation of target area, farming system and identification of farmers' need. • Provide farmers with options for selecting the most suitable and promising Nitrogen fixing plants and let them decide to choose the species. • Discussion on the source / availability of planting materials. • Seed inoculation with appropriate Rhizobia or planting hole inoculation with Rhizobia rich soil. • Preparation of land for sowing or planting (Ploughing / pitting etc). • Sowing or planting of Nitrogen fixing plants. • Use plant materials as green manure or mulch and other purposes. Materials • Seed, Seedlings, Cuttings, etc. based on propagation method of selected species (Table next page) • Rhizobia / Rhizobia rich soil Species • Legume crops: Sunhemp, Daincha, horsegram, cowpea, etc. Refer to Table next page for details Tools • Digging tools / Plough • Measuring tape • Rope Scope (Site for Application) • Rain fed marginal lands • Fallow lands • Crop fields (multiple crop, crop rotation, fallow land) • Degraded & waste lands • Farm boundaries • Terrace risers Precautions • Select right species to suit the specific location, farmer's needs and farming system. • The efficiency of green manure largely depends on growth stage of the plant and the period of application. Therefore, harvest must be made, when the N-content will be high. Maintenance • Weed control, irrigation, application of fertilizer / manure etc as per requirement of selected species.

References: Anonymous 2000. Anonymous 2057 (BS), DOR, 1999, NRRA and IIRR, 1992. ICIMOD, 1995. ICIMOD, 2001. Sen C. K. and Tej Pratap and Prem N. Sharma 1997. NAF, 2050 B. S., Singhal, R. M. and Pradeep Khanna, 1991.

Nutrient content in some Green Manuring plants:

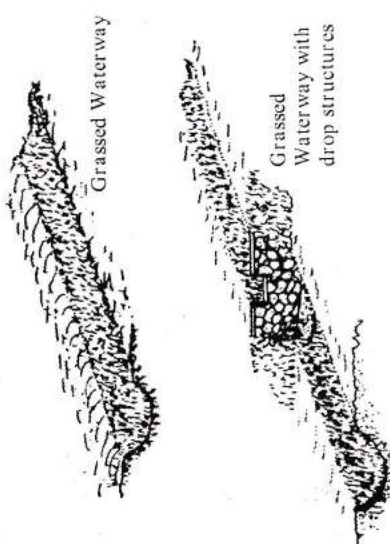
Plant species	Propagation	Nitrogen (N) %	Phosphorus (P ₂ O ₅) %	Potassium (K ₂ O) %
Asuro (<i>Adhatoda vasica</i>)	Hard wood cutting	3.49	0.26	2.44
Titepati (<i>Artemisia vulgaris</i>)	Seeding or Rhizome	2.06	0.22	4.10
Khirro (<i>Sapium insigne</i>)	Hard wood cutting	2.99	0.37	2.31
Ban Mara	Cuttings	2.22	0.35	4.02
Dhasure		3.22	0.22	1.92
Dhaicha (<i>Sesbania spp</i>)	Seed sowing	3.50	0.26	0.92
Cow pea (<i>Vigna spp.</i>)	Seed sowing	2.30	0.21	1.60
Sunhamp (<i>Crotolaria juncea</i>)	Seed sowing	2.30	0.11	1.38
Gliricidia		2.90	0.26	2.15
Siris (<i>Albizia lebeck</i>)	Seedlings from seed	2.90	0.60	2.60

Some Nitrogen Fixing species:

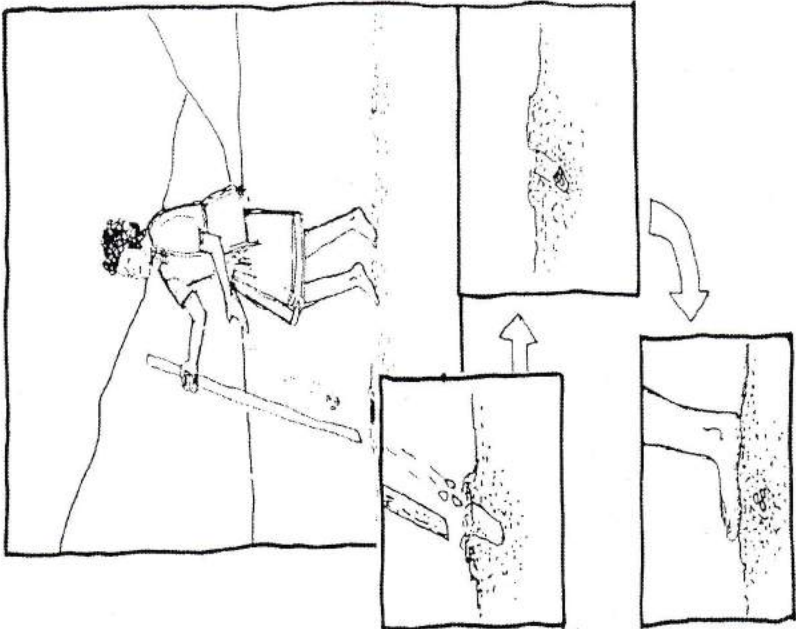
Forage species	N- kg/ ha	Propagation	Character	System Integration	
Joint vetch (<i>Aeschynomene falcata</i>)	180	Seeding	Highly shade tolerant	Pasture improvement	
<i>Desmodium</i>	80-100		Highly shade tolerance	Inter cropping with pasture or as cover crop	
Lucerne /Alfalfa (<i>Medicago sativa</i>)	1500	Seeding	Intensive fodder production purpose	Sole crop	
Bhattmase (<i>Neonotonia wightii</i>)	180		Inter crop with Setaria or Pennisetum		
Kudzu (<i>Pueraria thumbergiana</i>)	150		Cover crop in Plantation crop or Inter crop in pasture		
<i>Stylosanthis</i>	40-80	Seeding	Ground cover with fodder species or Inter cropping with grasses		
Berseem (<i>Trifolium alexandrinum L.</i>)		Seeding	High production & needs irrigation	Relay with rice, Inter cropping with pasture, fruit crops	
Clover (<i>Trifolium repens</i>)		Seeding	Forage production		
Ipil-ipli (<i>Leucaena spp.</i>)	35	Seeding	Reduces erosion & produce high bio-mass for fodder or green manure	Hedges with alley crop, on terrace riser	
Uris (<i>Abrus nepalensis</i>)		Seeding/Seedlings	Fast growing, prefers moist soils	Sowing in land slide areas, integration with cardamom, tea, coffee	
Siris (<i>Albizia lebeck</i>)	2.9	Seeding/Seedlings	Leguminous grows up to 1500 m, fire wood,	Good for agro-forestry, along stream bank and farm boundaries	

Grain species

Pigeon pea (<i>Cajanus cajan</i>)	80-150	Seeding	Grows in degraded land, provides shelter to young plants	Inter cropping with maize, Sesame, rice bond
Gram ()	50	Seeding	Sole or mixed with mustard	
Soybean (<i>Glycine max</i>)	60-80	Seeding	Sole, Relay with maize in lower hills	
Lablab bean / hiude simi (<i>lablab purpureus</i>)	60-120	Seeding	Grows in drought, low fertile and southern aspect.	
			Provides good cover during monsoon & pre-monsoon.	Cover crop under coffee & fruit trees
Lentil (<i>Lens culinaris</i>)	30-50	Seeding	Sole crop and Relay with rice	
Horse gram (<i>Macrotylomia uniflorum</i>)		Seeding	Cover crop in plantation crop & Relay with maize	
French bean (<i>Phaseolus vulgaris</i>)	60-120	Seeding	Inter crop with maize	
Peas (<i>Pisum sativum</i>)		Seeding	Inter crop with cereals and kitchen garden	
Broad bean/Bakula simi (<i>Vicia faba</i>)	100	Seeding	Sole crop, bonds, kitchen garden	
Mung (<i>Vigna radiata</i>)	100	Seeding	Green manuring	Sole crop
Cowpea/Bush type (<i>Vigna unguiculata</i>)		Seeding	Inter crop with fruits	
Tane Bodi (<i>Vigna unguiculata</i>)		Seeding	Inter crop with maize	
Kartike Bodi (<i>Vigna unguiculata</i>)	60-80	Seeding	Commercial vegetable	Sole crop boundaries

Title: Grass Waterways		What is it? Earth waterway planted with grasses.																											
Sketch																													
	Function:		Drains runoff Reduces velocity Armours and reinforces the waterway										Limitation Can only be used for small amount of runoff. Cannot be used where there is a continuous flow of water. Cannot be used until the grass cover is properly established.																
	Advantage:		Low cost Easy to maintain										Disadvantages Fragile																
	Construction Steps		Clear the site. Mark the lines with strings where waterways are to be constructed. Ensure that slope of the alignment properly. Dig the waterways giving uniform shape (cross-section) and slope. Size of the waterways for different runoff is given in the Table next page As a rule of thumb the maximum runoff from the area in cumecs can be obtained by measuring the area in hectare and then multiplying it by 0.1. Construct loose stone drop structure at breaking the slope length less than 30 m. Provide sufficient and strong foundation for the drop structure. After the structure is built, tramp earth solidly behind and around it to prevent cracking. Turfing the waterways																										
	Materials		Species		Tools Short planting bars Line string / Tape (30 meters) Shovels and Pick axes to make the waterways Means of transporting plants to site Hessian and water to keep the planting stock moist until planting																								
	Locally available sod-forming type grass.		Dubo, Paspalum and Centipede grass, etc.																										
	Specification		Construction Period During dormant season if the site is moist. Just before monsoon if the site is dry (May - June)																										
			Cross-section of the waterway should be shallow and in the parabolic shape. Ground slope not more than 20 %. The grass waterways should not be longer than 30 m; Provide drop structures if longer waterways. Drop structure not more than 50 cm high. Use big flat stones in construction. Maintain 3% slope between two drop structures. Side walls for the drop structure must be high enough to direct the flow to the weir.																										
	Precautions		Scope (Site for Application) Farm lands Degraded area																										
Maintenance		Inspect the waterways regularly (mainly during the first rainy season). Any damage (such as breaks, tunneling) should be repaired before it gets worse. Brush or large weeds should be removed before they weaken the grass. Regular grass cutting																											
Table: Size of Catch Drains (Cases)																													
Densely Grassed Waterways		I	II	III	III	IV	IV	V	VI	VI	VII	VII	VIII	VIII	IX	IX	X	XI	XI	XII	XII	XIII	XIII	XIV	XIV				
Parabolic		0.10	0.10	0.15	0.15	0.20	0.20	0.25	0.25	0.30	0.30	0.35	0.35	0.40	0.40	0.45	0.45	0.50	0.50	0.62	0.62	0.75	0.75	0.80	0.80	0.87	0.87	0.99	0.99
Q _{max} in cumecs		0.60	0.60	0.60	0.60	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.90	0.90	1.00	1.00	1.00	1.00	1.20	1.20	1.20	1.20	1.20	1.20	1.25	1.25	1.25	1.25
t = Top width in m.		0.30	0.30	0.30	0.30	0.40	0.40	0.40	0.40	0.40	0.40	0.50	0.50	0.50	0.60	0.60	0.60	0.60	0.70	0.70	0.70	0.70	0.70	0.70	0.80	0.80	0.80	0.80	
d = Depth in m.		0.04	0.08	0.04	0.08	0.04	0.08	0.04	0.08	0.04	0.08	0.04	0.08	0.04	0.08	0.04	0.08	0.04	0.08	0.04	0.08	0.04	0.08	0.04	0.08	0.04	0.08	0.04	0.08
s = Channel slope		0.04	0.08	0.04	0.08	0.04	0.08	0.04	0.08	0.04	0.08	0.04	0.08	0.04	0.08	0.04	0.08	0.04	0.08	0.04	0.08	0.04	0.08	0.04	0.08	0.04	0.08	0.04	0.08

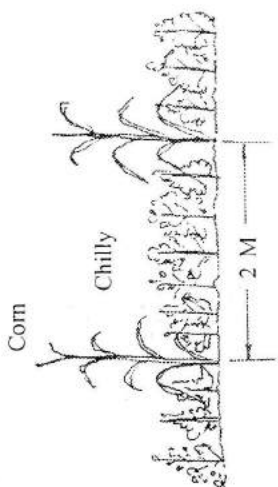
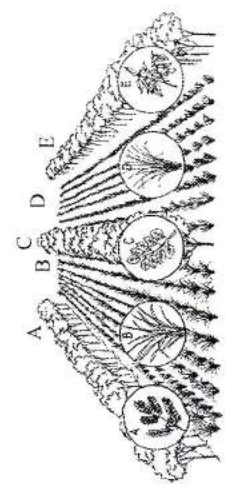
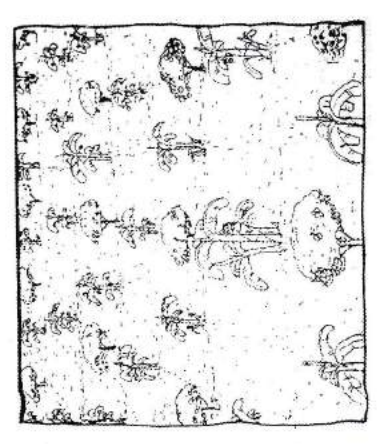
References:- CSWCS, 1987. DOR, 1999. FAO, 1977. Shapit, K. M., 1998.

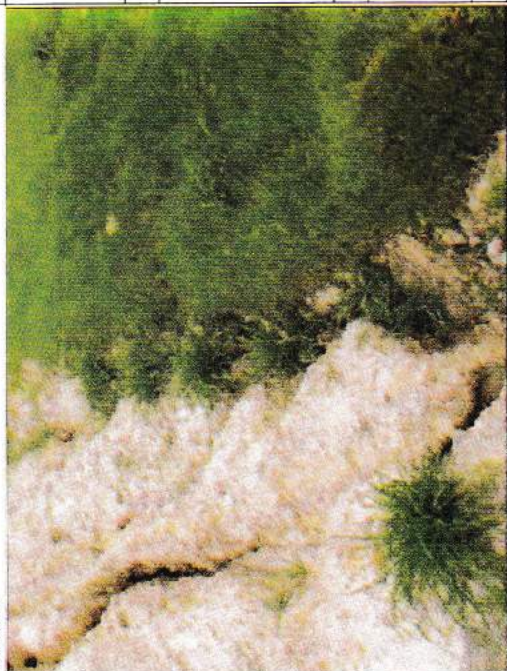
Title: Conservation Tillage		What is it? Preparation of soil to create better environment for germination and root development of the crop with minimum disturbance to soil.				
	Sketch		Function:		Limitation	
			- Reduces soil erosion. - Increases organic matter in the soil (Mulch tillage) - Maintains soil temperature.		- Poor seed germination and minimizes root development. - In some places, weeds may be the problem.	
			Advantage:		Disadvantages	
			- Less disturbance, thus reduces soil erosion. - Opportunity to use marginal lands for crop production. - Reduced cost for tillage. - Improve soil moisture status.		Sometimes zero tillage may increase run-off rate and hence the increase in erosion.	
			Tillage Steps			
			Zero Tillage: In zero tillage soil is opened only for placing the seed. This can be done by Dribbling, Drilling, Pitting etc.		Minimum Tillage: The land is partly ploughed along the contour and prepared for the seedbed after harvesting the previous crop rather than ploughing the entire plot.	Mulch Tillage: Tillage operation is reduced to minimum and land is continuously covered by mulch or growing crops. For crop sowing, ditches are dug in rows along the contour. The crop residues are used as mulch for new crops.
			Materials		Tools	
			Plant residues (Straws, Stack, Husk, Stubbles), Leaves litters, Sawdust / ash, grass / weed (without seeds) etc. for mulching.		- Hoe (Kuto) - Plough - Spade	
			Specification		Tillage Period	
			Vary with different tillage and cropping species.		Vary depending upon the cropping season.	
Maintenance		Scope (Site for Application)				
Loosening of crusted soil for seed germination and root development is necessary.		- Zero tillage in areas with periodic drought and coarse textured soils. - Minimum tillage or mulch tillage on sloping lands with silty-clay loam soils.				
Precautions		- Check whether tillage operation is enough for seed germination. - Check whether soil surface is properly covered with mulch or crops.				

References:- Ftingfu, Guo, 1992. FAO and IIRR, 1995. ICIMOD, 1995.

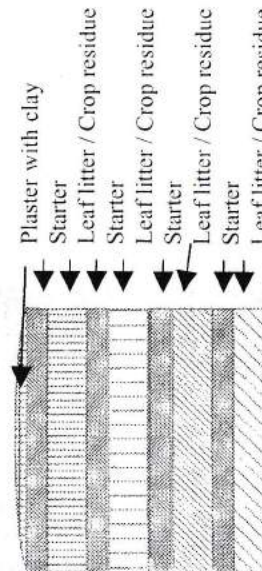
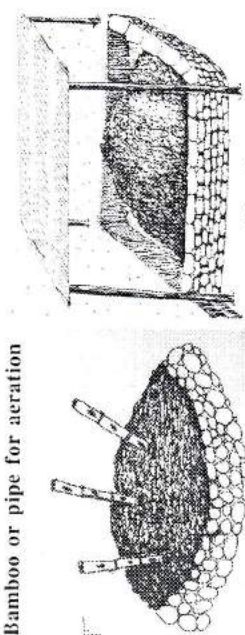
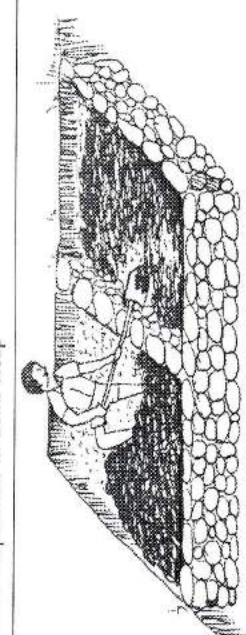
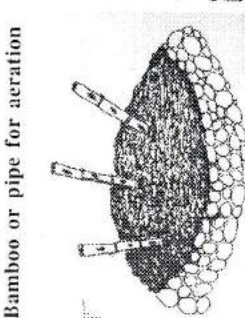
Title: Crop Rotation				What is it? Practice of growing different crops in succession in same piece of land.		
Sketch				Function:		
peanut peanut peanut				Limitation - Difficult for small farmers on rain fed areas. - Wide knowledge required for different crops.		
SEASON 1 SEASON 2 SEASON 3				Disadvantages Difficult in long term crops (such as sugar cane).		
Planting Steps - Select suitable crops based on local needs. - Consideration: - - Deep rooted should be followed by shallow rooted crops or vice versa. - Cereal crops (heavy feeder) should be followed by legume crop.						
Materials Seeds, Saplings, Seedlings etc. as per propagation methods of selected crops.				Crop Combination (Some examples): For Hills Upland :- - Maize - Vegetable - Maize - Wheat - Soybean - Tori For Irrigated Land :- - Rice - Wheat-Green manure - Rice - Vegetables - Rice / Lentil - Fallow For Terai Upland :- - Maize - Legume - Arhar - Fallow - Maize - Tori or Wheat Note: - Following crop / Relay crop		
Tools As per the requirement for the cultivation practices						
Specification Refer to technical notes for different crops				Construction Period As per crop season		
Maintenance Manuring, Fertilization, Weeding, Irrigation, Drainage				Scope (Site for Application) Farm land :- Annual, Cereals/ Vegetables/ , Upland/ Lowlands.		
Precautions As per crop requirement						

References: Deyi Wu et. al. 1998, FAO and IIRR, 1995, Pedro A. Sanchez, -1976, R.B.Shah, 1992, B. K. Bhomi, I. R. Pandey, 1992.

Title: Multiple Cropping		What is it? Growing of two or more crops overlapped on the same land during a year to intensify crop production.	
Sketch 	 A-Leucaena, B-Napier, C-Gliricidia, D-Guinea grass, E-Flemingia	Function: - Reduces erosion by covering the open inter-space. - Performs complementary functions (N from legumes to cereals). - Reduces erosion and catches soil materials.	Limitation Difficulty in cultural operations.
		Advantage: - Provides opportunity to diverse production. - Additional foodstuff from the waste inter-space. - Reduces risks (If one crop fails another crop pays). - Efficient use of nutrient from different layers of soil. - Multiple cropping may reduce pest / insect problems.	Disadvantages - Crop competition (Nutrients and Moisture) - Labor intensive
		Implementation Steps - Multiple cropping includes: Mixed cropping: Growing of two or more crops simultaneously with no distinct patterns. Land is prepared for sowing the crop. Generally, sowing is done by broadcasting method and seed is covered by planking. Relay cropping: Growing of two or more crops simultaneously during part of each one's life cycle. A second crop is planted after the first crop has reached certain stage of growth but before it is ready for harvest. Inter cropping: Growing crops in the vacant inter-space of the main crops is called inter-cropping. - Considerations: - Legumes crops with cereals and fast growing / short-term crops are suitable for inter-cropping. - Long rooted with shallow rooted crops.	
		Materials - Seeds, Saplings, Seedlings etc. - As per propagation methods of selected crops.	Tools As per the requirement for the cultivation practices
	Precautions - Heavy feeder crops like sugarcane, maize, wheat, rice, millet should not be grown as inter-crops in fruit orchards. - Inter crops are secondary crops they should not be overdone to injure the main crops in any way.	Crop Combination (Some examples):	
		Mixed cropping: - Wheat + Mustard, Wheat + Pea. - Maize + Cowpea or Beans or Soybeans - Mustard + Lentil or Gram - Groundnut + Pigeon pea	Inter-cropping: - Mango or Litchi + Ginger or Turmeric or Lucern or Stylo / Leafy vegetables or Banana or Papaya or Pineapple - Rice + Black gram or Pigeon pea (in bonds) - Potato + Radish or Bakulla simi - Uttis + Cardamom
		Relay Cropping: Rice / Lentil, Maize / Millet or Soybean	Note: + Mixed crops / Relay crop
		Specification Refer to technical notes for different crops	
Maintenance Manuring, Fertilization, Weeding, Irrigation, Drainage	References: Deyi Wu et. al. 1998. FAO and IIRR, 1995. Pedro A. Sanchez, -1976. R.B.Shah, 1992. B. K. Bhomi, I. R. Pandey, 1992.	Construction Period As per crop season	
		Scope (Site for Application) - Farmland: Annual / Perennial, Cereals / Vegetables / Upland / Lowlands. - Leasehold forests	

Title: Cover Crop				What is it? It is a technique in which land surface is densely covered with permanent grasses or leguminous plant species to reduce erosion and improve degraded soils.	
Sketch					
Maintenance • Cut the grass from 10-20 cm above the ground level and use for mulching or animals. • To maintain the soil moisture, cut grass just before the dry season. • Control rodents		Precautions • Cut the grass from 10-20 cm above the ground level and use for mulching or animals. • To maintain the soil moisture, cut grass just before the dry season. • Control rodents		Scope (Site for Application) • Fruit orchards • Fragile and Degraded lands • Drainage • Terrace risers • Gully, Landslide area, Road slope etc.	
		Function: • Protects surface from raindrops erosion by proving ground cover • Armours and reinforces the slope. • Creates rough to reduce the runoff velocity. • Catches soil material.		Limitation • Difficult to establish in most degraded lands. • Fire may break out.	
		Advantage: • Improves soil fertility (OM, physical, chemical and biological activities) are improved. • Rehabilitation of degraded land (Productive). • Forage / grass available for the animals. • Improves moisture status. • Suppresses weeds and reduces weeding cost		Disadvantages • Needs regular care. • Competition with companion crops.	
		Implementation Steps • Site assessment and species selection. • Land preparation (Entire area or in strips) • Direct seed sowing or vegetative propagation method depending upon the type of species.			
Materials • Seed, slips depending upon the propagation method of selected species		Species ▪ Palpa stylo ▪ Stylo-184 ▪ Arachis glabarata ▪ Dubo ▪ Napier	Tools • Measuring tape • Rope • Hoe / spade		
Specification • The space requirement for plant to plant is 30 cm and row to row 20 cm. • Planting of 2-3 tillers (in case of grass species) per hill for the successful establishment. • If seed is fine then sowing is done by mixing with soil / ash / sand. • Planting of cover crop in triangular pattern is better • If available, use of compost/manure or fertilizer will be useful for initial growth. • Apply urea @ 100-200 kg / ha in the first year.		Construction Period • Planting is done on cloudy or rainy days after the onset of monsoon.			

References: DOR, 1999, NNRR and IIRR, 1992, CSWCS, 1987, Liao, Mien-chun and Hucui-long Wu, 1987.

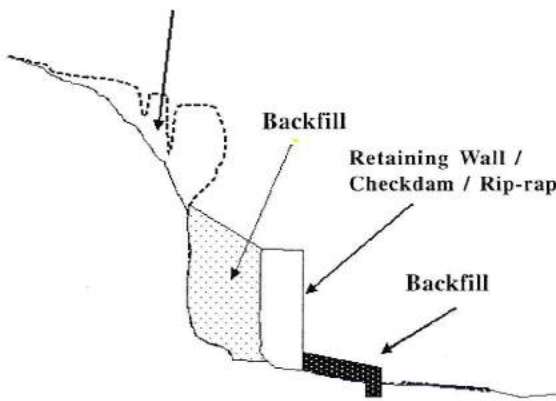
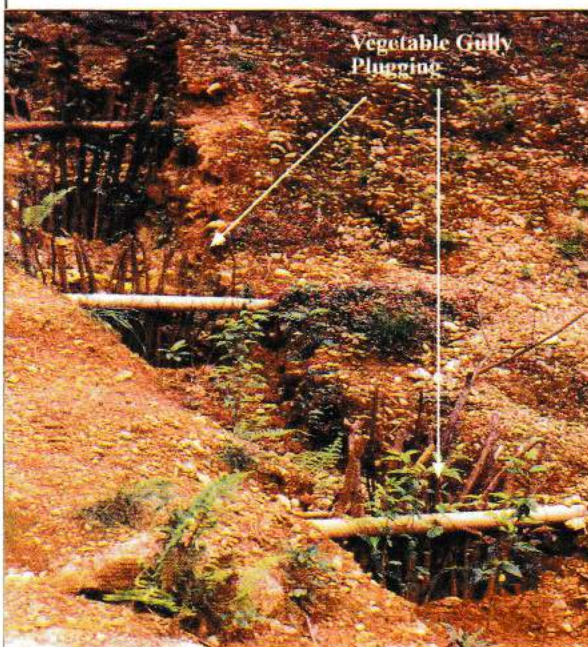
Title: Compost / Farm Yard Manure (FYM)			
What is it?			
Compost		: Decomposed vegetative products prepared under certain favorable condition and which can easily be mineralized after the application in soil.	
Farm Yard manure		: Farm Yard Manure is the decomposed organic product prepared from animal dung, urine, grass residues and leaf litters.	
Sketch			
 Shade		Function: - Adds plant nutrients including organic matter thus improving soil productivity. - Improves soil structures, moisture holding capacity and biological activities in the soil Advantage: - Use of local waste resources - Reduces dependency on chemical fertilizer and its negative impact on soil. - Easy for cultural operation (ploughing). - Promotes nutrients base organic farming	
 Turning of Compost			
Bamboo or pipe for aeration 		Limitation - Percentage of nutrients is low - Loss of nutrients through leaching and evaporation Disadvantages - Labor intensive - Un-decomposed manure increases infestation of insects and weeds. - Slow available of nutrients to the plants.	
Compost or Farm Yard Manure Preparation Steps - Collect plant materials and cut into pieces for compost making. Preferably animal bedding materials. - Put the materials into the pit and add starter after each layer of 50 cm of plant material. - Maintain moisture and seal the pit with plastic or mud. - Turn the material (every 2 – 4 weeks depending on climate) for uniform decomposition and good quality manure. In case of FYM, an alternative to turning bamboo sticks / pipe can be inserted into the pit for better aeration. However, in case of compost making turning is essential.			
Materials - Crop residues, grass, leaf litters, water and starter (such as lime, urea, animal products: urine, dung) for the compost. - Animal products: urine and dung, crop residue, grass, animal bedding materials etc for FYM.		Method - Pit method (Permanent, good for dry season to enhance decomposition) - Heap method (wet materials and in areas of high water table) - Semi-heap method (useful for rainy season)	Tools - Spade - Basket - Bucket
Specification - Generally one cubic meter space is needed to prepare 1 metric ton of compost or FYM. - Suitable size of the pit should be 1 m depth, 2m width, and 5m length.		Construction Period - Compost can be prepared in any season provided necessary precaution measures are taken. - It takes 15 days to 3 months depending upon the types of material used, season and methods. - Manure should be applied two weeks before crop sowing to avoid nutrient loss and mineralization of the compost.	
Maintenance Protect compost from direct sun and rain.		Precautions - Check whether the compost has turned to gray-black color, non sticky and friable. - Incorporate the manure into the soil immediately after transportation in the field. - Grasses with seeds should be avoided to discourage the weeds.	Scope (Site for Application) Compost could be used in all farmland and degraded land for crops, grasses and trees.

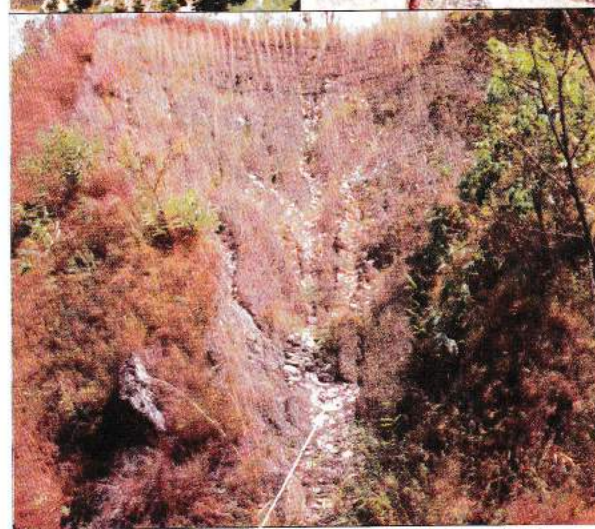
References: - SSMP 2001. DOA, 1999.

Nutrient Content in Organic Sources

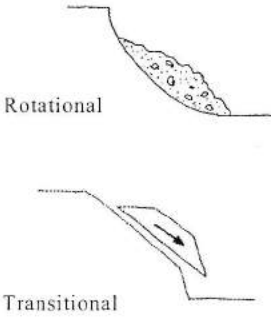
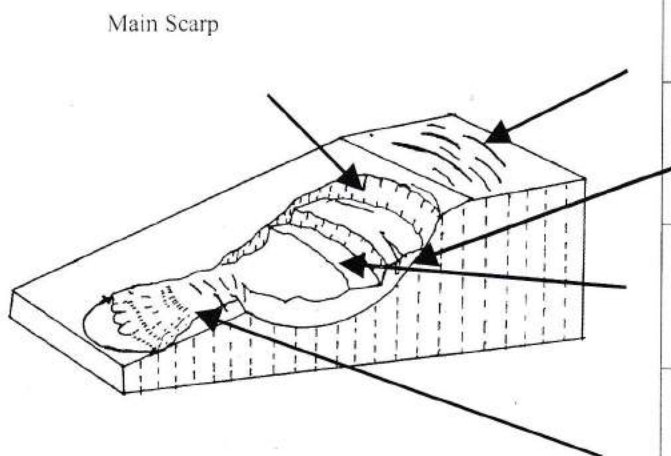
<i>Organic Sources</i>	<i>N %</i>	<i>P2O5 %</i>	<i>K2 O %</i>
Cattle fresh Dung	2.41	0.75	0.88
Pig Fresh dung	2.11	2.41	0.97
Buffalo fresh Dung	1.09	0.82	0.70
Poultry manure	2.85	4.21	2.00
Night soil	5.50	4.00	2.00
Compost	0.50	0.15	0.50
FYM	0.50	0.25	0.50
Mustard cake	5.20	1.80	1.20
Peanut cake	7.30	1.50	1.30
Neem cake	5.00	1.10	1.50
Caster cake	5.50	1.10	1.30
Urine fresh	0.60	0.17	0.80
Bone meal	0.00	20-25	0.00
Leaf litters	1.20	0.26	0.33

Activity:	Gully Treatment
Definition:	Gully: An erosion channel cut by concentrated run off but through which water commonly flows only during and immediately after heavy rains. A gully is sufficiently deep that it cannot be crossed by a wheeled vehicle or eliminated by ploughing. Refers to the vegetative and structural measures applied both in gully and its catchment to solve the problem of gully erosion.
Major Problems Caused by Gully Erosion:	• Expands gully causing damage to the surrounding areas and development infrastructures. • Soil erosion causing sedimentation of downstream fertile lands, streams, channels and reservoirs.
Major Causes of Gully Erosion:	• Erosion in the catchment. • Channel erosion by unmanaged runoff resulting downward or side ward scouring. • Steep unprotected slopes and drainage channels. • Gully head expansion. • Side slope failure due to toe cutting.
Objectives of Gully Treatment:	• To prevent further degradation of the gully and its watershed through controlling run off and erosion. • To improve water quality and regime. • To improve the site condition of the gully area.
Sketch/Photo	Scope of the gully treatment
	Gully treatment involves following techniques: - • Landuse improvement (Such as Conservation plantation, grass planting, Degraded land rehabilitation, and On-farm conservation) in the catchment, • Vegetative techniques: To reinforce the loose soil surface. This includes Fascines, Palisade, Brush layering, Brushwood checkdams, Wattling, Rip-rap • Structural techniques: Loose stone and Gabion checkdams, Retaining walls. • Drainage Management: To prevent runoff entering into the gully and draining the excess water from gully. - o Surface drainage techniques: Include construction of diversion waterways, sealing of tension cracks so that rainwater cannot get inside and build up pore-water pressure. - o Conservation pond to store and divert excess run-off. • Gully rim edging. • Gully head plugging. • Gully bank slope correction. • Protection of the gully area from livestock.
	Survey consideration • Prepare map of about 1:500 – 2000 scale (If not, at least sketch is mandatory) showing: - - o Catchment area and major landuse types. - o Gully area and active gully head areas. - o Water courses (including rills) • Survey the longitudinal profile and cross section of the gully, where the checkdams (Brushwood, Loose stone, Gabion) are to be installed. For simple procedure use of the clinometer or abneys' level and measuring tape is recommended.

Sketch/Photo	Survey consideration																										
Gully Head Slope Correction 	Classification of Gullies <table><tr><th rowspan="2">Name</th><th rowspan="2">Depth in m</th><th colspan="2">Recommended Techniques</th></tr><tr><th>Waterways</th><th>Gully area</th></tr><tr><td>Rills</td><td>< 0.30</td><td>Fascine (Community lands), Conservation Tillage (Agriculture lands)</td><td>Planting</td></tr><tr><td>Small</td><td>0.3 - 1</td><td>Palisade, Brushwood checkdams</td><td>Planting / Brush layering / Wattling</td></tr><tr><td>Medium</td><td>1 – 5</td><td>Brushwood and loose stone checkdams</td><td>Planting / Brush layering / Wattling</td></tr><tr><td>Large</td><td>5 – 10</td><td>Loose stone and Gabion checkdams</td><td>Planting / Brush layering / Wattling / Retaining walls</td></tr><tr><td>Ravines</td><td>> 10</td><td>Loose stone and Gabion checkdams</td><td>Planting / Brush layering / Wattling / Retaining walls</td></tr></table> Remarks: Depending upon the position in the gully, fascines, palisades, brushwood and loose stone checkdams could also be used in the large gullies and ravines.	Name	Depth in m	Recommended Techniques		Waterways	Gully area	Rills	< 0.30	Fascine (Community lands), Conservation Tillage (Agriculture lands)	Planting	Small	0.3 - 1	Palisade, Brushwood checkdams	Planting / Brush layering / Wattling	Medium	1 – 5	Brushwood and loose stone checkdams	Planting / Brush layering / Wattling	Large	5 – 10	Loose stone and Gabion checkdams	Planting / Brush layering / Wattling / Retaining walls	Ravines	> 10	Loose stone and Gabion checkdams	Planting / Brush layering / Wattling / Retaining walls
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	Design Consideration Gully treatment is categorised into three major areas: - • Improvement of Catchment Area: To reduce and regulate the quantity of runoff and sediment. - o Landuse improvement: Grazing land management, planting in degraded areas, treatment of slope failure areas, - o Conservation pond to manage the runoff • Treatment of Gully Head and Area: To prevent gully expansion and stabilize the gully area. - o Closure of gully area to grazing and other biotic interference - o Gully head stabilization: ~ Gully rim edging is done by trimming the sides of a gully to a straight slope of 35 to 45°. ~ Rip-rap ~ Retaining wall - o Treatment of gully area: Grass / shrub / tree planting, Hedgerow planting, Brush layering, Wattling, Retaining wall in steep slopes • Waterways Improvement: To drain water safely - o Fascine, palisade, checkdams (brushwood, loose stone, gabions), riprap to stabilize waterways preventing further down cutting of bed and to control the water speed and trap sediment. - o Stone lining of the natural drainage within the gully could dispose the surface runoff. - o Diversion waterways above the gully heads to divert water coming to gully. Waterways must be at a distance at least twice the width of the gully from the gully head. Waterways size must be wide enough to accommodate maximum runoff. Waterways can be earthen or lined, depending on the site condition. Precautions must be taken to safely dispose the diverted runoff not to create new gully.																										
	Remarks: • Management of runoff above the threshold quantity creating the gully expansion through storing the excess runoff in the conservation pond could ease the gully treatment.																										

Gully Before Conservation Pond 	Gully After Conservation Pond, Lalitpur 	Case <u>Conservation Pond as a means to stabilize gully, Bhardev</u> The village was severely affected by a gully. Even walking during intense rain became difficult. The Bagmati Watershed Management Project made an effort to control the gully expansion by putting checkdams and planting vegetation. Unfortunately, the gully could not be controlled. During the period a conservation pond was constructed at the top of the hill in grazing land to tap the surface run-off for cattle feeding. As a miracle, the gully starts stabilizing itself without much effort in the gully area. The fact is that the conservation pond stored the excess run-off, which is above the threshold capacity of the gully. As a result of the conservation pond, the gully was stabilized itself.
 Drainage Management in the Gully		Practical Consideration • Gully treatment could only be effective, if all the treatments described have been implemented as a package. • The choice of species, wherever possible, should be indigenous, and produce useful outputs, such as fodder, fuel and grass. • Vegetation should maximize the ground cover and reinforce the soil layer. • The vegetation should be light in weight so that large trees do not overload the slope. Generally shrub / bush, small trees or grass. • A high investment in structures is generally recommended when houses, lives or infrastructure are threatened. Working Unit: • The catchment area of a gully and gully area is taken as the working unit. Working Season • Any time during farmer's slack period for structural works. • During Dormant season if the site is moist and just before monsoon if the site is dry (Baisakh, Jestha) for vegetative works. Maintenance • Patch up areas as quickly as possible whenever erosion problems begin. • Prevent cutting, burning or grazing of vegetation whilst it establishes.

Reference: BIWMP, 2003. DOR, 1999. DSC, 1992. NRRA and IIRR, 1992. SCWMC, 2001. Sthapit, K. M., 1998. Sheng, Ted C. 1986. Weidlt, H.J. (compiled), 1976.

Activity:	Landslide Treatment			
Definition:	What is it? Down-slope movements of a mass of rock, earth or debris under influence of gravity, frequently occurring when the material is saturated.			
Landslide:				
	Types of Landslides			
	Fall	:	Abrupt movements of the slopes by free fall or rolling or bouncing.	
	Topples	:	Overturning or tilting of a block of rock on pivot or hinge.	
	Slides	:	Slope movement caused by distinct surface of shear failure.	
		Rotational	:	Movement is approximately on circular surface of failure. It may be single or multiple rotational surface failure.
		Translational	:	Movement is approximately on planar surface failure.
	Spreads	:	Movement caused by liquefaction, whereby saturated loose and cohesionless sediments are transformed into a liquid state.	
	Flows	:	Rapid movements of viscous fluid. Slip surfaces are almost absent.	
Complex	:	Combination of two or more principal types of movement.		
Landslide Zoning: Landslide is broadly divided into following zones: -				
	Zone of Cracking	:	Cracks above the slide and sometimes around its sides are developed.	
	Zone of Failure	:	The head scar (crown) and failure surface, which may occupy only a relatively small area at the top of the slide.	
	Zone of Transport	:	A damaged slope, scarred by the passage of debris on its way down slope, this part of the slope may be stable, and may recover on its own.	
	Zone of Accumulation	:	The area within which the displaced materials lies above the original ground surface.	
Landslide Treatment:	What is it? Vegetative and structural measures applied to treat landslides.			
Major Problems caused by landslide	- Expand landslide area causing damage to surroundings (lands and habitation), - Sedimentation of downstream fertile lands, streams, channels and reservoirs.			
Major Causes of Landslide:	- Erosion by unmanaged runoff on unprotected gullies, stream, rivers and drainage channels resulting cutting toe and downward scouring of the channel, - Weight of water from leaking pipes, canal, ponds increasing water content causing shear failure, - Steep unprotected slopes, - Alternation of permeable beds such as sandstone with weak impermeable beds such as shale (phyllite) causing flow of seepage water along the contact causing lubrication helping slides. - Human activities such as construction of canals, roads, borrow pits, which change hydrological processes.			
Objectives of Landslide Treatment:	- To prevent further movement of slopes through controlling runoff and erosion, - To prevent upslope and downslope damage, - To improve water quality and regime.			

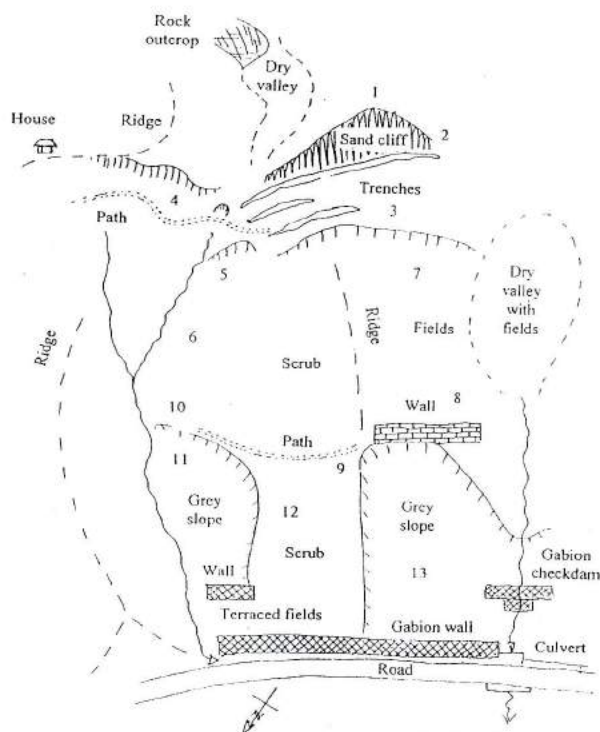
Scope of the Landslide Treatment

Landslide treatment involves the following techniques: -

- Landuse improvement (Conservation plantation, grass plantation and on-farm conservation) in the catchment,
- Bioengineering Techniques: To reinforce the loose soil surface. This includes Fascines, Palisade, Brush layering, Brushwood checkdams, Wattling, Loose stone checkdams, Rip-rap inter planted with brush cutting and grass.
- Drainage Management: To prevent runoff entering into the landslides and draining the excess water from landslides.
 - o Surface Drainage Management: Include construction of diversion waterways, sealing of tension cracks so that rainwater cannot get inside and build up pore-water pressure.
 - ~ Appropriate for controlling shallow slides
 - o Subsurface Drainage Management: Include Horizontal drains, Vertical drains, Drainage tunnels, Deep subsurface trenches,
 - ~ Appropriate for reducing pore-water pressure along failure planes.
 - o Conservation pond to store and divert excess run-off,
- Structural Techniques: To stabilize unstable slopes.
 - o Retaining Walls: Used on slopes. Could be creep walls, loose stone, gabions, masonry, and concrete.
 - o Checkdams: Used on channel. Could be brushwood, loose stone, gabion, masonry and concrete.
 - o Anchoring: Used in deep seated landslides. Not easy.
- Excavation and Filling: Removal of rock and soil from the head of a landslide to reduce the driving force. And filling at the toe to increase resistance against move.
- Toe Protection: To protect toe of the slope from cutting. This includes revetment, spurs, riprap toe wall.
- Protection of the landslide from biotic interferences.

Sketch/Photo

Landslide Mapping



Survey consideration

- Prepare map of about 1:500 – 2000 scale (If not, at least sketch is mandatory) showing: -
 - o Landslide boundary,
 - o Mark the major landslide scarp,
 - o Mark crack zone in the ground outside the main subsidence area,
 - o Catchment area including major landuse types requiring treatment,
 - o Surface drainage pathways (springs, swamp, ponds, irrigation ditches, canals, pipes) outside of the landslide area that may require diverting away from the landslide,
 - o Springs and seepage areas that may need to be drained,

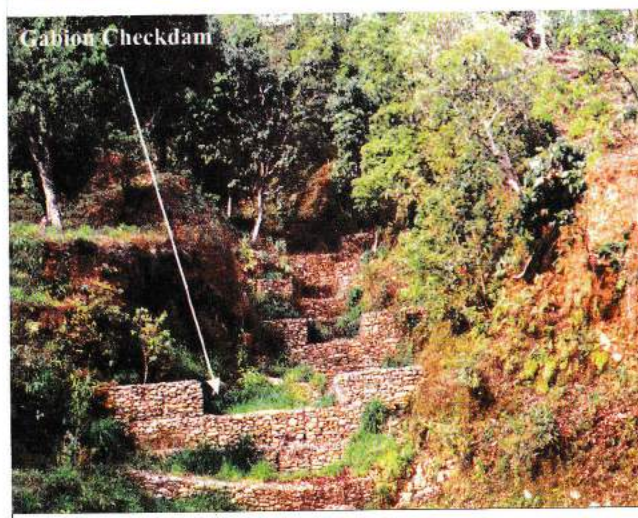
Note: - Recognition of seepage is sometimes aided by the identification of near surface channels, wet areas, tall vegetation on the slope. Delineation of drainage network, especially the presence of seeps or springs, is extremely important in any landslide investigation.

- o Stream and Gullies requiring special treatment,
- o Mark problems of toe cutting,
- o Locate the houses, roads, or other manmade structures both upon and in close proximity to the landslides,

- Record which part of the slope the landslide originated from i.e. upper third part (upper convex part) of the slope, middle third of slope or lower third (concave) of slope.
- Survey the longitudinal profile and cross section of the landslide area, where the checkdams (Loose stone, gabion) are to be installed. For simple procedure use of the clinometer or abneys' level and measuring tape is recommended.

Remarks: -

- Trees leaning in different direction often indicates a slow creep of surface materials downslope without imminent slope failure.
- Fresh debris at the base scarp indicates the landslide upslope.
- Most landslides enlarge with time. As a thumb rule, the area studied should be 2 – 3 times wider and longer than the area suspected.
- Analyze geology, topography, drainage, and other natural and man-made elements to understand the processes of the landslide to design optimal measures to treat the landslide.

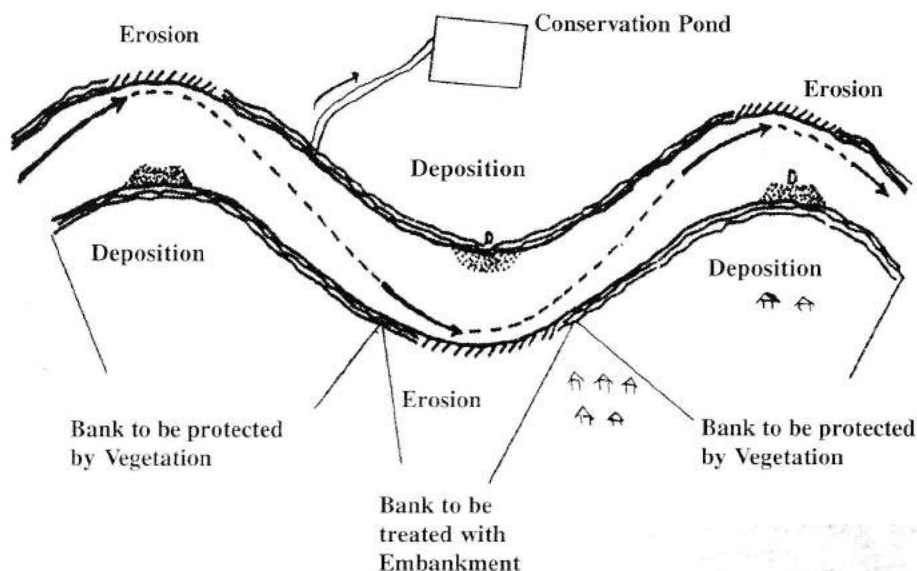
Sketch / Photo	Design consideration
Kulekhami 1987 	Landslide treatment involves following five major areas: - • Treatment of Catchment Area: To reduce and regulate the quantity of runoff and sediment. - o Landuse improvement: Grazing land management, planting in degraded areas, treatment of slope failure areas. - o Diversion waterways must be well above the cracking zones. Waterways size must be wide enough to accommodate maximum runoff. Waterways can be earthen or lined, depending on the site condition. Precautions must be taken to safely dispose the diverted runoff not to create new gully and landslide. - o Drainage waterways Improvement - o Conservation pond to manage the runoff. • Treatment of Cracking Zones: To prevent seepage of water into sliding area. - o Closure of cracks with clay materials. - o Closure of cracking zone to grazing and other biotic interference.
Kulekhami 1990 	• Treatment of Failure Zone: - o Failure Zone stabilization: ~ Reshaping of the steep slope to a straight slope of 35 to 45°. ~ Rip-rap ~ Retaining wall ~ Fill all depressions, where water can accumulate • Treatment of Transport Zone: - o Slope stabilization: ~ Treatment of slopes: Grass / shrub / tree planting, Hedgerow planting, Brush layering, Wattling, Retaining wall in steep slopes ~ Drainage waterways improvement
Gabion Checkdam 	• Treatment of Accumulation Zone: - o Closure of accumulation zone to grazing and other biotic interference especially from removal of the debris. - o Toe protection of the accumulation debris. - o Waterways improvement: To drain water safely • Drainage Improvement: To drain water safely. It will be integral part of all treatment described above. - o Fascine, palisade, checkdams (brushwood, loose stone, gabions), riprap with grass to stabilize waterways preventing further down cutting of bed and to control the water speed and trap sediment. Precautions must be taken to safely dispose the diverted runoff not to create new gully.
	Note: - ~ Always design drainage systems to run along natural drainage lines. ~ Never use contour drains; these block very easily and also highly susceptible to subsidence. A blocked or cracked drain can create terrible damage as a result of concentrated water flow. ~ Design and construct drains in such a way that water can enter them easily on the higher side but not seep out on the lower side. ~ A flexible design is usually an advantage.

Sketch / Photo	Practical Consideration
 Hard Rock Layer Soft Rock (Clay) Layer	• Landslide treatment could only be effective, if all the treatments described have been implemented as a package. This may require big resource. If resource is not available to implement as a package it is not recommended to implement the activity. • Geological (natural) landslides should not be treated with expensive structures unless and until they affect habitation or infrastructure (e.g. roads and reservoirs). • Landslide treatment could be some years project rather than one time activity. Landslides are continually changing phenomena. Therefore its treatment should consider the changing strategy and measures to treat it properly. Working Unit: • The catchment area of a landslide and landslide area is taken as the working unit. Working Season • Any time during farmer's slack period for structural works. However, rainy season is risky for the construction of structures. • During Dormant season if the site is moist and just before monsoon if the site is dry (Baisakh, Jestha) for vegetative works.

Reference: -

BIWMP, 2003. DOR, 1999. DSC, 1992. Marden, M., 1991. NRRA and IIRR, 1992. SCWMC, 2001. Sthapit, K. M., 1998. Thakur, V. C., 1996. Upreti, B. N., and M. R. Dhital, 1986.

Activity:	Stream Bank Protection / Torrent Control	
Definition:		
Stream	A stream is a waterway generally referred to perennial one. Stream bank erosion refers to the land adjoining the stream and or river, where stream and or river cutting is actively destroying habitation, agriculture and forest land.	
Torrent	A stream with great velocity or turbulence causing riverbank erosion and flooding during heavy rains. A torrent can be described as a natural channel or waterway with: ~ A small catchment or watershed. ~ Steep and irregular sections. ~ Extreme oscillation of the runoff with high flood peaks after rainstorms and snowmelt. ~ High bed load (due to intensive erosion and mass movement) and sedimentation.	
Torrent Control and Stream bank Protection:	Vegetative and structural measures applied in the torrential stream and its catchment, whereas stream protection confines to activity mainly to protect the stream bank erosion and adjoining property (habitation and farmlands).	
Major Problems caused by Stream Bank Erosion and Torrent:	• Stream bank erosion. • Flooding and sediment deposition in the farmlands.	
Major Causes of Stream Bank Erosion and Torrent:	• Steep stream slope. • Unprotected stream banks. • Excessive intense rain and runoff. • Erosion in the catchment.	
Objectives of Stream Bank Erosion and Torrent Control:	• Protect property (habitation and farmlands) from erosion, flood and sedimentation. • Dispose runoff safely.	
Sketch/Photo	Recommended techniques	
	• Appropriate landuse improvement (Conservation plantation, Silviculture management and degraded land rehabilitation) in the catchment , • Gully treatment (also if there is any landslide) in the catchment, • Water harvesting to manage runoff, • Stream bank protection measures, • Channelization efforts to manage the flood discharge. • Flood plain stabilization through bioengineering measures.	
	Remarks: - Stream bank protection confines its activities and only refers to: - • Stream bank protection measures, • Channelization efforts to manage the flood discharge. • Flood plain stabilization through bioengineering measures.	
	Survey consideration	
Mapping • Prepare map of about 1:1000 – 5000 scale (If not, at least sketch is mandatory) showing: - - o Stream course indicating straight, concave (where scouring and undercutting is prevalent) and convex (where deposition prevails) portions, - o Catchment area including major landuse types requiring treatment, - o Natural drainage and their direction and mark drainage requiring treatment, - o Gullies (also landslides if any) in the catchment requiring special treatment, - o Source of runoff (where does it come from and where does it go) and a proper place where it can be safely diverted, - o Water pathways (ponds, irrigation ditches, canals) in the catchment area that could be used to manage runoff, - o Possible sites for conservation pond construction for storage of water to manage the runoff, - o Stream and Gullies requiring special treatment, - o Locate the houses, roads, or other manmade structures both upon and in close proximity to the landslides,		
Assessment • Assess the problem of the stream bed as follows: - - o Whether the stream is at the stage of shifting laterally? - o Whether the stream is at a stage of degradation i.e. lowering of its bed? - o Whether the stream is at a stage • Historical background such as frequency, maximum flood height. • Sediment deposition		



Measurement

- o Measure the longitudinal profile and cross section of the stream, where structures to be installed to protect the habitation and farmlands are required.
- o Mark and measure different flood water level and assess frequency of its occurrence in the stream.
- o Estimate the maximum runoff in the stream.

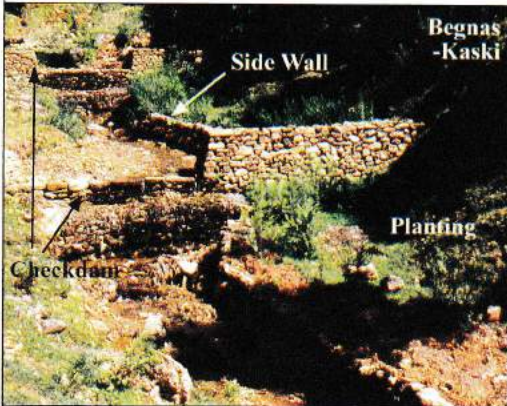
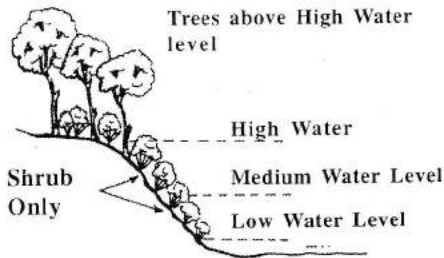
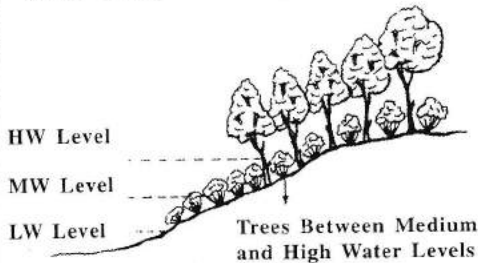
Note: - There are several methods to calculate the runoff. As a rule of thumb, the maximum runoff from the catchment area in cumecs can be obtained by measuring the area in hectare and then multiplying it by 0.1.

Design consideration

Torrent control is categorised into four major areas: -

- **Improvement of Catchment Area:** To reduce and regulate the quantity of runoff and sediment.
 - o Landuse improvement: Grazing land management, planting in degraded areas, treatment of slope failure areas.
 - o Conservation pond to manage the runoff.
 - o Waterways Improvement in the catchment (to stabilize waterways preventing further degradation of the waterways and retain the sediment): Fascine, palisade, checkdams (brushwood, loose stone, gabions), riprap with grass
- **Improvement of stream bank area,** where structures to be installed to protect the habitation and farmlands is required: -
 - o Lateral Shifting: -
 - ~ Construction of embankment and spurs.
 - ~ Improvement of the catchment should be emphasized
 - o Degradation: -
 - ~ Checkdams to maintain the stream bed level,
 - ~ Stop quarrying of the bed material,
 - ~ Protection of the stream banks (Revetments, rip-rap with grass and shrubs, retaining walls)
 - o Aggradation: -
 - ~ Improvement of the catchment should be emphasized,
 - ~ Regular clearing of the debris in the stream bed,
 - ~ Protection of the stream banks (Revetments, rip-rap with grass and shrubs, retaining walls)



Sketch/Photo		Design consideration, Continued.																								
Flood Plain Management: - To limit loss of life and damage. Using river survey information, the flood plain is categorized into following three zones and used as recommended:- Critical Zone : It is the river channel, which gets flood every year and should be prohibited for any human interference. Rationale is where a river has right of, stay out of its way. Restrictive Zone : It is next to critical zone, and gets flooded when design flood comes in the river. Any construction should be restricted and only agriculture is advocated. Warning Zone : It is next to restrictive zone, and experiences flood only during the largest flood expected. Here flood precautions would minimise flood loss during largest flood and construction with necessary measures can be allowed.		<table border="1"> <thead> <tr> <th rowspan="2">Zone</th><th rowspan="2">Area</th><th rowspan="2">Flood Frequency</th><th colspan="2">Recommended Land Use</th></tr> <tr> <th>Cultivation</th><th>Construction</th></tr> </thead> <tbody> <tr> <td>Critical</td><td>Waterway</td><td>Each Year</td><td>Not Allowed</td><td>Not Allowed</td></tr> <tr> <td>Restrictive</td><td>Next</td><td>3 – 5 Years</td><td>Allowed</td><td>Not Allowed</td></tr> <tr> <td>Warning</td><td>Next</td><td>20 – 25 Years</td><td>Allowed</td><td>Allowed with Necessary measures</td></tr> </tbody> </table>			Zone	Area	Flood Frequency	Recommended Land Use		Cultivation	Construction	Critical	Waterway	Each Year	Not Allowed	Not Allowed	Restrictive	Next	3 – 5 Years	Allowed	Not Allowed	Warning	Next	20 – 25 Years	Allowed	Allowed with Necessary measures
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Stream Bank Protection 		Runoff Management: - To allow the flow, which the channel can accommodate: - - Conservation pond: To store the excess water. - Diversion waterways: -To divert the excess water to another channel. Diversion waterways size must be wide enough to accommodate maximum runoff. Waterways can be earthen or lined, depending on the site condition. Precautions must be taken to safely dispose the diverted runoff not to create new gully. Vegetation in the watercourse: -In some cases (slow flowing lowland rivers, irrigation canals) planting alone is sufficient to stabilize banks. Some rules for planting on the river banks: - - In zones from low to medium water level usually only shrubs are allowed. The selected species must be able to survive prolonged inundation and must be flexible enough to break in the current. - In the adjoining zone from medium to high water level also mainly shrubs are planted, which occasionally are mixed with trees. In narrow stream or river beds, trees below the high water level would reduce the runoff diameter and so may increase the stream velocity and cause erosion. - Trees preferably mixed with shrubs are planted above the highest water level. - Sodding is a good way to establish banks if easily available.																								
		Practical Consideration - Sufficient free board height must be maintained to prevent overflow of the structures, - Closure of treated (bioengineering) areas to grazing and other biotic interference. - Bioengineering solutions are effective for river training only where they have been integrated fully with civil engineering measures (such as gabion and stone pitching).																								
Narrow River Wide River 		Remarks: The success of the torrent control lies mainly in the implementation of the interlinked activities as described (Improvement of Catchment Area, Improvement of stream bank area, Flood Plain Management and Runoff Management) as a package.																								
		Working Unit The catchment area along with stream and flood plain area must be considered as the working unit.																								
		Working Season - Any time during farmer's slack period for structural works. - Generally, grass/tree plantation is done at the onset of the monsoon in June/July.																								

Reference: - BIWMP, 2003. DSC, 1992. FAO, 1976. SCWMC, 2001. Sthapit, K. M., 1998. Weidlt, H.J., (Compiled), 1976.

Activity:	Degraded Land Rehabilitation
Definition:	Refers to the vegetative and structural measures applied on the degraded lands including forests, barren lands and graveled and sandy riverbeds.
Major Problems caused by Degraded Lands	• Soil erosion • Low productivity • Sedimentation down stream
Major Causes of Land Degradation:	• Lack of ground cover • Unmanaged surface runoff • Free / over grazing and human interference • Uncontrolled fire
Objectives of Degraded Land Rehabilitation:	• To reduce erosion and increase productivity through soil and moisture conservation preferably using vegetative measures.

Scope of Degraded Land Rehabilitation

- Planting of tree, shrub and grass with necessary conservation measures
- Erosion control measures such as fascines, palisades, contour wattling, brushwood checkdams
- Construction of diversion waterways for safe drainage
- Protection of the area (including live fencing) from grazing and human biotic interference
- Mulching on the degraded lands
- Seedling Production

Sketch/Photo	Survey consideration

Mapping

- Prepare map of about 1:2000 – 5,000 scale (If not, at least sketch is mandatory) showing: -
 - o Boundary of the degraded land and average slopes,
 - o Natural drainage and their direction,
 - o Gullies (including landslips if any),
 - o Different types of land units for various planting techniques (such as pit planting, terrace planting, bunding planting, trench planting, basin planting, brush layering),
 - o Diversion waterways if necessary,
 - o Water sources (such as springs, swamp, ponds, irrigation ditches, canals, pipes)
 - o Habitation including structures



Measurement

- o Slope of the land,
- o Land area,
- o Total length of the rills and gullies for the bioengineering measures such as fascines, palisades, brushwood checkdams for gully plugging,
- o Total length for live fencing,

Assessment

- o The average elevation of the area (Using topographic map) and aspects.
- o The suitable species of tree, shrubs, and grasses in consultation with the communities.
- o Appropriate legumes for inter cropping.
- o How the required planting stock could be made available.

Design consideration		
Site Condition	Preferable Planting Techniques	
Dry sites and Adverse Southern Exposure	Contour platform and trenches, Basin Pit,	
Rocky Sites	Contour trenches, Basin Pit,	
Sandy Sites	Contour trenches, Basin Pits	
Swampy Sites	Mound and Contour Bunds	
High Grass Sites	Contour strips	
Sketch/Photo	Planting Techniques	
	- Potted plants are better than bare root seedling. - Optimal size with well developed root system. - Cutting: waxed exposed tip to avoid drying. On cold and windy place such as Mustang planting of the big sized cuttings of populus of 4 to 10 feet long of diameter 5 - 6 inches gave good results. - Combination of trees, shrubs and grass planting on slopes create a dense network of roots in the soil and a canopy over the surface. - Combination of legumes with plantation will help to improve soil fertility, thus production.	
	Practical Consideration - At least one month before the time of planting, prepare the site. All weeds should be cut. - If possible, dig pits for the trees or shrubs well in advance of the planting program. Pits are usually prepared a month or two in advance of the actual planting program. The aim is to prepare soil for the rapid development of roots by providing a more permeable medium around the plant. - Refill pits with soils with all the stones and roots removed. - If possible put compost / manure / complete fertilizer at the bottom of planting pit in poor soils or add a good forest soil then leave for a few weeks to consolidate the loose soil. - When the ground is wet enough to support reasonable growth, plant out the seedlings. The bigger the hole made, the better it is for the plant; but there must be a compromise between helping the plant and excessively disturbing the slope. - Selection of suitable species is based on adaptability, multiple use, soil improving quality and preference of the local people. - Removal of polythene bag from the seedling by cutting from the side carefully. Planting: Most tree and shrub planting should ideally be carried out during early monsoon, as soon as the ground is wet enough to support sustained growth. Mulching with grass or leaves greatly reduces evaporation from the soil surface around the seedling and prevents hardening of the surface soil. When? ~ When there is too much sun and too little water: Poush to Asadh. Weeding to improve the growth of the desired species at its young age by removing competing vegetation (weeds). In some dry area, weeding is necessary to reduce the risk of fires. When? ~ Once unwanted plants have grown up. Srawan to Aswin. Thinning and Pruning: To promote ground cover / undergrowth and better growth of the planting, thinning and pruning should be carried out. When? ~ During winter (Poush to Falgun) when the disturbance will not hinder the growth of the remaining plants. Working Unit: Degraded land unit in consideration is taken as working unit.	

References: -

Anonymous 1985. Bhatta, P. N. 1983. Coppin, N. J., and I. G. Richards, 1990. DSC, 1992. Howell et. al., 1991. DOR, 1997. Sthapit, K. M., 1998. Weidelt, H. J., (Compiled By) 1976.

Activity:	Irrigation Channel Improvement
Definition:	IRRIGATION CHANNEL refers to the existing irrigation channel, which is susceptible to damage by erosion or causing erosion up slope and down slope and without properly constructed distribution system. IRRIGATION CHANNEL IMPROVEMENT refers to the vegetative and structural measures applied to manage and improve water use and to reduce sedimentation in the irrigation channel and reduce erosion in the adjoining. Note the activity applies only for the improvement of the existing channel. Scope of the irrigation channel improvement limit to community based small irrigation.
Major Problems caused by Unprotected Irrigation Channel	• Seepage and breakage of channel causing erosion. • Breakage of intake and blockage and breakage of channel depriving the farm from irrigation water at the time of needs.
Major Causes of Irrigation Channel Degradation:	• Unprotected slope up and down of the irrigation channel, • Unprotected channel causing seepage and breakage, • Unprotected / weak / improperly designed intakes, • Siltation of the channel, • Deep seated failure removing entire section of channel, • Undercutting by a river, • Scour caused by the overflowing of the channel, • Flood damage to the intake.
Objectives of Irrigation Channel Improvement:	• To protect irrigation channel from up-slope and down-slope erosion. • To prevent erosion from channel seepage. • To reduce seepage loss. • To improve water distribution.



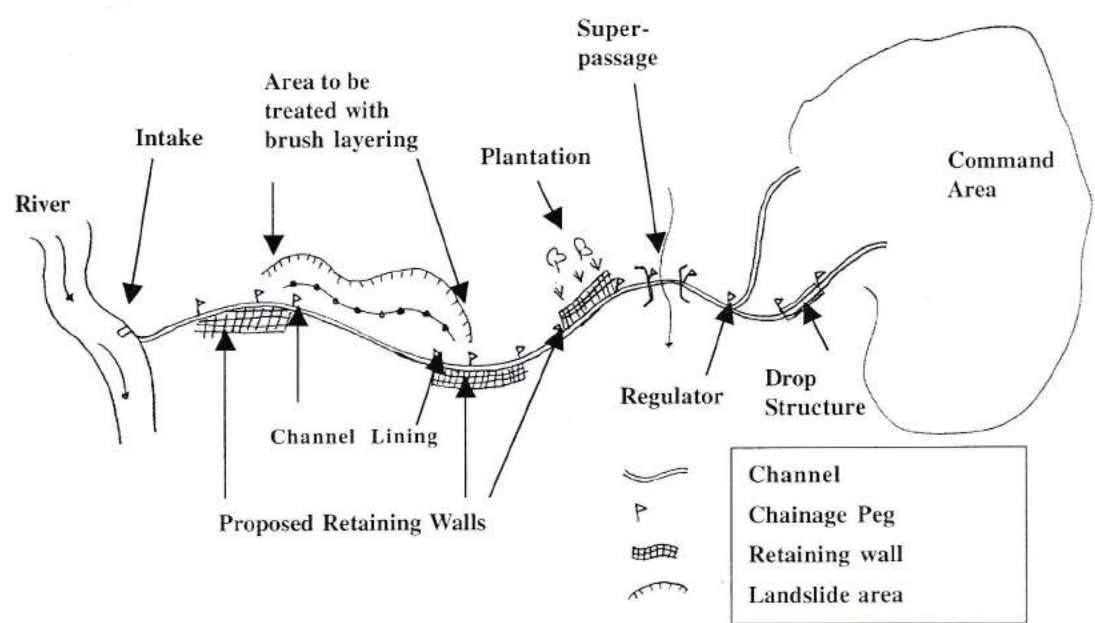
Scope of the Irrigation Channel Improvement

- Erosion control measures (Fascine, palisades, grass sowing, strip plantation, retaining wall) in up and down slopes of the irrigation channel and catchment in close vicinity.
- Construction and improvement of intake, distribution and sediment trap system.
- Improvement of irrigation channel including channel lining, Re-grade and/ or reroute.
- Construction of super-passes to protect the channel.

Survey consideration

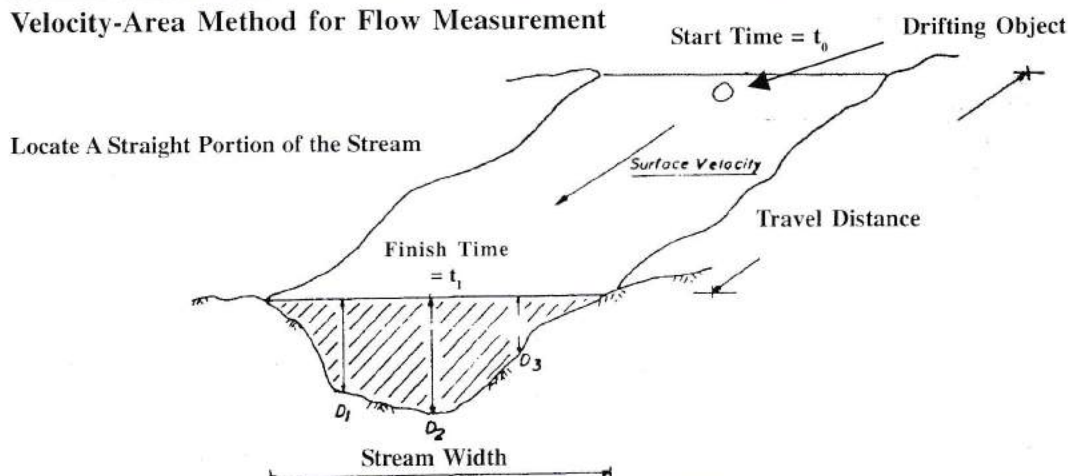
- Visit the intake site, main channels and command area and prepare map of about 1: 2000 – 5000 scale (If not, at least sketch is mandatory) showing: -
 - o Layout of the channel showing the command area and catchment area,
 - o Assess the channel improvement required as follows: -

Chainage from intake in (m)	Condition/Problems	Suggested improvement
0	• Assess intake stability	• Intake protection structures, reallocation of intake, etc.
.. m. - .. m.	• Seepage	• Lining (Cement, Clay or mix)
.. m. - .. m.	• Channel breakage	• Construction of stone masonry channel
.. m. - .. m. .. m. - .. m.	• Upslope / down slope degradation	• Loose stone retaining wall, grass sowing, and brush layering
.. m. - .. m. .. m. - .. m.	• Gully up and down slope	• Gully plugging with fascine, palisades and brushwood checkdams
.. m. - .. m. .. m. - .. m.	• Gully & stream with debris up-slope	• Super passage in dry stone masonry with RCC cover slabs
.. m. - .. m.	• Unstable channel	• Retaining wall from down slope
.. m. - .. m.	• Channel along the agriculture field	• Grass planting along the channel
.. m. - .. m.	• Gully / Stream crossing	• Overhead passing with concrete aqueduct or pipe.
.. m. - .. m.	• Unstable channel with toe cutting by stream	• Toe protection with riprap / small spurs
	• Steep channel slope	• Drop structures
	• Sedimentation	• Sedimentation trapping with flushing and Re-grading to non-sedimenting slope.
	• Distribution problems	• Regulator or divider to construct

Sketch / Photo	Survey consideration																
	- o Assess stability of the intake. - o Measure the dimension (Length, Width and Depth) of each suggested structures. - o Estimate the minimum and base monsoon discharge by asking the farmers how many times greater or smaller these are than the present discharge. - o Assess the adequacy of the irrigation water, compare to its needs for the possible command area. ~ If water is available adequately, water use management may not be analyzed, ~ If water availability is a problem, analyze the distribution and crop water requirement. And design accordingly the cropping pattern and system and water distribution system including timing and quantity. This is a complex process / analysis. Either take help of the agriculture engineering or appropriately decide in consensus with the farmers. Use of the drip or sprinkle irrigation, etc. could be recommended for the efficient use of the available water. ~ If the availability of the water is erratic, construction of conservation ponds to store the water during available period and use during scarce period will help the water management. - o Assess other uses of water such as water mills, drinking water etc., • List the name, address and irrigable land holding of each beneficiary household,																
Design consideration																	
• Crop Water requirement: Water requirement can be estimated using different methods. For preliminary planning purposes, the water requirement at intake for the Hill and Terai can be taken as follows: -																	
<table><tr><th>Soil Type</th><th>Hill</th><th>Terai</th><th>Water Requirement</th></tr><tr><td>Clay soils</td><td>2</td><td>1.5</td><td>liters / sec / ha.</td></tr><tr><td>Loamy soils</td><td>3</td><td>1.75</td><td>liters / sec / ha.</td></tr><tr><td>Sandy/Loam soils</td><td>5</td><td>2</td><td>liters / sec / ha.</td></tr></table>	Soil Type	Hill	Terai	Water Requirement	Clay soils	2	1.5	liters / sec / ha.	Loamy soils	3	1.75	liters / sec / ha.	Sandy/Loam soils	5	2	liters / sec / ha.	
Soil Type	Hill	Terai	Water Requirement														
Clay soils	2	1.5	liters / sec / ha.														
Loamy soils	3	1.75	liters / sec / ha.														
Sandy/Loam soils	5	2	liters / sec / ha.														
• Assess the command area and soil types. Estimate the total water requirement by multiplying the factor given in the above table for respective soil types with the corresponding areas.																	
Sketch/Photo	Design consideration																
• Intake: - Hill stream are characterized by very steep slope channels and by a high degree of active erosion and sediment transport. - o Consider following points in designing intake: - ~ Do not interrupt the present course of the stream, ~ Avoid rigid and impervious structures and provide flexible (gabion box) weirs in place of masonry or concrete structures, ~ Provide sufficient waterways and low weirs for the passage of floods, ~ Side wall intake structures should be higher than the expected maximum flood levels, ~ Omit complicated engineering structures, and suggest appropriate low capital cost structures even at the expense of relatively high running costs in the form of labor requirement for annual maintenance. Such as use bamboo wattle fence and brushwork rather than stone masonry for diversion structures.																	

Sketch / Photo	Design consideration
o Tips for choosing site for intake: - ~ Use outside of a bend where the flow is deeper and clearer, and toward the downstream end where the effects of the secondary currents have fully developed, to exclude as much sediment as possible, especially coarse sediment from the intake. ~ Use natural controls: Natural outcrops of rock can control a river in either elevation or plan, or sometimes both. There are many situations where, at the bend in a valley, a river has attached itself to a rock face on the outside bend which it will follow until the valley curvature reverses direction or the rock outcrop ends. The downstream end of such a reach can often be a site for an intake. In some rivers, the flow will be constrained by a rock gorge. Intakes can be located immediately downstream of the end of the gorge. If the intake is located too far downstream, there may well be problems of sediment deposition. ~ At the confluence of two river streams: Often, due to the additional water provided, intakes are located downstream of confluences. In many cases, deposits occur at the confluence, resulting instability. Therefore, intakes have to be sited some distance downstream where good conditions exist. ~ Bank stability: Advantage should be taken of stable banks such as rock outcrops or armored boulder bank to protect the intake from erosion.	

Velocity-Area Method for Flow Measurement



Design of the Channel:- It involves flow measurement, calculation of crop water requirement and designing channel size and channel lining,

- **Flow measurement:** - Discharge is estimated in consultation with the farmers. For more accuracy flow can be measured as follows: -

o Estimate the Velocity

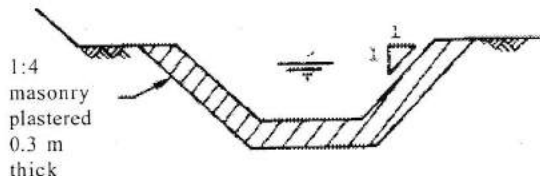
Float Method

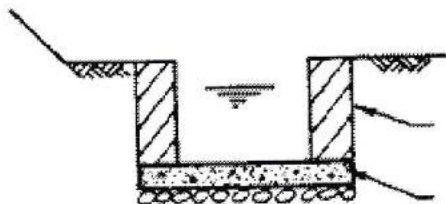
- ~ A piece of wood or floating material is placed in the stream and the time required to travel a fixed distance between the cross sections is measured. Calculate Velocity ($V = \text{Distance in m} / \text{time in second}$) in m/sec. cannot be measured accurately where the streambed is irregular in profile. The distance between the cross sections should be 15 m in minimum. The float should be thrown into the water several meters upstream of the first cross section for it to reach a constant velocity.
- ~ Calculate average velocity as, $v = c * V$, Where c is the constant = 0.65 for stream of depth upto 30cm, $c = 0.7$ for 30cm – 1.2m stream depth and 0.75 for stream depth > 1.2m. The accuracy will be +/-10 to 20%.

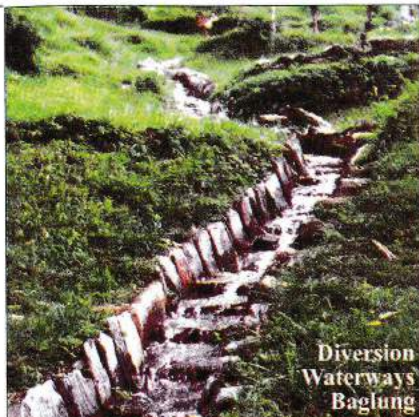
Current metering: Flow could be measured more accurately with current meter. Guideline comes with the equipment.

Sketch/Photo	Design consideration
	o Estimate the Cross Section ~ Stretch a tape across the stream channel, ~ Starting from one side of the channel, measure the distance and water depth at wherever the water depth change (preferably every meter) in meter,
	~ Average the water depth of two successive measurements and multiplied by the distance. Summing of the figure will give the cross sectional area of the channel.

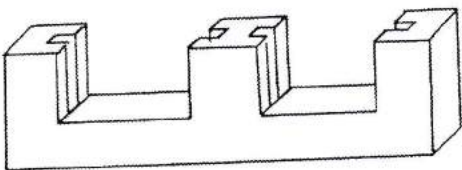
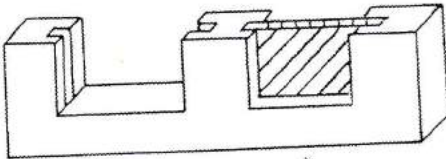
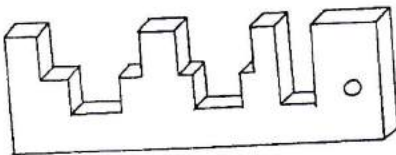
Sketch/Photo		Design consideration	
Where, Measurement $x_1, x_2, x_3, x_4, \dots$ distance between two measurement points A, B, C, D, E, F, water depth at the measurements. Calculation Cross-sectional Area = $x_1 * (0+A)/2 + x_2 * (A+B)/2 + x_3 * (B+C)/2 + x_4 * (C+D)/2 + \dots$		Flow Calculation: Multiplication of the cross sectional area and velocity gives the flow in cumecs i.e. cubic meter per second.	
• Channel lining: Seepage makes the irrigation channel ineffective as well as erosion prone. Therefore, channel lining is done to avoid seepage. Followings are the generally used channel lining: -			
Material	Slope Limit	Thickness	Typical Use
Grassed	< 11° (20%)	Low thick sod forming grasses	Canal bed and bank erosion protection.
Dry-stone	< 14° (25%)	20/25 cm	Canal bed and bank erosion protection.
Stone masonry	> 20°	25/30cm	Seepage reduction, Canal bed and bank erosion protection.
Red soil: Cement (7:1)	> 20°	3 layers; each layer 2 cm thick	Seepage reduction, Canal bed and bank erosion protection.
Plastic	Steep slope	0.2/2mm	Canal seepage prevention.
Plain concrete	Steep slope	7.5/10 cm	Seepage reduction, Canal bed and bank erosion protection.
Polythene, GI Cement-Pipes	Steep slope	45/60/100cm	Seepage reduction, Canal bed and bank erosion protection.

Masonry Canal Lining  1:4 masonry plastered 0.3 m thick		Channel Size: - Step-1: Estimation of the crop water requirement gives the quantity of the water to be managed by the channel i.e. Q. Step-2: Estimate the permissible velocity of flow, V (m/sec) for the desired channel type. Example: For dressed channel V = 2m/sec. The permissible maximum velocity is as follows:-
Channel Lining	Maximum Permissible Velocity m/sec	
Clay Loam	0.90 to 1.15 $\approx$ 1.00	
Densely Grasses	1.50 to 2.50 $\approx$ 1.50	
Dressed masonry	2.00	
Boulder lining	1.5	
Cement masonry with cement pointing plaster	2.00 – 3.00 $\approx$ 2.50	
R.C.C.	4.00 – 6.00 $\approx$ 5.00	

 1:4 masonry plastered 0.3 thick 10 cm thick concrete or 30cm masonry 1:4		Step-3: Compute approximate cross-sectional area of the channel to carry out the calculated run-off using the formula, Quantity of water, Q = A(Channel Area)*V (Velocity)
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Sketch/Photo		Design consideration	
 Diversion Waterways Baglung		Step-4: Determine the channel dimension in such a way that the area of cross section equals the area of cross section computed as in step 3. Refer to Grass waterways techniques. Step-5: Compute Hydraulic radius 'R' from the cross section obtained in step 4. R = Hydraulic radius in meters = Area / wetted perimeter (Cross sectional Length of channel with water contact) Step-6: Compute the velocity V using the Manning's formula. V (Velocity) = $(R^{2/3} * S^{1/2}) / n$, Where, R = Hydraulic radius in meters and S = Water Surface slope corresponding to high water level = It is the ratio of vertical drop to the length of the channel, and n = roughness coefficient	

Sketch/Photo	Design consideration	
	Type and Description of Ditch Conduits	n Value
	Clay soil, straight and uniform	0.020
	Sandy loam or clay loam, straight and uniform	0.020
	Loosely grassed	0.040
	Densely grassed	0.050
	Mixed pebbles from 1 to 3 cm in diameter	0.022
	Mixed pebbles from 2 to 6 cm in diameter	0.025
	Smooth, homogeneous stony bed	0.0325
	Rough stony bed	0.040
	Lined ditch	
	Paved, brick	0.014
	Paved, rubble	0.025
	Rubble	0.033
	Uniform earth bottom, rubble sides	0.025
	Rough earth bottom, rubble sides	0.030
	Cement paved, smooth sides and bottom	0.012
	Step-7: Verify that the computed velocity is approximately equal or less the velocity as assumed under step 2. If not increase the dimension of the channel.	
	Channel side slope - To reduce land covered by the channel, the side slopes of a channel are usually designed to be as steep as possible. Typically used slopes: - For Hills: 1:1 (V:H) in earth and 1:½ (V:H) in rock. For Terai: 1:1½ to 1:2 (V:H) for main and secondary channels and a vertical drop structure, 1:1 to 1:½ (V:H) for tertiary and quaternary channels.	
	Drop Structures: - To reduce the water velocity in the channel, slope gradient of the channel is maintained providing drop structures. Water velocity in the channel should be optimal so that no weeds is promoted and transport the anticipated sediment load. Generally the earthen channels are designed with velocities ranging from 0.6 to 0.9 m/s. - However, water velocity in the channel should not exceed the permissible maximum water velocity of the channel lining.	
	Drop Structures - Changing the channel slope can reduce water velocity. This could be made by the construction of the drop structures. Some of the commonly used drop structures are: - - A stone paved channel, - A vertical drop structure, - A cascade drop structure, - A chute drops structure.	
	Some consideration in designing drop structures: Design the drop structure so that there is: - ~ No channel scouring due to high water speed, ~ No scouring at the base of the structure	

Sketch/Photo	Design consideration
	Regulator • Equitable distribution of water among the beneficiaries plays a major role in the management of the irrigation channel. The design of the regulator must be flexible to accommodate the farmers' requirements and be easily adjustable. Some of the commonly used regulators (also known as Saachos) are: - • Design to make rotation easier. During low flows, one side can be closed to implement a rotation schedule. During high flow conditions, one side can also be partly blocked off with a narrow flashboard, both to protect that side from flooding and to send excess water down through the system to an extension area. The same structure can be used in places where canal branches but in which one side has primary water right. • To take better advantage of different flow level, the structure is designed so that under low and normal flows, opening for water flow is one set of proportions, while under high flows a different opening is used to regulate different rates of flow. Each gate is made up of several removable narrow vertical strips of wood, permitting a wide range of flow control.
	Overflow Passes Time and often the excess water from the irrigation channel need to be disposed safely. Therefore, provide an overflow arrangement in the channel to dispose an excessive amount of water safely. Free Board To avoid overflow of the channel, sufficient free board in the channel must be provided. Free board is estimated as: $F_b = 0.2 + 0.253 Q^{1/3}$ Where, F_b = Free board in m., and Q = Design discharge in cu.m. / sec.
	Package Implementation • Along with the channel design, other conservation activities such as fascines, palisades, brush layering, grass sowing, surpasses, retaining wall, etc. must be designed and implemented as the package based on the survey made for each channel sections.
 Irrigation Channel Improvement, Dhading	Practical Consideration • Avoid the use of rigid structures in unstable areas. It takes only a slight ground movement to damage and crack a rigid structure, and then a major (and costly) failure will occur. • For the sustainability of the channel, its continuous maintenance is very essential. Which need resource to procure materials, which are not available locally and labor, which could be contributed from the community. Therefore, mechanism to raise the resource for the maintenance must be made mandatory for the resource investment on the irrigation channel improvement. • Make a series of discussion among the beneficiaries regarding raising of service fee as water tax based on the proportion of the water used by the individual household. This can be assessed based on the size of the land that will be irrigated. The amount to be levied, as water tax must be decided by the community. However, the amount thus raised must be sufficient for the maintenance, otherwise such structures with time will be degraded and will not function. Working Unit Intake, channel, up-slope and down-slope area affecting the channel and water distribution on the command area is taken as the working unit.

References: BWP, 1996. BIWMP, 2003. Cosmos Engineering Services, 2000. DSC, 1992. IOE, 1995. SCWMC, 2001. Sthapit, K. M., 1998. Ted C. Sheng, 1986. UNICEF, 1996.

Activity	Trail Improvement
Definition	Trail Improvement refers to the vegetative and structural measures applied to protect trail from erosion and to improve the trail for general human and livestock traffic. Only Trail, • Which has potential for gully formation • Which is susceptible to damage by erosion up slope and down slope, • Which is causing erosion up slope and or down slope, • Which is not convenient for the general human and livestock traffic. is subject for trail improvement activity.
Major Problems caused by unmanaged trails	• Unprotected / unmanaged runoff on or from trails often erode to form rills and gullies. • When trails are damaged, people start to walk along the surrounding land, damaging the vegetation and compacting the soil; these results in turn lead to erosion.
Major causes of trail degradation	• Unprotected trail on slopes, • Unprotected trail side up slope and down slope, • Unmanaged runoff through the trail.
Objectives of Trail Improvement	• To reduce erosion from un-managed trails, • To protect trails from erosion, and • To improve the trail for general human and livestock traffic.

Scope of Trail Improvement

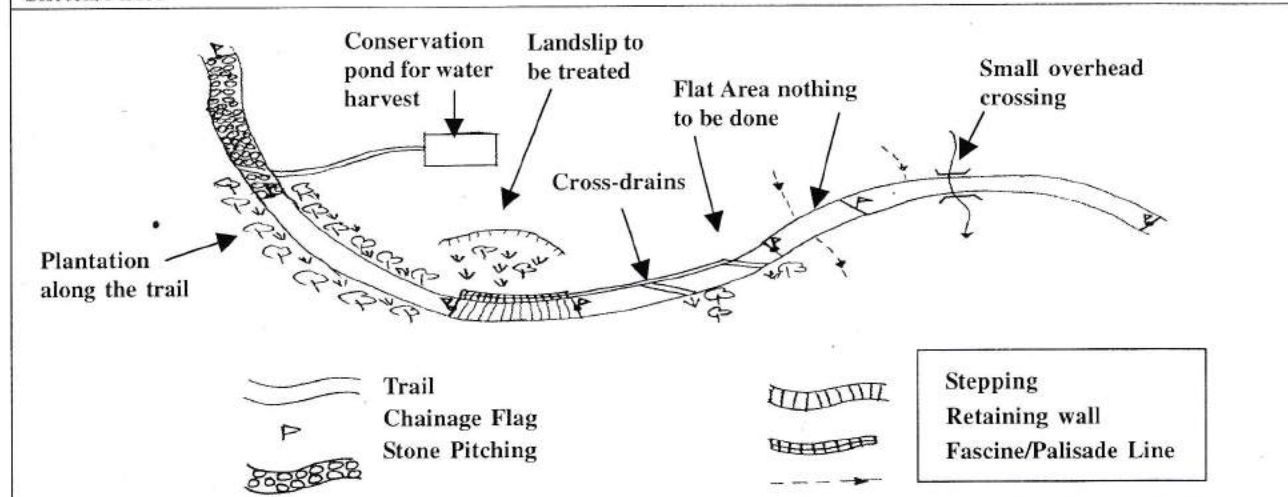
- Improvement and construction of trail (stone paving / stepping on steep trail segments).
- Provision of diversion channel and safe drainage along the trail.
- Re-grade and or reroute trails where erosion is advanced.
- Re-vegetate abandoned trails, while rerouting.
- Vegetative (Planting of appropriate grass, shrubs, trees) and structural erosion control (fascines, palisades, wattling, brush layering, brushwood checkdams) measures required up slope and / or down slope of the trail.
- Construction and protection of small bridges and other minor structures wherever needed (within the trail segment).
- Construction of resting place (Chautara).

Survey consideration

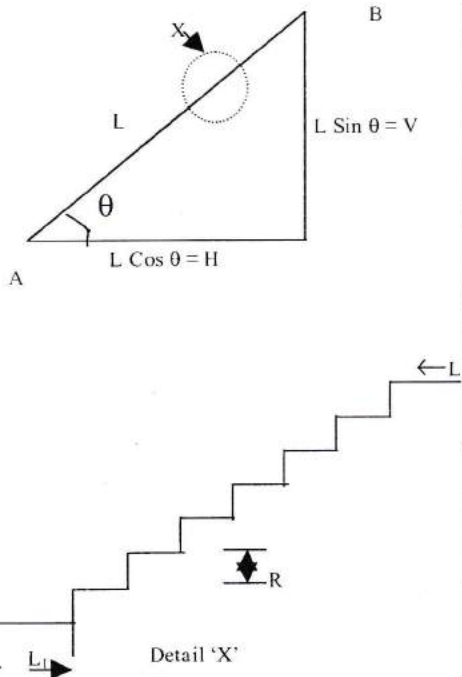
Survey

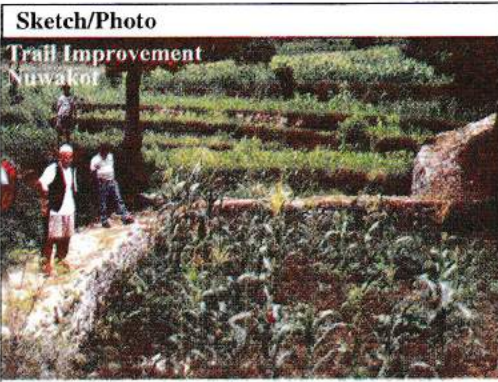
- Walk along the trail and prepare map of about 1: 2000 – 5000 scale (If not, at least sketch is mandatory) showing: -
 - o Layout of the trail showing the alignment and profile.
 - o Starting from one end of the trail, assess the trail improvement required as follows (For example): -

Sketch/Photo



Chainage (m)	Slope in degree	Condition/Problems	Suggested improvement
. m. - . m.	Flat	• Earthen, no problem seen	• No work required, only protection of surrounding vegetation.
. m. - . m.	< 8°	• Earthen, rills	• Rill plugging with fascine, palisade, grass sowing, cross drains and leveling of the trail
. m. - . m.	> 12°	• Earthen, with gullying	• Stone stepping, grass sowing, drainage management
. m. - . m.	< 12°	• Earthen, with gullying	• Stone paving, cross drains and plating at the disposal sites
. m. - . m.	< 12°	• Trail used as waterways	• Stone pavement with concave shape and drop structures, protection at disposal sites

Sketch/Photo	Survey consideration																					
Erosion on Unmanaged Trail - Kavre 	• Peg the point of measurement for future reference. • On map or sketch, locate - o Landslides, gullies, cross-drains - o Water sources, such as irrigation, springs, conservation pond, etc. along the trail - o Area up and down slopes of the trail for planting - o Chautara to be made, for resting or halt place - o Footbridge and culvert, for crossing small streams. Measurement: Make the following measurement for each section of the trail: - - o Length of trail (m.) = L, - o Slope of trail (Degree) = θ, - o Cross-section of the trail where earth and stone work to be carried out, - o Necessary measurement for gully treatment (Length, Slope and Cross sections), drainage improvement (Length, Slope and Cross-sections), and plantation (Suitable species and area). Assessment - Availability of the suitable stone for the pavement and stepping, - Skilled and unskilled labor for the stone works, - Seedlings for plantation and suitable species Estimation • Decide sections, where different types of the (earthen, stone pavement) trail improvement or stone stepping to be made. • Note the places, where different conservation measures to be installed.																					
 Given: - $L = 30 \text{ m}$ $\theta = 30^\circ$ $R = 0.2 \text{ m}$ (From Table) $T = 0.3 \text{ m}$ (From Table) Calculation: - $V = 30 * \sin 30^\circ = 15 \text{ m}$ $H = 30 * \cos 30^\circ = 25.98 \approx 26 \text{ m}$ $N = 15 / 0.2 = 75$ $n_1 = (26 - 75 * 0.3) / (1 - 0.3) = 4.97 \approx 5$ $n = 75 - 5 = 70$ $L_1 = (26 - 70 * 0.3) / 5 = 1 \text{ m}$ $n_2 = 70 / 5 = 14$	Design consideration General: - • Generally, follows contour for alignment, • All conservation measures required on the trail and side slopes of the trail must be designed and implemented as a package, • Provide drainage ditch on the uphill side of the trail, • The trail should be sloped toward the downhill. Maximum cross slope of 1:20 (V:H) is recommended to avoid cross ruts, • An average gradient of 10% is generally considered the maximum for comfortable walking. 15% Slope is considered as permissible gradient, • Cutting and leveling with grass sowing for slopes below 8° ($\approx 14\%$), • Stone pavement for the gradient 8° to 12° ($\approx 20\%$), • Stone stepping for the gradient above 12° ($\approx 20\%$), • Width of the trail should be more than 1.2m. • The length of the landing can be maintained as 1 m. Design of Stepping • Size of the steps should be maintained as follows: - <table><tr><th>Slope (Degree) θ</th><th>Riser Height in m. (R)</th><th>Tread Length in m. (T)</th></tr><tr><td>12-16</td><td>0.12</td><td>0.35</td></tr><tr><td>17-20</td><td>0.15</td><td>0.35</td></tr><tr><td>21-23</td><td>0.15</td><td>0.30</td></tr><tr><td>24-26</td><td>0.17</td><td>0.30</td></tr><tr><td>27-30</td><td>0.20</td><td>0.30</td></tr><tr><td>> 30</td><td>0.20</td><td>0.25</td></tr></table> • Calculation of number of steps in the stepping: - o Length of trail (m.) = L, From measurement - o Slope of trail (Degree) = θ, From measurement - o Riser Height (m.) = R, From Table above - o Tread Length (m.) = T, From Table above - o Vertical Height Difference, V (m.) = $L \sin \theta$, From calculation - o Horizontal Length, H (m.) = $L \cos \theta$, From calculation - o Number of risers, $N = V/R$, - o Number of treads, $n = N - n_1$ - o Number of Landing, $n_1 = (H - N * T) / (1 - T)$ - o Length of landing, L_1 (m) = $(H - n * T) / n_1$ - o No of steps between two landings: $n_2 = n / n_1$	Slope (Degree) θ	Riser Height in m. (R)	Tread Length in m. (T)	12-16	0.12	0.35	17-20	0.15	0.35	21-23	0.15	0.30	24-26	0.17	0.30	27-30	0.20	0.30	> 30	0.20	0.25
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Sketch/Photo	Design consideration																																														
 Trail Improvement Nuwakot	Format for Stepping in the Trail <table><tr><th colspan="2">Chainage (m)</th><th rowspan="2">No. of landings (n_1)</th><th rowspan="2">Length of Landings (L_1)</th><th colspan="2">Design of steps</th><th colspan="2">Design of flights</th></tr><tr><th>Start</th><th>Finish</th><th>Riser height (R)</th><th>Tread width (T)</th><th>Flight length (m)</th><th>No. of steps.</th></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr></table>	Chainage (m)		No. of landings (n_1)	Length of Landings (L_1)	Design of steps		Design of flights		Start	Finish	Riser height (R)	Tread width (T)	Flight length (m)	No. of steps.																																
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Start	Finish			Riser height (R)	Tread width (T)	Flight length (m)	No. of steps.																																								
	Design consideration Footbridges: - Only small bridges (preferably < 8 m length) should be considered under the trail improvement, - Some considerations for locating suitable sites for footbridges:- - Emphasized only single span bridge to avoid the damage by the floods, - Foundation must be on firm ground, preferably hard rock, - Foundation must be located on a straight stretch of river, where there is no evidence of erosion, land sliding or lateral channel shifting, - There must be at least 2 m freeboard between the lowest of the bridge and the highest flood level, - Expert consultation (Engineers) is recommended to make longer bridge and further consultation.																																														
 Stepping on Steep Slopes	Practical consideration - Trail can be used as waterways during the monsoon. Make the stone pavement in concave shape. Ensure the speed of the runoff does not exceed the resistive force of the lining material. - Trail runoff can be stored in the conservation ponds for use whenever required. - Safe disposal of the trail water is key to the erosion control associated with the trail. - Use stones wherever possible. - On sloping section of path, where water may run down the line of the trail, install open, stone-lined cross-drains at intervals of 10 to 15 meters. These should lead off to a soak away area or into a well-vegetative line of natural drainage. - Plant double lines of thorny shrubs along the side of the footpath. These will discourage people and animals from straying away from the trail. - Plant trees, shrubs, or grasses in nearby areas, improve drainage, treat rills and gullies wherever necessary and do them as described in respective technique chapter.																																														
 Stepping on the Trail, Dadeldhura	Maintenance - Regular clearing of silt and weeds from the side and cross drains. - Regular maintenance of the stone stepping and side drains before it gets worse. - Maintaining the shape or grading of the surface (especially earthen) and clearing of the standing water to avoid cross ruts. - Protection and replacement planting on the side slopes of the trail as precautionary measures. - Regular maintenance of vegetative and engineering structures for its effective actions. Working Unit Trail, up-slope and down-slope area affecting trail, safe disposal of trail water is taken as the working unit. Working Season - Any time during farmer's slack period for structural works. - During Dormant season if the site is moist and just before monsoon if the site is dry (Baisakh, Jestha) for vegetative works.																																														
 Trail Side Planting, Dadeldhura																																															

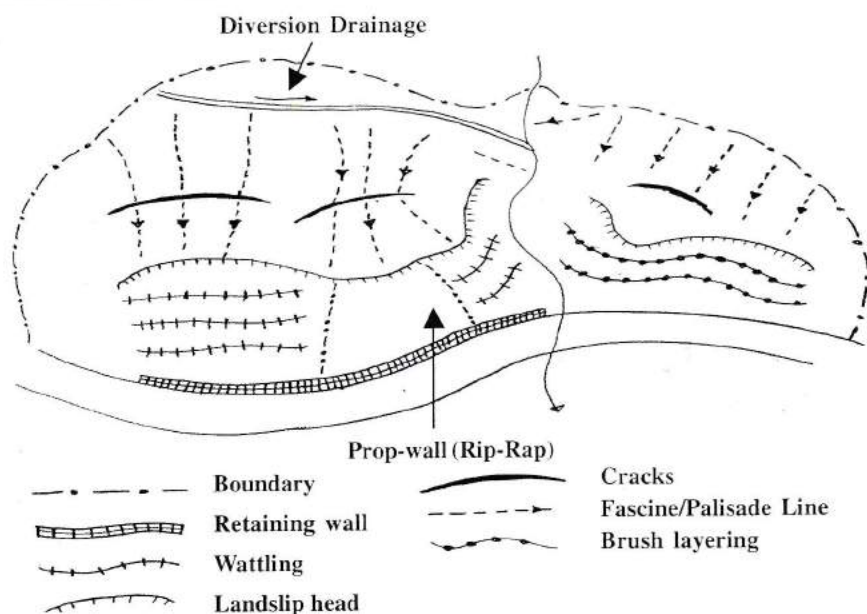
References: -BWP 2049/50, BIWMP 2003, DSC 1992, SCWMC 2001.

Activity:	Road Slope Stabilization
Definition:	Road Slope: Refers to the slope up and / or down of the road, where it is susceptible to erosion or degradation affecting stability of the road. Road Slope Stabilization refers to the vegetative and structural measures applied in the road slope to maintain stability of road from erosion.
Major Problems Caused by Unprotected Road Slopes	• Unprotected / unmanaged road side often blocks the road traffic, • Degrade down slope agriculture fields.
Major Causes of Road Slope Degradation:	• Unprotected road side up and down slope, • Unmanaged runoff through the road, • Toe cutting while constructing road,
Objectives of Road Slope Stabilization:	• To reduce erosion from un-managed road slopes, • To protect road from erosion, and • To improve the road for general human and livestock traffic.

Scope of the Road Slope Stabilization

- Planting of grass, shrubs and tree planting with necessary conservation techniques such as contour terracing, contour trenching, contour bonding,
- Erosion control in rills and gullies by fascines, palisades, wattling, brush layering, brushwood checkdams,
- Improvement of roadside drainage system including cross drains,
- Live fencing to control livestock and human interference.

Survey consideration

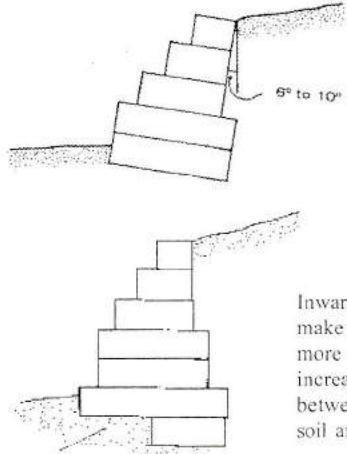
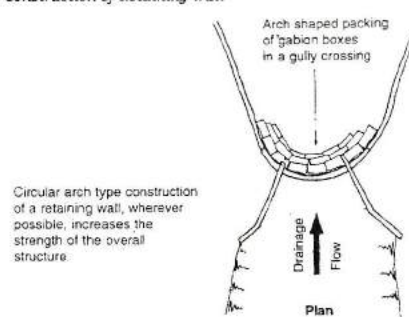


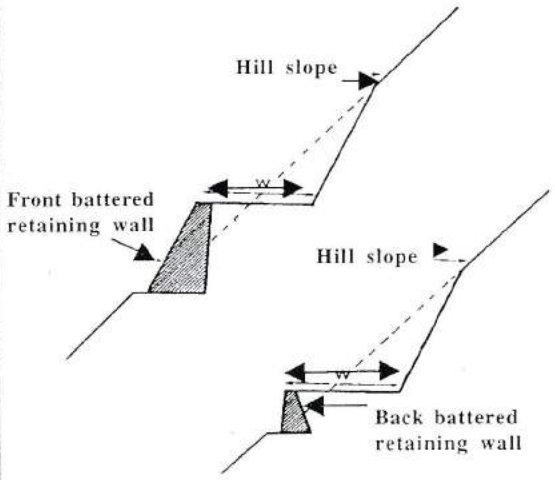
Survey

- Walk along the road and prepare map of about 1: 2,000 – 5,000 scale (If not, at least sketch is mandatory) showing: -
 - o Boundary of the road slope requiring protection (reference should be made to the chainage of the road),
 - o Locate
 - ~ Rills and Gullies,
 - ~ Drainage and cross-drains,
 - ~ Water sources, such as irrigation (crossing the road slope), springs, etc. in the road slope,
 - ~ Natural drainage and its direction
 - ~ Diversion waterways if any
 - o Area up slope and down slope of the road for planting grass, shrubs and trees

Measurement

- o Slope of the area.
- o Total area to be treated with grass, shrubs and tree planting.
- o Total length of the rills and gullies for the bioengineering measures such as fascines, palisades, brushwood checkdams for gully plugging.
- o Total length of drainage to be improved.
- o Total length of diversional waterways to be installed.
- o Total length for live fencing.

Survey consideration																				
Assessment - o The average elevation of the area (Using topographic map), - o The suitable species of tree, shrubs, and grasses in consultation with the communities, - o How the required planting stock could be made available,																				
Analysis - o Key to the success of the road slope stabilization lies on the detailed analysis of the causes of slope instability and measures accordingly. Major cause of the road slope instability are: - ~ Toe cutting of the slope, ~ Management of runoff from up slopes within the slope.																				
Sketch/Photo		Design consideration																		
Tilting of Retaining Wall for Increasing Stability  Tilting retaining walls towards the hill slope increase the stability of the wall by increasing the magnitude of the restoring moment about the toe point of the wall. Inward sloping bench can make retaining walls more stable by helping to increase the bond between the foundation soil and the wall		Slope Area Treatment: - o Landuse improvement: Grass / shrub / tree planting in degraded areas, Hedgerow planting, Brush layering, Wattling, in steep slopes, - o Treatment of rill and gully: Fascines, Palisades, Wattling, Brushwood checkdams - o Diversional waterways to divert excess runoff from up-slope.																		
Benching		Toe Protection																		
		Toe protection is essential to maintain the angle of repose of the slope. This is generally done by the construction of retaining wall, or revetment at the base of the slopes.																		
		Retaining wall helps to support / protect the road slope segments from the active earth pressure. Whereas, revetment is constructed to protect the base of the slope from undermining or other damage, such as grazing by animals. Retaining wall acts as revetment but not vice versa.																		
		Recommended dimensions of dry masonry retaining walls on different slopes																		
		<table><tr><th>Slope</th><th>Wall height</th><th>Base width</th><th>Top width</th></tr><tr><td>30-35°</td><td>1.50 - 2.00 m</td><td>1.25 - 1.50 m</td><td>0.75 m</td></tr><tr><td>35-40°</td><td>2.00 - 2.50 m</td><td>1.50 - 2.00 m</td><td>0.75 - 1.00 m</td></tr><tr><td>40-45°</td><td>2.50 - 3.00 m</td><td>2.00 - 2.30 m</td><td>1.00 m</td></tr></table>			Slope	Wall height	Base width	Top width	30-35°	1.50 - 2.00 m	1.25 - 1.50 m	0.75 m	35-40°	2.00 - 2.50 m	1.50 - 2.00 m	0.75 - 1.00 m	40-45°	2.50 - 3.00 m	2.00 - 2.30 m	1.00 m
Slope	Wall height	Base width	Top width																	
30-35°	1.50 - 2.00 m	1.25 - 1.50 m	0.75 m																	
35-40°	2.00 - 2.50 m	1.50 - 2.00 m	0.75 - 1.00 m																	
40-45°	2.50 - 3.00 m	2.00 - 2.30 m	1.00 m																	
Sloping Stone Layers in Retaining Walls Increase Stability  Inward sloping stone layers of a dry masonry wall can prevent stones coming loose from the wall		• Careful design and supervision of foundations are of paramount importance. • For higher retaining wall, consult the appropriate reference for the stability analysis. • The foundation should be taken deep enough to safeguard against weather and should be at least $h/10+30\text{cm}$ below the ground level (For 2m. high wall, foundation depth = $2/10+30 = 50\text{ cm}$).																		
Curved Construction of Retaining Wall  Circular arch type construction of a retaining wall, wherever possible, increases the strength of the overall structure		Techniques for increasing overall stability of masonry retaining walls include:																		
		Tilting: Tilting the wall towards the hill slope increases the stability of the wall and its effectiveness. Typically, walls may be tilted by 6 to 10 degrees.																		
		Benching: Benching the foundations as indicated can add to the stability of the wall by providing more anchorage between the wall and the soil.																		
		Sloping Stone Layers: Stones can be prevented from coming loose by packing the stone layers of a masonry wall so that the layers dip into the slope. Keep the angle of the foundations (1v:3h) with each layer of stone. The outer face of the wall will automatically come to 1h:3v if this is done.																		
		Bond Stones: Long, flat stones extending well into the soil slope and placed at regular intervals in the wall can increase the bond between the dry-stone wall and the soil slope.																		

Sketch/Photo	Design consideration
 Phewa Tal, Kaski	Circular or Arch Type Construction (in plan): Retaining walls that, in plan, are constructed in a way similar to arch type are stronger than linear walls. Drainage gullies along irrigation canals are examples of suitable locations for such types of arch retaining walls.
Back-battered versus Front Battered Retaining Walls  A back-battered retaining wall is more economical than a front battered retaining wall. Typically, for platform width (W) carrying between 1.5m to 2m the back battered wall section will be 2 to 3 times smaller than the front battered section.	Integration With Bio-Engineering Bioengineering techniques should be used in conjunction with walls, according to site characteristics, as follows:- • Protection of backfill. • Protection from scour and undercutting of the foundations and sides. • Flexible extension to the wall by planting large bamboos, shrubs or trees above the wall, increasing the catch function . FRONT-BATTERED OR BACK-BATTERED A front-battered retaining wall has a sloping exposed face and a vertical buried face. A back-battered retaining wall has a vertical exposed face and a sloping buried face. Front-battered retaining walls are many times more expensive than back-battered walls because the weight of the backfill contributes towards the forces stabilizing the wall. Diversional Waterways Refer to waterways and irrigation channel improvement for the design and practical consideration for the waterways. Practical consideration
 Kulekhani, Makwanpur	• Use dry stone masonry upto 4 m. Only use other types of wall when one is certain about its needs and can justify the additional cost. • Ensure that walls are properly backfilled and compacted in layers. Fill the back of the wall with gravels first and then sand. Drainage blanket with a porous membrane of filter fabric (geotextile if possible, or hessian) over weep holes or drainage area is preferable. • Dress all stone (if it is rounded) into rectangular blocks. • Use stones as large as possible. If mainly small stones are available, use large ones at least every one metre to improve the tying. • Use flatter stones for the top layer. • Dry walls co-exist with, and are strengthened by plant roots. Encourage or plant vegetation. • Use these dimensions for dry stone retaining walls, depending on slope angle. This table provides a guide to the dimensions of walls on different slopes.

References: -DSC, 1992. DOR, 1999. SCWMC, 2001.

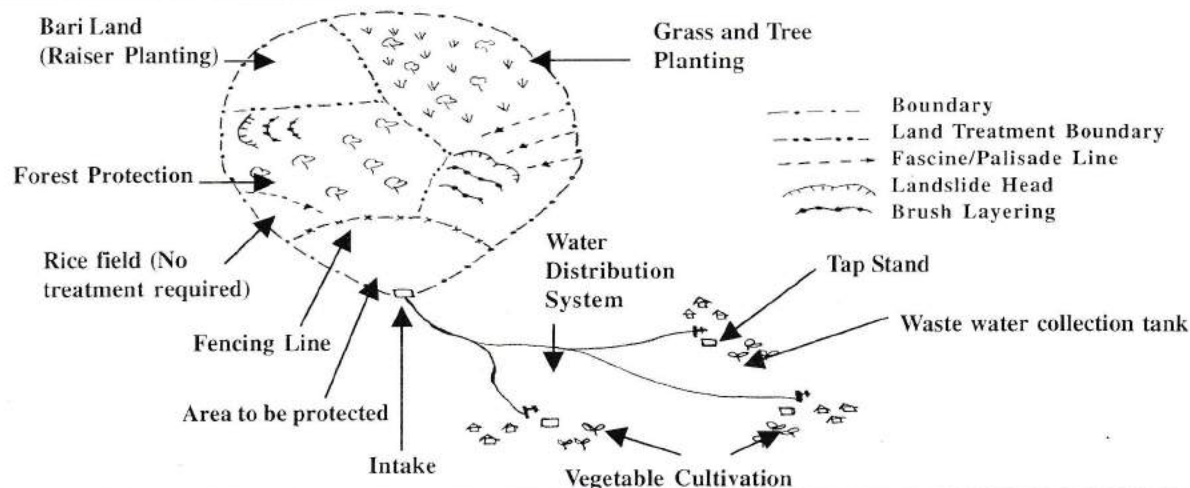
Activity:	Water Source Protection
Definition:	Water Source: Refers to the rural water source, such as springs and Kuwas. Water Source Conservation: Refers to the vegetative and structural erosion control measures applied in the water source and its catchment and distribution system. Scope of the water source protection generally applies either to spring to be protected and thus collected water is supplied to small number of households, or to kuwa, where it is protected and community fetch water from the kuwa itself.
Major Problems Caused by Unprotected Water Source	• Drying of the water source, • Poor regime and quality of the water yield, • Poor health and disease from water contamination
Major Causes of Water Source Degradation:	• Environmental (erosion, degradation of the vegetation, pollution, use of pesticides) degradation in the catch area of the source. • Bacterial contamination
Objectives of Water Source Protection:	• To improve the quality and regime of water through soil and water conservation in the catch area of the source.

Scope of the Water Source Protection

Water Source Protection involves following:

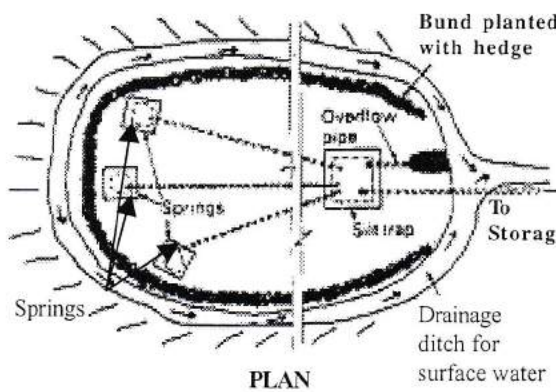
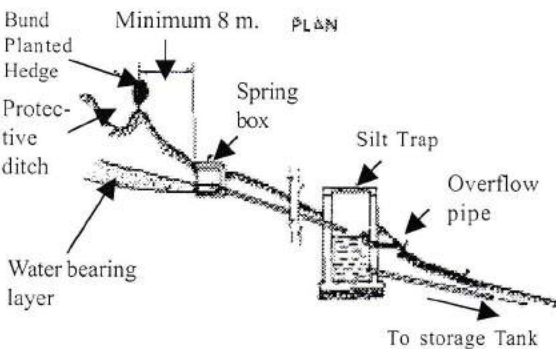
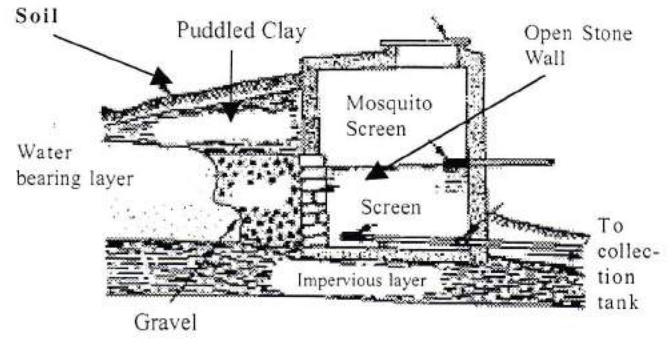
- Catchment Treatment:
 - o Planting in the catchment (Tree and grass planting on the open and degraded lands with necessary conservation techniques such as contour terracing, contour trenching, contour bunding).
 - o Erosion control in rills, and gullies by fascines, palisades, wattling, brush layering, brushwood checkdams, in the catch area.
- Source Protection:
 - o Live fences around the area.
 - o Construction of waterways to manage water.
 - o Control of contamination of the source by surface flow of water e.g. fertilizer, disease/ pathogens from animal and human waste.
- Distribution System: Construction of intake, water storage tanks and water distribution system.

Survey consideration



Visit the spring, habitation in the village and prepare map of about 1: 2000 – 5000 scale (If not, at least sketch is mandatory) showing:-

- o Probable springs,
- o Catch area of the spring and landuse and erosion problems (Rills and Gullies) in the catch area.
- o Point source pollution.
- o Households map intended to serve from the spring.
- o Survey the longitudinal profile of the probable alignment of water supply lines (Figure ..)
- o List the name, address and irrigable land holding of each beneficiary household.
- o With thorough consultation with the community, identify a suitable location for a tap stand. Make sure it is physically below the source and acceptable to the intended users.
- o Measure the dimension (Length, Width and Depth) of each suggested structures (Collection chambers and tanks).
- o Measure the length of the fence around the intake, particularly on the higher side.
- o Make sure that it is not possible for the intake to be used as toilet or for washing.
- o Assess Contamination of the source, whether the
 - ~ Source shared with animals,
 - ~ Aquatic lives living in the source, and
 - ~ Contaminated runoff mix in the source.

Sketch/Photo	Survey consideration Continued.
 PLAN  PLAN	Survey consideration Continued. - A minimum of five villagers should accompany the two surveyors during the detailed survey. Survey requires following materials: - ~ Abney level, altimeter, field book and 50m measuring tape. ~ Khukri or heavy knife for clearing bushes along the way. ~ Large dekchi (known volume) and watch for measuring the source yield. ~ Three ranging rods or straight sticks of equal height for the Abney level survey. ~ Enamel paint and wooden pegs to mark the survey route. Design consideration 
Catchment Treatment: To improve and regulate quality and quantity of water to the collection tank. - Landuse improvement: Grass / shrub / tree planting in degraded areas, Hedgerow planting, Brush layering, Wattling, in steep slopes, Grazing land management, - Treatment of rill and gully: Fascines, Palisades, Wattling, Brushwood checkdams - Diversion waterways to divert polluted runoff coming to the source. Capacity of the Source - Measure the volume of water produced by the source in the driest period (Chaitra-Baisakh). ~ <i>Procedure:</i> - Take a container of known volume and note the time required to fill. If “v” be the volume of container in liters and “t” be the time in seconds required to fill, the water produced is “v/t” liters per second. - Maximum number of the persons the source can serve is calculated by multiplying “v/t” (liters per second) by 2160. (Water requirement per person is 40 liters a day).	
Example Calculation: Given: - v = 20 liters T = 30 seconds Calculation: - Flow, $V = v/T = 20/30 = 0.666$ liter/sec Total water yield / day = $V * 24 \text{ hours} * 60 \text{ minutes} * 60 \text{ seconds} = 0.666 * 24 * 60 * 60 = 0.666 * 86400$ liters = 57542 liters Number of Persons that could be supported = $57542/40 = 1438$ persons Check quality of water: Put four drops of a solution of potassium carbonate in a small glass of the water. If decomposed organic matter is present, the water turn pale yellow indicating organic pollution rather than of bacteria contamination (although the two are usually linked).	

Sketch/Photo	Design consideration
	Water Collection Chamber: Major part of the water source protection. - Design the collection chamber: Major steps in the construction of the collection chamber (Figure): - - When the spring is identified, the area is cleared and dug, to form a depression, - A square or rectangular shaped structure. Upper part is made of the loose stone, and upper slope of the wall is filled with gravels and covered with puddle clay and soil at the top. - Other three sides are made with either concrete or stone cement masonry to collect the water. - Collection chamber will be provided a pipe with filter to take the water to the collection tank, and overflow. - The floor of chamber should be of P.C.C. (1:2:4). - Upper side of the chamber is closed with a provision of lockable cover.
	Water Collection Chamber: Continued. - The size of the collection chamber depends upon the discharge of the spring. The maximum size is 120cm*120cm and depth of 70cm, the minimum size being 70cm*70cm*70cm. - Collection chamber is protected from the contamination with the construction of the bund planted with hedge or diversion waterways around it. Also the area is generally fenced. Retaining Wall: The spring after excavation needs protection. A retaining wall is constructed in the upper side. To allow more discharge to collect, retaining wall is generally extended laterally. A number of collection chambers could be provided to increase the flow to the collection tank.
	Reservoir Tank - Decide whether there is enough water for the pipe to run constantly, or it would be better to have a storage reservoir and regulate supply to the tap stand. - Calculate the volume of reservoir tank needed to store twelve hours' discharge from the source (or more if resources allow for a bigger tank). Minimum size of the reservoir tank is - $V/t * 12(\text{hours}) * 60(\text{minutes}) * 60(\text{Second})$ liters = $43.2 * V/t$ cu.m. - Provide the overflow mechanism in the reservoir tank. - Provide free board of minimum of 50cm. - Reservoir tank must be closed with a provision of lockable cover. - Flushing mechanism must be provided in the reservoir tank. - Dugout reservoir tank is preferable, if the appropriate site is available. However, such reservoir tank needs protection. - If silt is a problem from the collection chamber, silt trap must be provided before collecting water in the reservoir tank from the collection chamber.
Example: A tap stand is to be supplied from a tank whose outlet is 30 meters above the tap, through a pipeline 750 m long. The tap requires an estimated supply of 1000 liters/hour, which is nearly 0.3 liter per second. What size of galvanized iron pipe should be used? Try a 19mm ($\approx 3/4$") diameter pipe. From the table, the frictional loss per 1000 m for a 19mm pipe for a flow of 0.3 l/sec is 181m. The loss on 750 m of pipe is $0.75 * 181 = 135.75$m. But only 30m of head is available. The loss on a 25mm (≈ 1") diameter pipe is $0.75 * 42 = 31.5$m, which is still too much. Therefore, try a larger pipe, say 31mm ($\approx 1 1/4$") in diameter. The loss is then $0.75 * 13.8 = 10.35$m. Hence a 31mm pipe should be used.	Pipe Design - Flow through pipe depends on its diameter, frictional characteristics and the applied head. A simple rough calculation for the discharge is given the values in the charts in Table. - For detail and more complex water supply scheme requiring break pressure valves/tanks, consultation with the water supply engineers is required.

Table for Calculating pipe friction head loss in metres per 1000 meters of pipe length: GI Pipe

Flow l/sec	GI Pipe diameter (mm)									
	13	19	25	31	38	50	63	75	88	100
0.05	40.8	5.1	1.1	0.4	0.1					
0.10	162.0	20.2	4.7	1.5	0.6	0.1				
0.20	630.0	80.7	18.6	6.1	2.4	0.5				
0.30		181.0	42.0	13.8	5.3	1.2	0.4			
0.40		319.0	74.0	25.5	9.7	2.2	0.7	0.2		
0.50		500.0	116.0	39.0	15.0	3.5	1.0	0.3		
0.75			260.0	90.0	33.5	7.5	2.4	0.6	0.3	
1.00			465.0	161.0	60.0	13.5	4.3	1.1	0.5	0.2
1.50				372.0	136.0	30.2	9.5	2.5	1.1	0.6
2.00				670.0	242.0	53.0	17.0	4.4	1.9	1.0
2.50					380.0	83.0	26.6	7.0	3.1	1.6
3.00					525.0	119.0	38.0	10.1	4.4	2.3
3.50						165.0	51.0	13.7	6.1	3.1
4.00						210.0	67.0	17.8	8.1	4.1
5.00						325.0	107.0	28.5	12.6	6.5

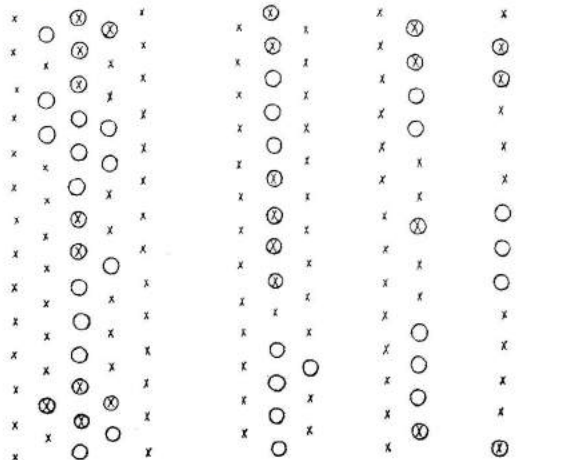
Table for Calculating pipe friction head loss in percent of discharge per 100 m of HDPE pipe

Flow l/sec	HDPE outside pipe diameter (mm) / pressure rating (kg/cm ²)																	
	16/10	20/10	25/10	32/10	32/6	40/10	40/6	50/10	50/6	63/10	63/6	63/4	75/10	75/6	75/4	90/10	90/6	
0.10	12.6	3.7																
0.12	17.5	5.5	1.7															
0.14	23.0	6.7	2.2															
0.16	29.2	8.5	2.8															
0.18	36.1	10.5	3.4	1.1														
0.20	43.7	12.6	4.1	1.3														
0.22	51.9	14.9	4.9	1.6														
0.26	70.2	20.2	6.6	2.1	1.2													
0.28	80.4	23.1	7.5	2.4	1.4													
0.30	91.1	26.2	8.5	2.7	1.6	0.9												
0.32		29.3	9.5	3.0	1.8	1.0												
0.34		32.7	10.6	3.3	1.9	1.1												
0.36		36.2	11.8	3.7	2.1	1.2	0.7											
0.40		43.9	14.2	4.4	2.6	1.5	0.9											
0.42		47.9	15.5	4.8	2.8	1.6	1.0											
0.44		52.1	16.9	5.3	3.0	1.7	1.0											
0.48		61.2	19.8	6.1	3.6	2.0	1.2	0.7										
0.50		64.7	21.3	6.6	3.8	2.2	1.3	0.7										
0.54			24.5	7.6	4.4	2.5	1.5	0.8										
0.56			26.1	8.1	4.6	2.7	1.6	0.9	0.5									
0.60			29.6	9.2	5.4	3.0	1.8	1.0	0.6									
0.64			33.3	10.2	6.0	3.4	2.0	1.2	0.7									
0.68			37.2	11.4	6.7	3.8	2.2	1.3	0.8									
0.70			39.2	12.1	7.0	4.0	2.4	1.3	0.8									
0.72			41.3	12.7	7.3	4.2	2.5	1.4	0.9									
0.74			43.4	13.3	7.6	4.4	2.6	1.5	0.9	0.5								
0.76			45.6	14.0	8.0	4.6	2.8	1.5	0.9	0.5								
0.80			50.1	15.4	8.9	5.0	3.0	1.7	1.0	0.6								
0.84			54.7	16.8	9.7	5.5	3.3	1.9	1.1	0.6								
0.88				18.3	10.6	6.0	3.5	2.0	1.2	0.7								
0.90				19.0	11.1	6.2	3.7	2.1	1.3	0.7	0.4							
0.94				20.6	12.0	6.7	4.0	2.3	1.4	0.8	0.5							
0.95				21.4	12.5	7.0	4.2	2.3	1.4	0.8	0.5							
1.00				23.0	13.4	7.5	4.5	2.5	1.5	0.8	0.5	0.4						
1.10				27.3	16.0	9.0	5.3	3.0	1.8	1.0	0.6	0.4	0.5					
1.20				32.1	18.8	10.5	6.3	3.5	2.1	1.2	0.7	0.5	0.6					
1.30				36.9	21.7	12.1	7.2	4.0	2.4	1.3	0.8	0.6	0.6	0.4				
1.35				39.4	23.3	13.0	7.8	4.3	2.6	1.4	0.9	0.6	0.6	0.4	0.4			
1.40					24.8	13.9	8.3	4.6	2.8	1.5	0.9	0.7	0.4	0.4		0.3		
1.45					26.5	14.8	8.9	4.9	3.0	1.6	1.0	0.7	0.8	0.5	0.4			
1.50					28.1	15.7	9.4	5.2	3.2	1.7	1.0	0.8	0.8	0.5	0.4	0.3		
1.60						17.7	10.5	5.9	3.5	1.9	1.2	0.8	0.9	0.5	0.4	0.4		
1.65						18.8	11.2	6.3	3.7	2.1	1.2	0.9	0.9	0.5	0.4	0.4		
1.70						19.8	11.8	6.6	3.9	2.2	1.3	0.9	0.9	0.6	0.5	0.4		
1.75						20.9	12.5	7.0	4.2	2.3	1.4	1.0	1.0	0.6	0.5	0.4		
1.80						21.9	13.1	7.3	4.4	2.4	1.4	1.0	1.0	0.6	0.5	0.4		
1.90						24.2	14.4	8.0	4.8	2.6	1.6	1.1	1.2	0.7	0.5	0.5	0.3	
1.95						25.4	15.1	8.4	5.1	2.8	1.6	1.2	1.2	0.7	0.6	0.5	0.3	
2.00						26.6	15.8	8.8	5.3	2.9	1.7	1.2	1.3	0.7	0.6	0.5	0.3	

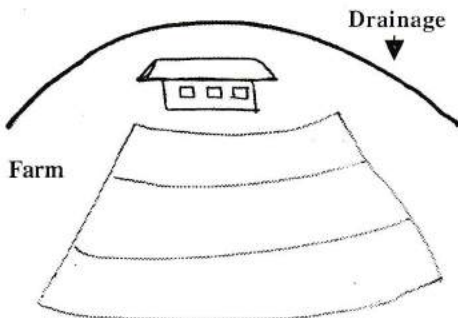
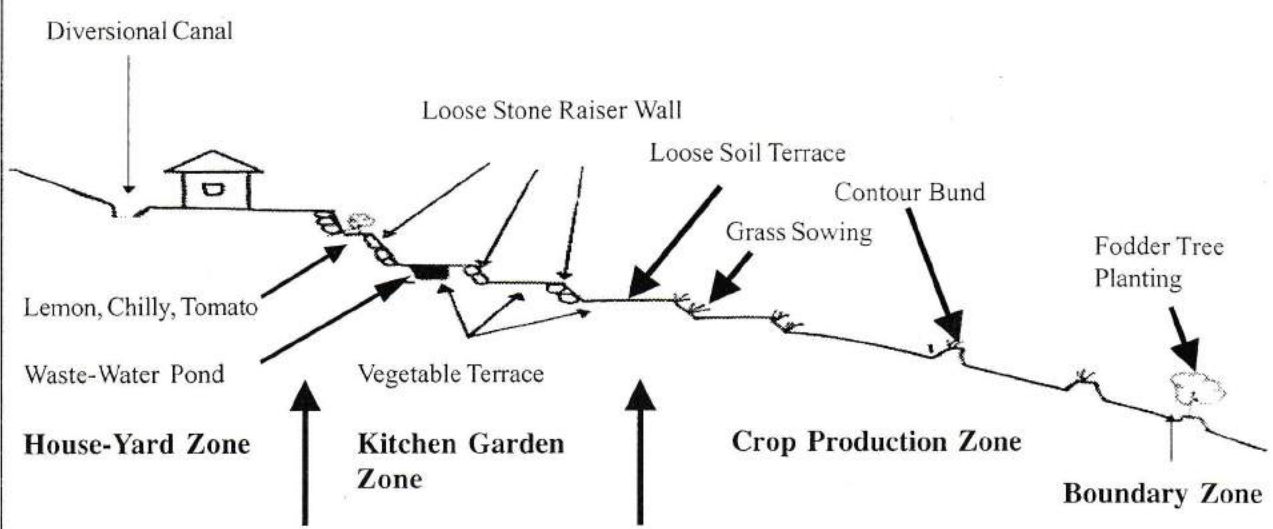
Sketch/Photo	Practical Consideration
 Kuwa Renovation, Dadeldhura	• Pipes are properly buried at least 50 cm below the surface. • Avoid the number of bends in pipe layout. It is best to use straightest possible course for pipeline. • Foster kitchen gardening as a package to water source protection. Package Design Water source protection should be designed as a complete package considering the proper treatment of the catchment area of the source to improve its hydrological regime, water supply to community or individual houses addressing the community's needs and using the wastewater for the vegetable farming adding economy to the community. This includes proper land-use and erosion control works in the catchment area to protect environment, proper construction of intake, piping, tap to supply water as service and construction of small ponds to collect water for vegetable farming using wastewater to generate economy. Working Unit Catch area, spring, distribution system (if required) and use of waste water is taken as working unit.

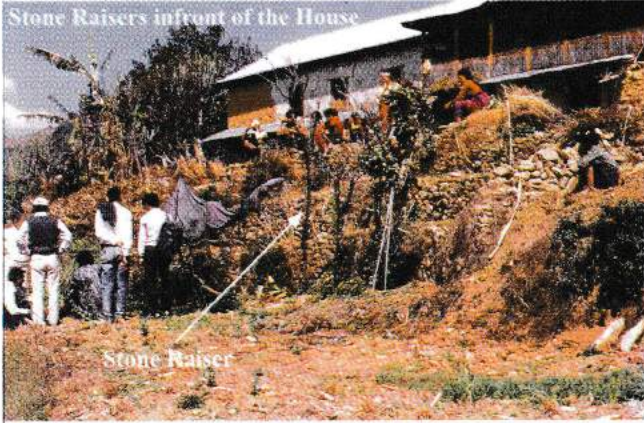
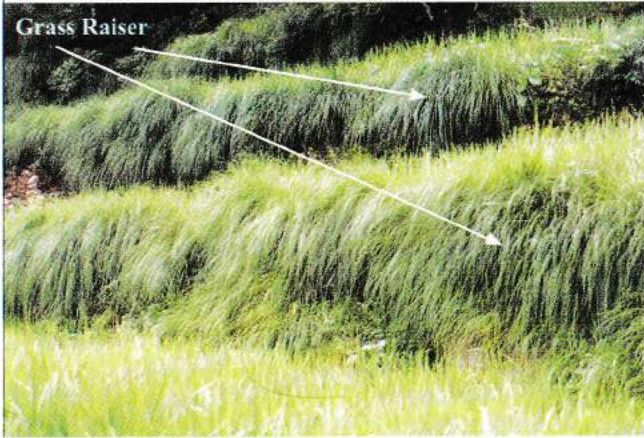
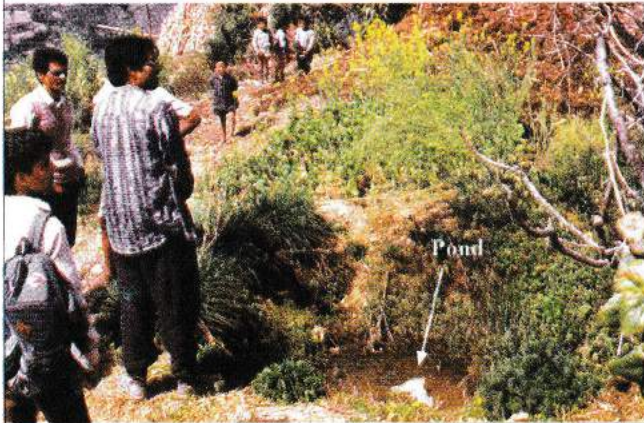
Reference: - UNICEF, 1996. BIWMP, 2003. DSC, 1992. SCWMC, 2001.

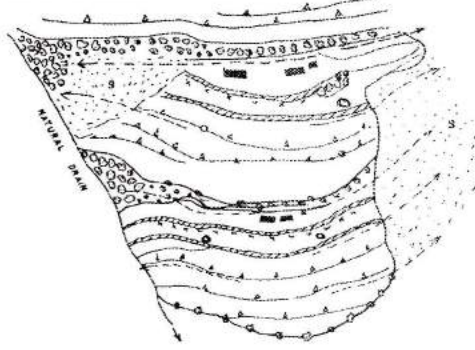
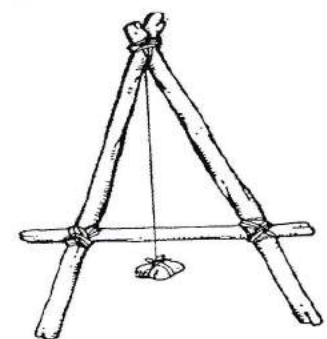
Activity:	Shelter-Belt / Buffer Strip	
Definition:	Shelter Belt Refers to a belt of trees and shrubs maintained to protect soil and plant resources from wind and conserve moisture to increase productivity of the agriculture lands. Buffer Strip Refers to a belt of erosion resisting vegetation (trees, shrubs and grasses) maintained to reduce the effects of upslope to the area. It is generally maintained to protect lakes, reservoirs and crops. Shelter Belt / Buffer Strip Refers to the planting of trees, shrubs and grass vegetation in rows mostly across general wind direction in case of shelterbelt and across the slope in case of buffer strip.	
Major Problems caused by Wind or Upslope Runoff	• Soil erosion (wind erosion in case of shelter belt and water erosion in case of buffer strip) • Desiccation (by wind) of plant • Reduced soil fertility (caused by moisture deficiency and erosion) • Damage to plant (Upslope runoff)	
Major Causes of Degradation caused by high wind and upslope runoff:	• High wind velocity (in case of shelter belt) and Upslope erosion (in case of buffer strip) • Unmanaged runoff	
Objectives of Shelter Belt / Buffer Strip:	Shelter Belt • To reduce wind erosion and conserve soil and moisture for better production of crops. Buffer Strip • To reduce adverse effect from upslope erosion and conserve soil and moisture for better production.	
Scope of Shelter Belt		Scope of Buffer Strip
• Planting of trees and shrubs in pre-designed pattern of spacing and height. • Protection of the vegetation from grazing and human interference. • Seedling production.		• Planting of trees, shrubs and grasses in pre-designed pattern of spacing and height. • Protection of the vegetation from grazing and human interference. • Construction of diversion waterways for safe drainage mainly for buffer strips. • Erosion control measures (such as fascines, palisades, contour wattling, brushwood checkdams) in the case of erosion prone area. • Seedling production.
Survey consideration		
Mapping: Prepare a map of about 1:2,000-5,000 scale (if not, at least sketch is mandatory) showing: - • Area to be protected (showing affected land units). • Survey and prepare location / orientation of strip. • Rills, gullies and drainage. • Water sources. Measurement • Length and width of the strip (land strip in which shelter belt / buffer strip has to be planted). • Slope of the land in case of buffer strips. • Total length of the rills and gullies. • Total length of the live fence. Assessment • Type of land and the problem • Soil type, climate, (maximum and minimum temperature, windy period) • The average elevation of the area (Using topographic map), • Suitable species of tree, shrubs, and grasses in consultation with the communities, including legumes • How the required planting stock could be made available, In case of shelter belt • Location (distance from home stead, cropping pattern etc) • Wind velocity and direction		
 Flow of wind over a moderately penetrable Shelter belt. Flow of wind over a dense Shelter belt.		

Design consideration Shelterbelts must be dense in their lower part, whereas the middle and upper parts should be more open. A shelterbelt should consist of approximately 65 % shrubs and 35 % trees, which are further subdivided into about 15 % tall and 20 % medium sized trees.			
Sketch/Photo   ⊗ Tall tree ○ Medium sized tree x Shrub, Vine	Design consideration Wind permeability: Dense vegetation reduces air flow. Permeable structure allows about 30-35% air flow and porous structure allows more than 40% air flow. Effective shelter belt needs to allow 30-35% air flow. For Windbreak: - Design wind break perpendicular to the wind direction, Permeable (screen allows 30- 35% air flow). In the field, a plant / crown density of 50-60 % is generally maintained for permeable screen. - Preferably 3 storey and 3 -5 rows, - Have a great height, - Permeable shelter protects a far distance on leeward side compared to dense one. - Shelterbelt protects an area up to 15-20 times its height on the leeward side and 5 times on windward side. For agricultural and range lands - Intervals between individual shelterbelts may be taken at up to 20 times the height of the tallest growing trees. - At all levels of shelterbelt and both sides of the belt should contain rows of tree for uniform permeability that will remain dense near ground. - Spacing between rows is generally 3-4 m. and between plants is 1.5-3m.		
For livestock - To provide shelter during hot season. Establish small, dense windbreaks in V or U shape, with the open end of the V and U downwind. For Protecting farmstead - Needs the greatest reduction in wind velocity around the farmhouse, barnyard and garden therefore establish dense (screen does not allow air flow) belt around farmstead. For Buffer strip to protect soil from water erosion - Several structural type (multi-storey) dense belt is constructed on slopes and banks. For Buffer zone to reduce harmful emissions from factories - Dense structure with grasses, shrubs and higher trees around factory areas to form Buffer zone. For Scenic value - Various combinations of different species is used depending upon the landscape. Shelter for wild animals - Coppice strips of spiny, thorny, fruit -bearing species in scattered pattern and not too dense.			
Practical Consideration - On hill slopes dense vegetation is established as buffer strip intercepting surface run-off and reducing water erosion. - Buffer strip along streams also serves as a bank protection. - Select those species, which are known to grow best in the locality. Preferably evergreen or else be in full foliage during the main problem period and with desirable features such as rapid early growth, adequate height, longevity, dense crown, wind firmness and multiple use. - Shelterbelts must be dense in their lower part, where as middle and upper part should be more open. - Multi storey belt with multiple tree species are preferred. - Complete soil preparation to a depth of 40-60cm over the entire strip is needed for planting trees.			
Some Tree species	Soil conditions	Some Tree species	Soil conditions
<i>Accacia auriculiformis</i>	Alkaline and water logged	<i>Casurina equisetifolia</i>	Clay
<i>Accacia nilotica</i>	Heavy soils	<i>Dalbergia sissoo/ Syzygium cumini</i>	Sandy, alluvial
<i>Alnus nepalensis</i>	Moist sandy clay	<i>Eucaliptus spp.</i>	Moist sandy loam to alkaline
<i>Azadirachta indica</i>	Moist sandy clay loam	<i>Leucaena leucocephala</i>	Heavy soils
<i>Albizia procera</i>	Sandy loam		

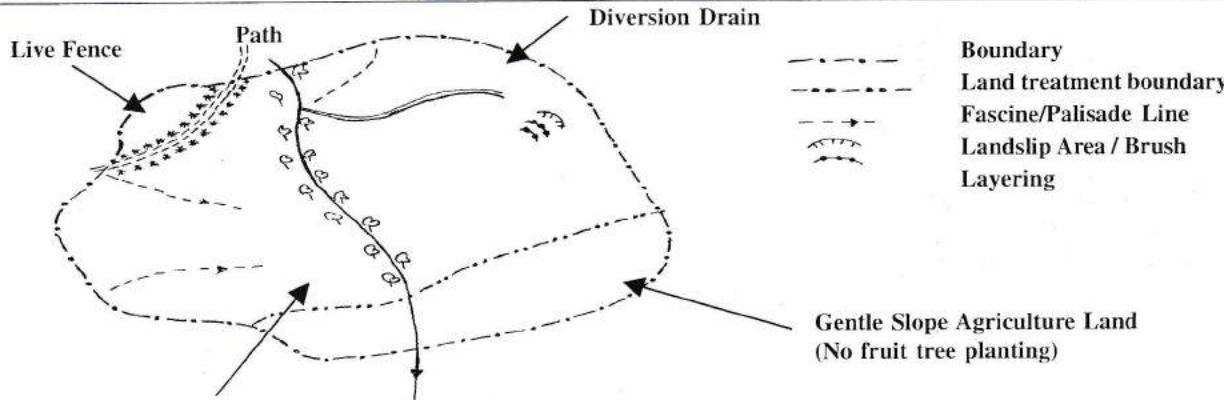
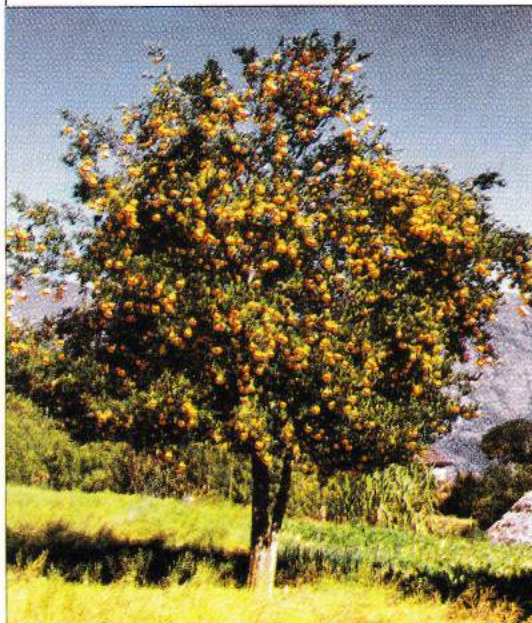
Reference: - FAO, 1976. Rief, Albert and Thomas Schmuz- 2001. Weidelt, H.J. 1976.

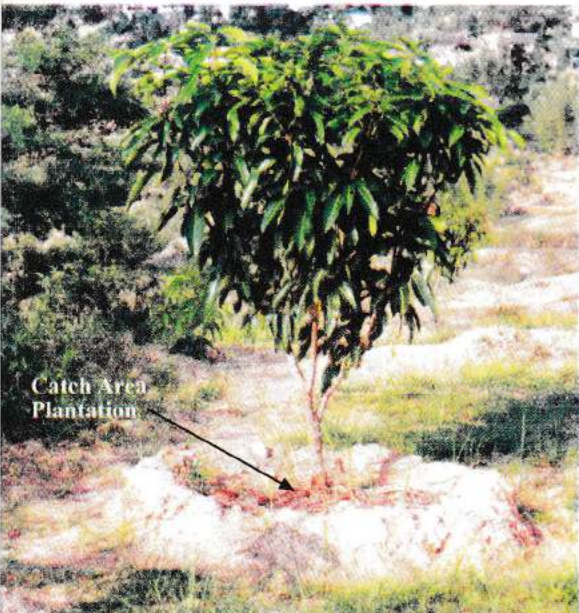
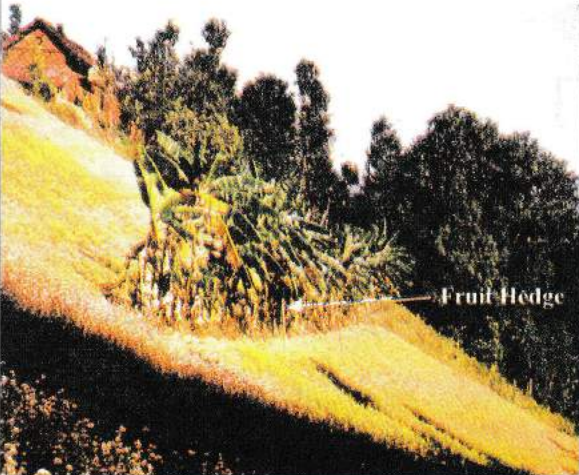
Activity:	On-Farm Conservation	
Definition:	Management of the farm resource to conserve soil and water and improve production through various measures.	
Major Problems Caused by unmanaged on-farm	- During the rainy season fine topsoil from the unprotected farmlands are lost each year. Along with topsoil, valuable nutrients such as Nitrogen, Phosphorus, Potassium and organic matters are also lost, resulting in decrease in crop yield. - Loss of topsoil decreases the overall quality of the soil as the moisture holding capacity becomes low, organic matter content is reduced and the soil becomes infertile, hard and sterile.	
Major Causes of on-farm degradation:	- Unprotected slope and sloping length of the farmland including raisers. - Unmanaged runoff and moisture constraints. - Lack of safe drainage and irrigation canals.	
Objectives of On-Farm Conservation:	- Reduce soil erosion - Conserve moisture and nutrient - Increase production	
Sketch/Photo	Scope of the On-farm Conservation	
		- Vegetative (hedgerow / strip planting / bio-terracing) and physical measures (retaining wall) applied in the farmland including slope correction / modification of the terrace. - Planting of trees, herbs, or grass on marginal / waste land in between and / or within farmlands. - Planting of grass, trees and leguminous shrubs on the risers. - Management of runoff / moisture for erosion control and crop production through improvement of drainage / irrigation canal (within the plot) and water harvesting (tanks/pond). - Gully plugging (fascine, palisades, wattling, grass planting, brushwood checkdam, brush layering).
		
Survey consideration		
Mapping Visit the farm and prepare map of about 1:2000 – 5,000 scale (If not, at least sketch is mandatory) showing: - - Boundary of the farm land under consideration for conservation. - Map the individual terrace plan. - Natural drainage and their direction - Source of runoff (where does it come from and where does it go) and an appropriate place where it can be safely diverted - Drainage from housing complex including tap - Possible place for pond construction for harvesting water from the housing complex - Gullies - Waste Area (waste and marginal lands within the farm units and risers) for possible planting.		

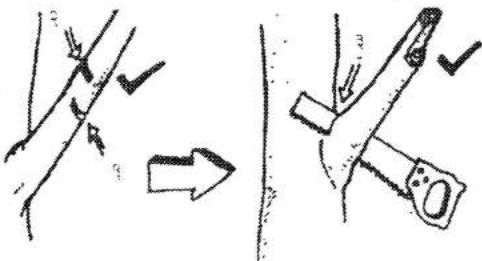
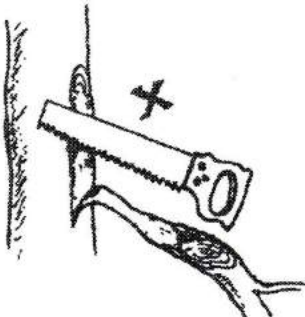
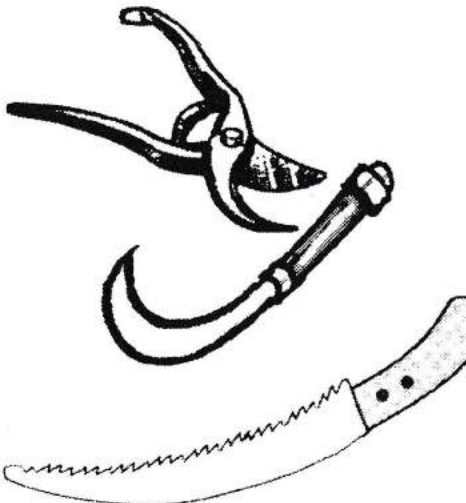
• Measurement - o Measure 1 – 2 representative cross section of the farm for designing the slope correction / modification of the farm unit. - o Measure the dimensions of stone retaining walls in front of the house if required to support terrace. • Assessment - o Identify grasses/shrub/fodder trees that will be planted at suitable area that includes waste and marginal lands, bunds and risers within the farm units and boundary of the farm unit. - o Identify and list the beneficiaries	
Sketch/Photo	Design consideration
Bagmati Watershed, Lalitpur Stone Raisers in front of the House 	Farm unit may be generally divided into four major zones • House Yard Zone: Generally required: - o Retaining walls: To protect the house from sliding and erosion. It may require to level 2 to 3 terraces in front of the house basically to dissipate the energy of the concentrated runoff from the housing complex. Do not plan on leveling more than 3 terraces, as more leveling may cause stability problem by holding excess water. - o Drainage: To drain runoff water from roof and house yard either to collect into pond or disposed safely. - o Small pond: To collect runoff or household wastewater and irrigate the crops / vegetable. - o House yard boundary wall: A half meter stone-wall constructed along the bottom side of the house yard area to keep animal either in or out of the farm. • Kitchen Garden Zone: Generally required: - o Level terraces: Below house-yard boundary wall 2-3 terraces can be leveled for growing vegetables. Water from the ponds can be used to irrigate these terraces. - o Loose stone retaining walls: Help to dissipate the energy of the runoff and reduces erosion. - o Terraces: Level terraces with grass raiser and unleveled terraces with grass bunds. • Crop Production Zone: Generally required: - o Partially Leveled Terraces with Grass Raiser: For better soil, moisture and nutrients conservation, mulching is done. Hedgerow is planted at the rim of the terraces to help bio-terracing. Hedgerow will be regularly trimmed to avoid shading effect on agriculture crop. - o Sloping Land with Strip Bund Planting: Bunds are planted with grasses such as Seteria, Desmodium, and small leguminous fodder species. Regularly trimmed to avoid shading effect on agricultural crops. Soil accumulated at the bund will help bio-terracing. • Boundary Zone: Generally required: - o Fodder Planting: At the rim of the boundary fodder and fruit trees, bamboos or hedgerows are planted. Remarks: - All farms may not have all of these zones and may not need all the measures. However, package treatment considering different aspects of the farm unit is essential to make the activity result oriented.
Bhusundi-Watershed, Gorkha Grass Raiser 	
Bagmati Watershed, Lalitpur 	

Sketch/Photo	Design consideration
 ■ Farmer's House — Leveled Terrace - - - Fruit Trees . . . Terrace Bunds with Grasses ○○○ Fodder Trees ××× Drainage Channel ● Pond ▲ Shrub Field Assessment of Farmland, BWP, 1997.	Terrace Dimension: • Raiser Height: Generally, height upto 2 meters is recommended. (Experience has shown that using the local skills the farmers have built and maintained the stone riser up to 2m high without problems. With this riser slope up to 60% can be terraced giving a terrace width of 2m., which is essential for ploughing the land using, the bullock power.) • Terrace width: Minimum of 2 meters width bench terraces is required for the plowing by the bullock. (Depends on various factors such as raiser height, slope, soil depth, crop to be grown, crop needs and tools to be used as well as farmer's interest, financial status and the farmers' choice. Generally, it is desirable to keep the width between 2 and 5 m. Too wide a terrace is not only costly but also needs a deep cut and requires a high riser, which is not desirable.) • Terrace length: Depends upon the size and shape of the field, the degree of dissection of land and so on.
 	Practical Consideration • Mark out the lines of terrace formation, using an "A" frame to mark contour. • Start building the terraces from the top of the hill and proceed down slope. • Remove topsoil and collect nearby place. • Raiser and bund construction. • Once the main benches have been formed, complete the surfaces by smoothing them to even grade. • After every 15cm of fill, the soil should be compacted firmly by a beater. • Replace topsoil on terrace steps. • Immediately after the construction of terraces, raisers and bunds should be shaped. • The edge of a terrace should be built a little higher than planned, because of settling. The rate of settling may be as high as 10% of the depth of fill. • Both the reverse and horizontal grades should be checked by a level during construction. • Shape the slope of the riser to 0.75:1 (v:h, in case of soil riser). • The top and sub-soil are thoroughly mixed if the top soil is not adequate for the terrace. If the sub-soil condition is not good, then it is necessary to keep them apart and should be spread on the terrace after construction. • Working down the slope on each terrace, cut out the back of the terrace benches and pile the subsoil along the front of each step. • Plant grasses and possibly also fodder or fruit shrubs and trees on the terrace risers, bunds and boundary.
Consideration for soil productivity maintenance: -	
• Deep plowing, ripping or sub-soiling is needed on the cut part of the bench terraces to improve the structure of the soils. • Green manuring, composting or sludge application is also needed in the initial period for improving soil fertility. • Maintain soil productivity by proper crop rotation and fertilization.	
Remarks: • The success of terraces lies mainly in safe water management and regular maintenance of the vegetation on the raisers, bund and boundary. Working Unit • Individual farm plot is considered as working unit. Working Season • Build the terrace when the land is not too dry and too wet. • Generally, a farmer can complete the entire improvement work within 2 months except for grass/tree plantation, which is done at the onset of the monsoon in June/July. • Operation must be timed within the agricultural season, so that the land settles back properly before the next crops are sown. Farmer's slack period is most appropriate time.	

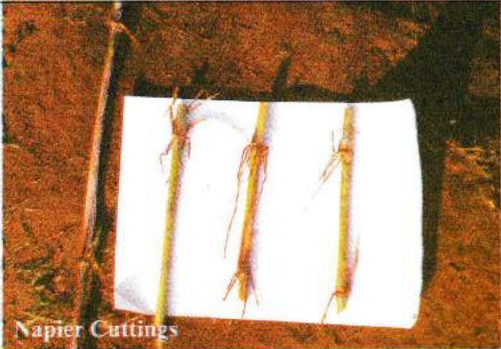
References: - NRRA and IIRR, 1992. BWP, 1997. BIWMP, 2003. DSC, 1992. SCWMC, 2001. Sthapit, K. M., 1998. Ted C. Sheng, 1986.

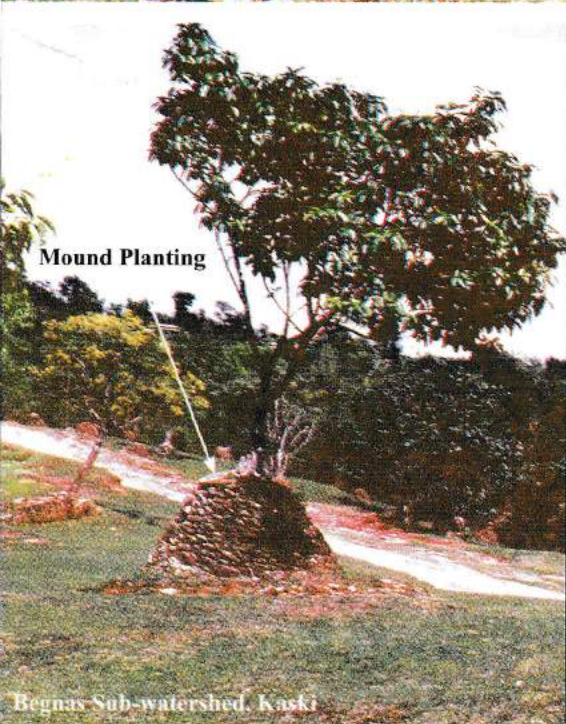
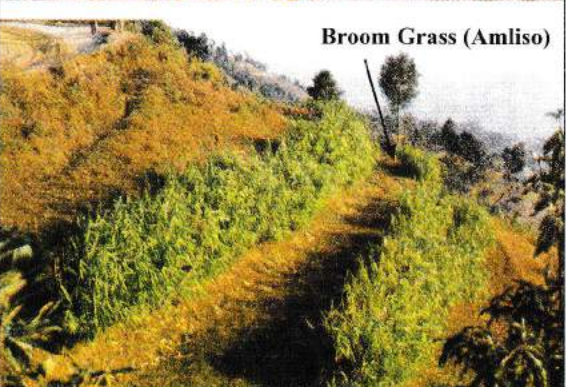
Activity:	Fruit Tree Planting
Definition:	Refers to the fruit tree planting along with vegetative and structural erosion control measures applied on the agriculture land, which is not suitable for annual cultivation or communal land under some local institution such as school and non-governmental organization.
Major Problems on Marginal Lands:	• Soil erosion • Low productivity
Major cause of degradation:	• Overuse of the marginal lands (Private or Communal) • Unmanaged runoff • Inadequate protective vegetative covers
Objectives of Fruit Tree Planting:	To reduce erosion and increase productivity on the individual's overused agriculture land and communal land by introducing fruit trees. Cultivation on marginal lands (steep slope beyond its capability) is harmful for the soil and water conservation. Therefore, for better land husbandry change of landuse from annual cultivation to permanent crop (such as grass or forest) is very essential. However, question is whether small farmers can give up cultivation and live on grasses or forest? If not one of the alternatives could be to plant fruit trees, which could earn in few years. Therefore, planting fruit trees under physical activity is aimed at the marginal lands as a scheme of changing landuse. Planting fruit trees other than marginal lands for better economy must be covered from the income generating fund.
Scope of Fruit Tree Planting	
• Fruit tree planting with necessary conservation techniques such as contour terracing, contour trenching, contour bunding • Erosion control measures such as fascine, palisade, wattling, grass planting, brush layering, brushwood checkdam, as needed • Construction of diversion channel and safe drainage • Protection of fruit trees (such as live fence)	
Survey consideration	
	
Sketch/Photo	
Mapping • Prepare map of about 1:2,000 – 5,000 scale (If not, at least sketch is mandatory) showing: - - o Boundary of the degraded land and average slopes - o Natural drainage and their direction - o Gullies (including landslips if any) - o Diversion waterways if necessary - o Water sources (such as springs, swamp, ponds, irrigation ditches, canals, pipes) Measurement - o Area of the land, - o Total length of the rills and gullies for the bioengineering measures such as fascines, palisades, brushwood checkdams for gully plugging - o Total length for live fencing if required - o No of seedling required Assessment - o The average elevation of the area (Using topographic map) - o Soil depth, Texture, Status of organic matter and NPK, and pH - o The suitable fruit species in consultation with the farmer - o Appropriate species (crop, shrub, tree) for inter cropping - o How the required planting stock could be made available - o Aspect	

Sketch/Photo	Design / Practical consideration																																			
 Pot Irrigation	Site Selection: Appropriate site for fruit tree planting: - • Preference to good drainage & irrigation facility • Well aerated • With reasonable transport facilities for market accessibility. • Soil: ~ Fertile well drained loamy soil ~ At least 1.5 m deep ~ Good water holding capacity																																			
Demonstration Site, Dhankuta  Catch Area Plantation	Site Preparation • Alignment: There are different pattern for alignment. ~ Square: Pits are aligned at the square shape ~ Rectangular: Pits are aligned at the rectangular shape ~ Triangular: Pits are aligned at triangular shape ~ Contour Raiser and Terrace: Pits are along rim of the terrace • Spacing: Depends on the species, slope and shape of the land unit. • Pitting: ~ Generally, size of the pit is 1m in diameter and 1 m deep, ~ Pitting is done well in advance (about 1 – 2 months before planting) ~ Dig top 45 cm of the pit, and put the soil separately ~ Further dig the pit to 1m depth, thus dug soil is exposed to sun for about 15 days to destroy harmful insects ~ Mix some pesticides such as aldrin in the top 45 cm soil, and put at the bottom of the pit ~ Rest of the pit is filled with well mixed soil of compost or FYM, bone meal and pesticides. Then firmly press the filling. Filling of the soil should be 45cm higher than the ground.																																			
Demonstration Site, Dhankuta  Fruit Hedge	Amount of Compost and Farm Yard Manure used in pit: <table><tr><th>Species</th><th>Compost</th><th>Phosphorus</th><th>Potassium</th><th>Lime</th></tr><tr><td>Apple, Peach, Plum, Pear</td><td>40 gms.</td><td>80 gms.</td><td>150 gms.</td><td>1 kg</td></tr><tr><td>Orange, Sweet orange</td><td>40 gms.</td><td>80 gms.</td><td>150 gms.</td><td></td></tr><tr><td>Mango, Litchi</td><td>50 gms.</td><td>80 gms.</td><td>300 gms.</td><td>1-2Kg</td></tr><tr><td>Guava</td><td>30 gms.</td><td>160 gms.</td><td>150 gms.</td><td>1 kg</td></tr><tr><td>Banana</td><td>20 gms.</td><td>40 gms.</td><td>100 gms.</td><td></td></tr><tr><td>Papaya</td><td>20 gms.</td><td>40 gms.</td><td>60 gms.</td><td></td></tr></table>	Species	Compost	Phosphorus	Potassium	Lime	Apple, Peach, Plum, Pear	40 gms.	80 gms.	150 gms.	1 kg	Orange, Sweet orange	40 gms.	80 gms.	150 gms.		Mango, Litchi	50 gms.	80 gms.	300 gms.	1-2Kg	Guava	30 gms.	160 gms.	150 gms.	1 kg	Banana	20 gms.	40 gms.	100 gms.		Papaya	20 gms.	40 gms.	60 gms.	
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Farmer's land, Palpa	• Planting ~ Dig the pit sufficiently deep for the planting. ~ Ensure that roots of the plants are not bent when planted, ~ Plant the seedling at the center, ~ Press the soil firmly around the plant, ~ Give support to keep the seedling straight, ~ Regular watering is required for better growth, ~ Mulching will help the seedling to conserve soil and moisture and protect from heat.																																			

Sketch/Photo	Design / Practical consideration	
	Maintenance - Regular Pruning - Why? ~ To control the spreading of the crown (Temperate fruits: Apple, Pears, Peach, Plum) ~ To avoid insect attack ~ To reach the pesticides inside the plants ~ For good aeration and sunlight to reach inside ~ For good fruiting (big size) ~ For fruiting for longer duration	
	How and When? Start pruning from the beginning	
Banana Plantation	1 st Year	Cut top leaving 60 cm and side leaving 10-15 cm (Only for Apple, Pear, Peach and Apricot)
	2 nd –5 th Year	Keep main branches growing in the four directions and cut rest of the branches
  	3 rd Year	Pruning should be made leaving 50 cm
	4 th Year	Cut main branches with two sub-branches.
	After 5 th Year	Prune - All new branches growing from the main stem - Dead, dying and diseased branches - Branches growing towards center, ground, and sky
	General: - - Vertical distance (upper to lower) between branches should be about 20 cm - In case of grafted plants, all branches below grafting must be pruned - Lowest branches from the ground should be above 45-60 cm - No portion of the cut branch should be left at the joint - To spread the branches at the joint put some wood - Branches shorter than 50 cm need not be pruned - Do not prune when the leaves and fruits are still in the plant	
Pruning Tools		- Scateur, - Pruning saw
Treatment		- Apply the "Bordeux Paste" or "Wax" on the pruned surface to avoid infection and drying "Bordeux Paste" is prepared by mixing 90 grams of Copper sulphate, 90 grams of lime with 1 liter of water - For the effectiveness of the "Bordeux Paste", apply it within 12 hours of its preparation
Working Unit: - Land unit in consideration is taken as working unit.		

Activity:	Fodder / Grass Plantation
Definition:	Refers to fodder tree and grass planting along with other vegetative and structural measures applied on the marginal/grazing/shrub/waste lands, terrace risers, kharbari, road slopes, gullies, waster and fodder orchards.
Major Problems in Marginal Lands:	• Soil erosion • Low productivity • Lack of forage & fodder for livestock production.
Major Causes of Degradation:	• Inadequate protective vegetative covers • Unmanaged surface run-off • Over grazing & human interference
Objectives of fodder/ Grass Plantation	To reduce erosion from degraded grassland, shrubland and private non-cultivated areas and increase forage and fodder production.

Sketch/Photo	Scope of the Fodder / Grass Planting																												
 Napier Cuttings  Amliso Rhizomes  Grass Slips	• Conservation planting of fodder tree, grass and legumes, • Erosion control measures such as fascines, palisades, contour wattling, brushwood checkdams, • Introduction of rotational grazing and harvesting, application of fertilizer and irrigation, • Construction of diversion waterways for safe drainage, • Protection of the area (including live fencing) from grazing and human biotic interference.																												
	Survey consideration																												
	Mapping • Prepare a map of about 1:5000 - 10,000 scale (If not, at least sketch is mandatory) showing:- ~ Boundary of the land for silvi-pasture management and average slope, ~ Natural drainage and their direction, ~ Gullies (including landslips if any), ~ Different types of land units for various planting techniques and combination of plants (Ownership and land use) ~ Diversion water ways if necessary, ~ Water sources (such as springs, swamp, ponds, irrigation ditches, canals, pipes)																												
	Measurement - Land area, - Total length of live fencing - Total length of the rills and gullies for bioengineering treatment such as fascines, palisades, brushwood checkdams,																												
	Assessment - Suitable plant species in consultation with the communities. Choice of the species should consider its adaptability and resistant to loping, growing season, priority to local species, community's preference, quality (nutritive value, palatability, toxicity) of the species, and availability of planting stock.																												
	Total requirement Feed requirement for different animals is different. One buffalo is taken as one live stock unit (LSU), which requires 9 kg of sun dried grasses / forage per day which is equivalent to 20-25 kg of green grass. Live stock unit of some animals is categorized below:																												
Given: - Community has 100 milking buffaloes, 100 Calf, 300 Cows/ Oxen, 1000 goats and 50 kids. Calculation	<table><tr><th>Animal</th><th>Live stock unit</th><th>Livestock No</th><th>Requirement</th></tr><tr><td></td><td>a</td><td>b</td><td>= a*b</td></tr><tr><td>Milking buffalo</td><td>1</td><td></td><td></td></tr><tr><td>Calf</td><td>0.50</td><td></td><td></td></tr><tr><td>Cow / oxen</td><td>0.75</td><td></td><td></td></tr><tr><td>Goat</td><td>0.10</td><td></td><td></td></tr><tr><td>Kids</td><td>0.05</td><td></td><td></td></tr></table>	Animal	Live stock unit	Livestock No	Requirement		a	b	= a*b	Milking buffalo	1			Calf	0.50			Cow / oxen	0.75			Goat	0.10			Kids	0.05		
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Feed Deficit: Summing up of the requirement for different livestock gives total requirement. Total requirement minus total production gives deficit. Attempt should be made to fulfill the deficit.																													

Sketch/Photo	Design consideration								
	Preferable planning techniques								
	<table><tr><td>Grazing Lands</td><td> - Fodder tree planting on big mounds protected with stone walls </td></tr><tr><td>Marginal lands within the agriculture</td><td> - Leguminous forage. Preferably perennial. Fodder trees sparsely planted or hedgerows and forage in alleys. </td></tr><tr><td>Kharbari</td><td> - Fodder trees on boundary. </td></tr></table>	Grazing Lands	Fodder tree planting on big mounds protected with stone walls	Marginal lands within the agriculture	Leguminous forage. Preferably perennial. Fodder trees sparsely planted or hedgerows and forage in alleys.	Kharbari	Fodder trees on boundary.		
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	<table><tr><td>Site Condition</td><td>Recommended Measures</td></tr><tr><td>Dry slopes with poor soils</td><td> - Sowing grasses/herbs in contour ditches 75cm apart or terraces. - Contour hedges of leguminous shrubs. - Cut and carry management </td></tr><tr><td>Over pressure on land resources due to grazing</td><td> - Balancing the number of animal population with carrying capacity of available land. - Replace unproductive animal with improved one - Effective closure and scientific management practices. - Protect form grazing (Live fencing, ditch core wall). - Seeding with high yielding perennial grasses. - Inter-planting of leguminous herbs. - Weeding - Use of fertilizer (if cost is recovered) - Cut and carry management </td></tr><tr><td>Low quality feed, specially during dry season</td><td> - Feeding grasses/ forage at right stage of its growth. - Making silage/hay to preserve nutrients and enriching of cereal straw. - Growing shrub and tree fodder in combination with grasses / legume herbs to supplement during slack season. </td></tr></table>	Site Condition	Recommended Measures	Dry slopes with poor soils	- Sowing grasses/herbs in contour ditches 75cm apart or terraces. - Contour hedges of leguminous shrubs. - Cut and carry management	Over pressure on land resources due to grazing	- Balancing the number of animal population with carrying capacity of available land. - Replace unproductive animal with improved one - Effective closure and scientific management practices. - Protect form grazing (Live fencing, ditch core wall). - Seeding with high yielding perennial grasses. - Inter-planting of leguminous herbs. - Weeding - Use of fertilizer (if cost is recovered) - Cut and carry management	Low quality feed, specially during dry season	- Feeding grasses/ forage at right stage of its growth. - Making silage/hay to preserve nutrients and enriching of cereal straw. - Growing shrub and tree fodder in combination with grasses / legume herbs to supplement during slack season.
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	Practical Consideration - Sowing of grass seeds @ 1-2 kg / ha in the beginning of monsoon & the depth of sowing is 5-8 cm. - Planting slips / rhizomes of grass species is more successful than seeding. 2-3 weeding is good for grass-sown area in the first year. - Pit size for fodder tree and shrub is 30cm*30cm and spacing varies from 1 m to 3 m. - Tree fodder species which can also be grown by direct seeding are Tanki, Bhatmase, Caliandra, Tephrosia, Ipil-ipil. - It is essential to take necessary actions well in advance for the required planting stock including nursery. - For sustainable land management, grazing should not exceed the carrying capacity (land required for grazing by one live stock unit), which varies with land types, plant type, climate, management, etc. Therefore it should be assessed locally. - Carrying capacity of pastoral land can be increased by inter planting of shrubs and trees. They provide green fodder during dry season this planting system provides permanent coverage and constant supply of animal feed.								
									

Seasonal Availability of fodder

Fodder species	Main months for fodder supply	Other months in which fodder can be supplied	Altitude range (in Meters)	Production / plant / year in kg
Tanki (<i>Bauhinia purpurea</i>)	Kartik to Magh	Ashwin, Falgun & Chaitra	< 700-1800	7-80
Chuletro (<i>Brassaiopsis hainla</i>)	Paush & Magh	Mangsir & Falgun	700->1800	40-60
Badhar (<i>Artocarpus lakoocha</i>)	Mangsir to Falgun	Kartik & Chaitra	< 700- 1200	60-200
Koiralo (<i>Bauhinia variegata</i>)	Mangsir to Falgun	Kartik & Chaitra	< 700-1800	60-150
Khanyu (<i>Ficus semicordata</i>)	Mangsir to Falgun	Kartik, Chaitra, Baishakh & Jesth	< 700-1800	50-100
Kutmiro (<i>Litsea monopetala</i>)	Paush to Falgun	Mangsir, Chaitra & Baishakh	< 700- 1800	60-100
Nimaro (<i>Ficus roxburghii</i>)	Magh & Falgun Magh & Falgun	Ashoj, Kartik, Mangsir, Paush, Baishakh, Jesth & Ashadh	< 700- > 1800	60-120
Gogan (<i>Saurauia nepalensis</i>)	Magh, Jesth & Ashadh	Mangsir, Paush & Chaitra		100-120
Dudhilo (<i>Ficus nemoralis</i>)	Kartik, Mangsir,	Paush & Falgun	700- >1800	50-80
Ginderi (<i>Premna spp.</i>)	Paush, Jesth & Ashadh	Ashoj, Magh, Falgun & Baishakh		
Bhimsenpati (<i>Buddleia asiatica</i> or <i>paniculata</i>)	Kartik & Falgun Chaitra, Baishakh, Jesth	Mangsir, Paush, Magh, Chaitra, Ashadh, Shrawan & Bhadra		
Kabhro (<i>Ficus lachour</i>)		Falgun	< 700-1800	100-150
Molases (<i>Melinis minutiflora</i>)			< 700-1800	
<i>Stylosanthes</i>			<700- 1200	
Amriso (<i>Thysanolaena maxima</i>)			< 700-1800	

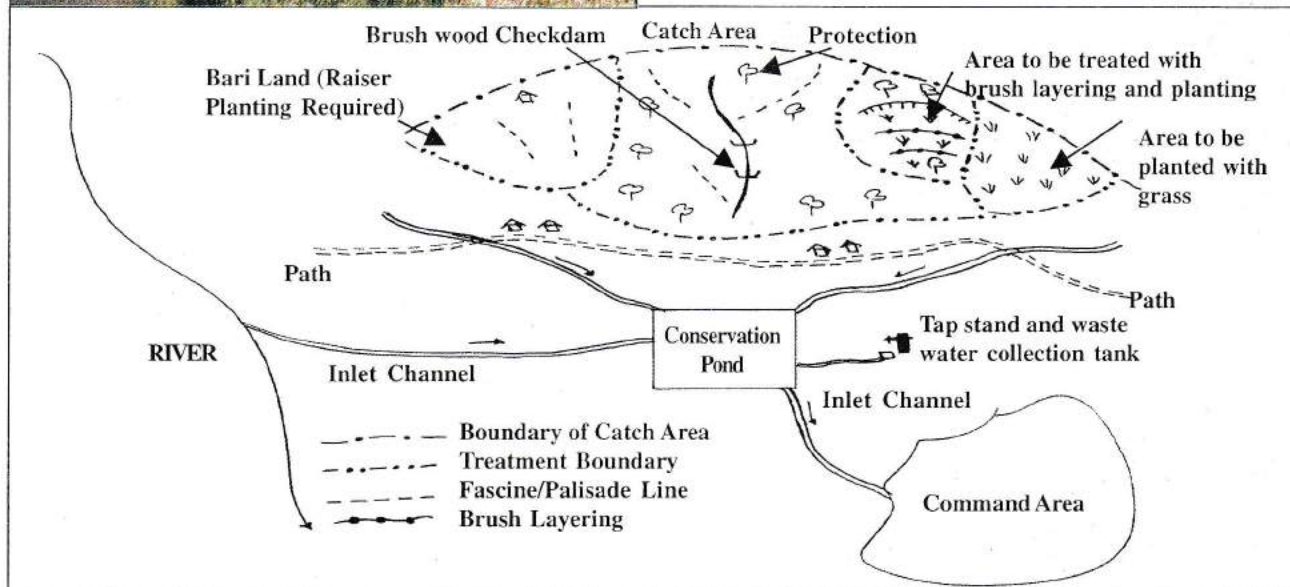
Combination of Grasses, herbs & fodder tree species

Land unit	Objective	Perennial Grass		Leguminous herbs		Fodder tree	
		Species	Planting technique	Species	Planting technique	Species	Planting technique
Kharbari	Thatching materials	Local khar	Contour line			Tanki, Nimaro, Bhimsenpati, Dudhilo, Siris, Gidari, Chuletro, Khanyu, Badahar Paiyu,	- Spacial plantation - Boundary plantation
	Animal feed & fuel wood	Mollases, Setaria, Gajyo	Contour planting on slopes	Stylo, common vetch, Kudzu, Siratro	Mixed or inter planting with grasses	Tanki, Koilralo, siris, Bakaino, Ipil-ipil	do
	Animal feed & fire wood	Molases, para grass, Centro, Napier Amriso	contour or strip planting, terrace riser planting	Stylo, common vetch, Kudzu, Siratro,	Mixed or inter planting with grasses,	Tanki, Koilralo, siris, Bakaino, Ipil-ipil, Flemengia, Gliciridia	Spacial, boundary, riser planting or contour hedge method and any method on waste lands
Grazing land	Improve quality / quantity & availability of forage.	Molases, para grass, Centro, Dinanath, Rai grass Paspalum, Setaria, Amriso	Broad casting or line sowing	Stylo, common vetch, Kudzu, Siratro, Desmodium, Lucerne	Mixed or inter planting with grasses,	Tanki, Koilralo, siris, Bakaino, Ipil-ipil, Flemengia Gliciridia	Spacial or boundary planting or contour hedge
Forest land	Forage production	Molases, Amriso	Broad casting or line sowing	Stylo, Siratro, Desmodium,	Inter-planting with grasses.	Tanki, Koilralo, siris, Bakaino, Ipil-ipil, Flemengia Gliciridia	Inter planting with other trees

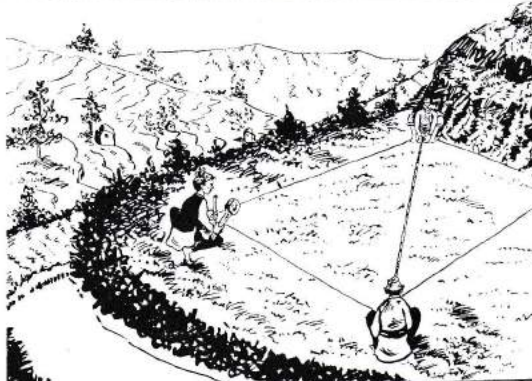
References: - Pokhriyal, T.C.et.al, 1992. Kayastha, B.P., 2002, Singh, Surya B., 2002, NAF, 2058 B.S.

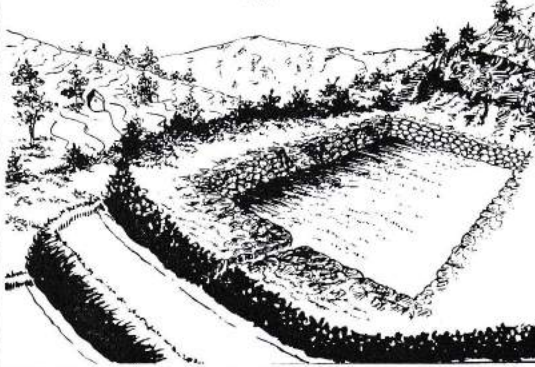
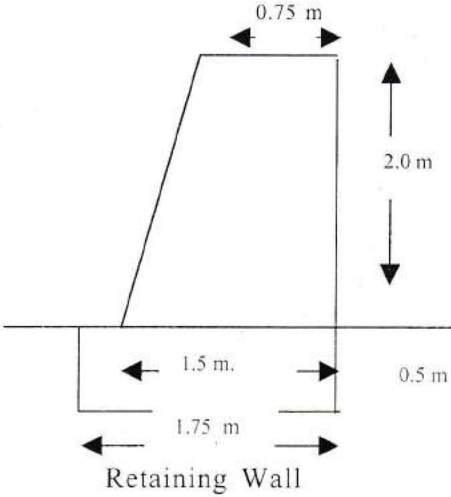
Activity:	Conservation Pond
Definition:	Pond (new or old) used for storage of run-off water during excess rain to reduce erosion and for later use.
Major Problems of Conservation Pond:	• Seepage and evaporation loss • Erosion in the catch area • Sedimentation of the pond
Objectives of Conservation Pond:	• Store excess runoff reducing soil erosion. • Gradually soaks water into ground improving soil moisture. • Use stored water for production (aahale, irrigation, fisheries, entertainment). Conservation pond in the community must aim to store excess surface runoff and its use during other period for production and / or to store runoff from the water source (spring / river / etc.) to manage runoff reducing the torrent.

Sketch/Photo	Scope of Conservation Pond
 Phewa Watershed, Kaski	• Construction of new pond or improvement of old ponds • Landuse improvement (Conservation plantation, degraded land rehabilitation, grass planting) and erosion control measures such as micro-gully plugging (fascine, palisades, wattling, brush layering, brush wood checkdam) in the catch area. • Water harvesting • Construction of conveyance system (inlets and outlets). • Protection of the pond.
	Survey consideration Survey: - Prepare map of about 1:1000 – 5000 scale (If not, at least sketch is mandatory) showing: - - o Appropriate site for conservation ponds. - o Catch area of the conservation ponds - o Different landuse types as per conservation measures required in the catch area - o Erosion problem (such as Micro-gully, rills, slope failure) - o Appropriate alignment for drainage channel: Inlet / Outlet and measure length of channel



Estimate: -
• Different landuse types and assess conservation measures required for each landuse type, • Command area if the pond is for irrigation. • Sediment delivery from the catchment: - ~ 5 - 10 cu. m. /ha./ year from good catchment (with good vegetation and paddy field), ~ 10 - 15 cu. m. / ha./ year from moderate catchment (with grass covers and sloping agriculture land grass covers), and ~ > 40 cu. m. / ha. /year from poor catchment (with gullies and rills) • Average and minimum soil depth at the construction site. This will help in designing the size of the pond and to estimate quantity of cutting and filling.

Survey consideration 	Survey consideration Measurement:- • Measure cross-sections at X and Y directions at every 3 meters interval covering at least 10 meters more on either side of the proposed construction sites. This may be less if the topography is more steep. Assess:- • Recognize the soil type and its availability in the construction site. This will help to estimate the clay material required for the pond construction. • Assess appropriate conservation measures required on either side of the inlet and overflow channels • Assess availability of the construction materials to estimate the cost.
 Lowest Land Area For Conservation Pond to Collect Runoff  Narrow Valley for Embankment Type Conservation Pond	Design consideration General • Conservation pond is operated as a system with three components: the catch area generating runoff, reservoir holding runoff, and the service area using harvested water. • For low maintenance and use of local materials, dugout ponds should be made. No raised pond should be constructed except for drinking water that is also only if the site is not suitable for dugout pond. Site Selection:- ○ For harvesting catchment runoff, locate at lowest land area, so that the largest volume of water can be obtained. ○ For harvesting stream runoff, locate the site so that runoff from the source can conveniently be fed to the pond. ○ For tapping water from spring and water tap, locate immediately below and close to such source. ○ For convenience, conservation ponds are preferable to be located close to the trail for aahale, above the field for irrigation and village for drinking water supply. ○ Do not install a pond less than 50 m upslope from a house. ○ Avoid sites to install pond ▪ where there are evidences of slope movement, subsidence, landsliding or gulying (which may affect if extended) below the area, ▪ where valley side is not stable to hold standing water ▪ at the toe of the slope, where instability of the slope may increase ▪ close to the cliff, where slope failure may occur due to seepage or water pressure Preferable sites for conservation ponds are: - ○ For embankment type of conservation pond, such sites are suitable where valley is narrowing, side slopes are relatively steep and where slope of the valley floor permit large deep basin. Such sites are suitable. ○ For dugout pond site having flat terrain with heavy soil are suitable.
	Calculation of Catch Area: - Estimate runoff flow into the pond/reservoir. ▪ <i>For surface runoff harvesting</i>, as a rule of thumb in Nepal, it is recommended that every 2 cu. m. volume of conservation pond should have at least 1.5 to 2 ropanies (1 Hectare $\approx$ 20 Ropanies) of catchment area during monsoon period and 5 ropanies during other period so as to accommodate 4 consecutive day's rain. It is recommended that pond size be decided based on winter criteria and sufficient safety measures to dispose excess water must be installed. ▪ <i>For spring water or piped source</i>, first measure an average inflow to the pond and calculate the size of the pond to be constructed. ▪ <i>Procedure: -</i> Take a container of known volume and note the time required to fill. If "v" be the volume of container in liters and "t" be the time in seconds required to fill, the inflow "Q" in liters per second is given by v/t.

Survey consideration 	Design Considerations A pond of 1 meter height if it receives water for “H” hours in a day, the area (A) of the pond required to hold water for a day with inflow rate of “$Q=v/t$” liters per second is given by $3.4 * Q * H$ sq. m. Similarly, for the pond height 1.5 m., required pond area to accommodate the water from the source for a day, $A = 2.32 * Q * H$ sq. m. Minimum land width around the pond:- To strengthen the pond walls and reduce side-seepage, there must be minimum of 2 (pond upto 50 sq. m.) to 5 (200 sq. m. pond) meters of land around the pond. Even around the exposed walls, soil should be filled and compacted up to minimum of 2 meters width. Such filling should be rammed sufficiently after every 20 cm of filling.												
	Due to slope constrain, mixed type of pond i.e. partially dugout and partially raised ponds may need to be constructed. For 2-3 meters high pond minimum dimensions of the wall should be considered as follows:- <table border="1"> <tr> <td>Dimension of Retaining Wall: -</td><td></td></tr> <tr> <td>▪ Height = 2 m</td><td>▪ Height = 3 m</td></tr> <tr> <td>▪ Top width = 0.75 m</td><td>▪ Top width = 1.0 m</td></tr> <tr> <td>▪ Base width = 1.5 m</td><td>▪ Base width = 2.3 m</td></tr> <tr> <td>▪ Foundation width = 2 m</td><td>▪ Foundation width = 2.5 m</td></tr> <tr> <td>▪ Depth of foundation = 0.5 m</td><td>▪ Depth of foundation = 0.5 m</td></tr> </table> Construction of retaining walls: - • Use only flat stones that are bigger than 30 cm. Dress all stones (if it is rounded) into rectangular blocks. • Back slant 5 to 10 % (toward ground) of the wall. • Overlay all joints. • Use flatter and longer stones for the top layer. • Cover the top of the wall with soil. • Keep the angle of the stone layering in the foundations (1v:3h). • To allow livestock into the pond stepping for livestock should be provided in the conservation ponds.	Dimension of Retaining Wall: -		▪ Height = 2 m	▪ Height = 3 m	▪ Top width = 0.75 m	▪ Top width = 1.0 m	▪ Base width = 1.5 m	▪ Base width = 2.3 m	▪ Foundation width = 2 m	▪ Foundation width = 2.5 m	▪ Depth of foundation = 0.5 m	▪ Depth of foundation = 0.5 m
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Stepping Wall   Puddling Helps Sealing Seepage Loss	Seepage • Seepage Losses: - o More porous the soil and the cracks in the rock more will be the seepage losses. Studies have shown that seepage losses are enormous in freshly constructed embankment cum-dug out type of ponds amounting upto 10 cm/day. Such ponds tend to stabilize only after about 8 to 10 years. The seepage rates in dug out ponds can increase from 0.28 cm / day to 10.4 cm / day as the water depth varies from 0.5 m to 2 m. - o Seepage losses of 5 cm/day is considered to be permissible for the dugout conservation ponds that have 30-cm thick clay layering at the bottom and sides. • Seepage Sealing: - o Use of Clay ~ To reduce the vertical seepage loss, bottom of the pond should be filled and compacted with minimum of a foot thick of heavy clay. Addition of cow-dung and puddling by the livestock will help the sealing of floor. More the depth of puddling, less will be the seepage loss. Therefore, aahale of buffaloes in such pond is beneficial for reducing the seepage. ~ To reduce the horizontal seepage, 30 cm wide heavy clay should be filled and compacted between the wall and the ground. ~ If there is heavy clay around the construction site, before digging such clay should be put aside so that such clay could be used for seepage sealing later.												

Survey consideration	Design consideration
 Low Density Polythene Sheet Used for Seepage Sealing  Growing Rice Seedling in the Pond Area	○ <i>Seepage Sealing:</i> ○ Use of Soil-Cement ~ Layers of clay-cement (7:1 plaster) uniformly lined coat after coat until a thickness of 3 cm is attained. ~ Soil (Clay)-Cement Plaster are only appropriate where there is no trampling damage by livestock and human beings. ○ Use of Low Density Polythene ~ Lining of 500 to 800 gauge LDPE film buried under 20 cm of soil at the conservation pond will reduce seepage significantly. <i>Preparation for lining</i> ~ Side slope of the ponds should be less than 1:1 (v:h). ~ All protruding stone, roots etc. should be removed. ~ The sides and bottom of the pond should be lined with sieved soil (preferably clay) and cow-dung mix (6:1) to make surface of the pond quite smooth. ~ The surface should be rammed to smoothen the surface. This is necessary otherwise the sheet is liable to be punctured by rough or protruding surface. ~ Neatly lined the LDPE without any folds over the pond. Keep overlapped of about 50 cm at the joint. Fold the overlapped section to reduce the leakage. ~ Overlay 20 cm. thick fine soil (preferably clay) on the LDPE film. ~ To provide good anchorage, additional portion of the film at the top should be embedded by the stones and soil. - Such pond should be protected from the livestock and humans going into the pond, which may puncture the LDPE film.
	Moisture Conservation Ponds ○ Percolation from the conservation pond improves the moisture status of the soil mantle, which results in increased production. This could be a major activity to improve the moisture status in the tar area. Percolation ponds also improve the ground water status. While making ponds for percolation purpose, seepage control measures are not necessary. ○ Distance between the percolation ponds to improve soil moisture should be less than 250 meters. Depression of the Conservation Pond Will Have Better Moisture Condition and Can be Used for Rice Seedling Before the Rainy Season (As Shown in the Picture) or Growing Vegetable during Dry Period.
Maintenance consideration: -	
Removal of Sediment and treatment of catch area: ○ Sedimentation problem is more serious in case of runoff harvesting and canal feeding. To reduce sedimentation, catch area of the pond should be conserved properly. All the rills and gullies, barren lands should be treated using bioengineering measures. ○ Depending upon the sedimentation problem, it is recommended to remove the sediment regularly and use it (if fertile) in the agriculture fields for fertility regeneration or deposit it around the pond to strengthen the embankment or sides. ○ Or sediment trap tank could also be constructed before the pond. Such tank should have sediment flushing mechanism otherwise cleaning of the tank will be burdensome and expensive. ○ If the livestock (buffaloes) is allowed to enter the pond for the bathing and puddling purpose, the steps to the ponds should be regularly maintained. Maintenance of inlet / overflow channels: ○ Leakage in the channel reduces the efficiency of the ponds as well as it may cause erosion hazard. Therefore, lining in the channels must be regularly maintained. Also, sediment deposit in the channels may cause overland flow, which may trigger the gullies. Thus, sediment in the channel must be removed regularly. ○ Protect vegetation on down-slope of the pond. Working Unit ○ Catch area generating runoff, pond holding runoff and utilization of water for production is taken as working unit	

Nursery Techniques and Management

What? : Nursery is a place, where seedlings of plantable size are produced either from seed or other vegetative parts under favorable conditions.

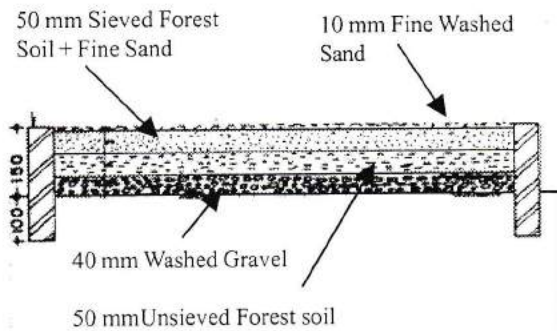
Why: - Experience indicates that quality planting stock and selection of appropriate species are the reasons for successful plantation.

To produce good planting stock, following considerations must be made:

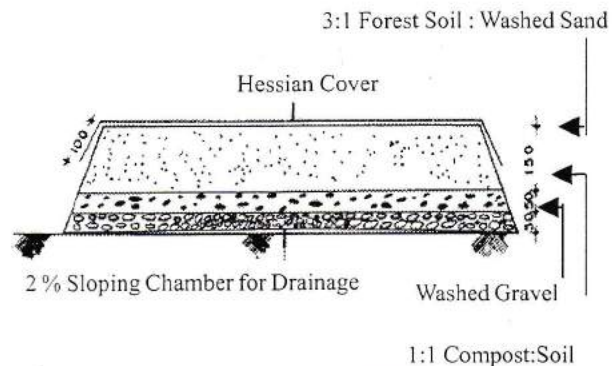
- Selecting suitable species for the site and demanded by the communities fulfilling their basic needs,
- Sowing seed / seedling at correct time and in an appropriate way,
- Selecting quality planting stock (seed, seedlings, cutting, slips, stem, and rhizome).
 - o Quality planting stock can be achieved by: -
 - ~ Paying more attention to the quality of potting mixture
 - ~ Ensuring proper spacing and root pruning
 - ~ Culling the plants before they leave the nursery
 - ~ Hardening of the planting stock

Design consideration: - Fence or wall, internal paths, water tanks and distribution system, seed beds and stand out beds, storage, shelter, working area, compost making area.

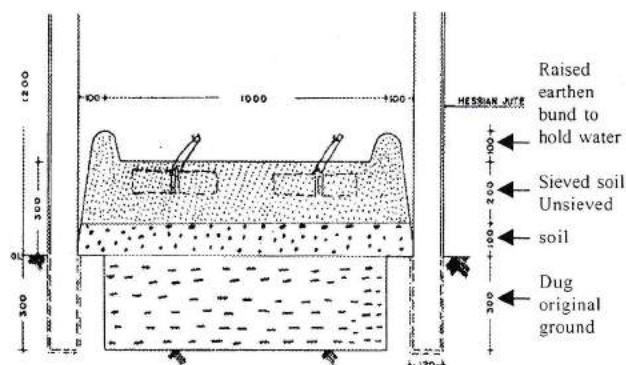
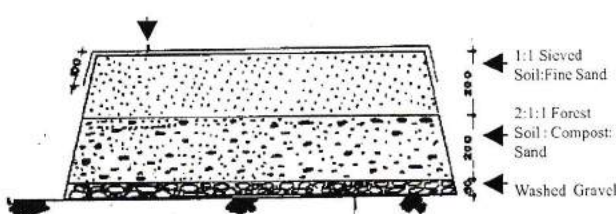
Tree / Shrub Bed



Grass Bed



Bare Root Plant Bed



Major types of propagation techniques of tree and shrub species: Tree and shrubs are generally propagated by using seed, seedling and cuttings.

	Seedlings	Germinated directly in polybags	Hardwood cuttings
When the technique is used?	Germinated in seed bed/ tray	Seeds are large enough. Easily available. Cheaper in cost. Have high germination percentage.	Seed is unavailable, difficult to obtain or difficult to germinate. Seed is costly with high market value, short viability; nursery technique is difficult / unknown. To maintain vigor as the mother plant. To shorten the time for plant to reach maturity. Good sprouting capability.
	Steps: How the technique is used?	Construct 1 m. wide and 2to5 m. long bed in a well drained area without permanent shade from nearby Frame the bed up to at least 15cm above ground by Flat stone, brick, bamboo or wood. Fill bottom 5 cm layer by gravel, stones or broken bricks, cover it with a 2-3 cm forest top soil, and fill to within 2 cm of the top of the frame with 1:1 mixture of sieved sand and forest top soil. Fill the trays with sieved clean sand or a 1:1 mixture of sand and sieved top soil Rake the top layer. Level the surface. Water the bed lightly before seeding. Sow seeds either broadcast or in drills Press seeds slightly and cover 5 mm of soil for larger seeds or with clean fine sand for smaller seed Cover with a mulch	Select 1year old healthy woody branch from a healthy tree. Take branches from the lower crown near to, not from the main stem. Take cutting before buds start to grow (between Jan. and April) Preferably 3 to 4 buds in a cutting. With the use of sharp blade, cut the top of the cutting straight across about 2 cm above the top bud and at an angle just below the bottom bud at the bottom of the cutting. Remove all side branches and leaves to minimize desiccation. Plant the cuttings into nursery beds in the same day to prevent from drying out. If possible dip the bottom of the cutting in rootex to promote root growth and top of the cutting in wax to prevent drying. Never expose the cutting to direct sun. Cover with wet jute mat. Put cuttings either in nursery beds (at a 30cm * 30cm spacing) filled with the mixture of sieved sand and forest top soil or 4** 7" sized polypot. Place the cutting into the soil with the top bud just above the soil surface. Water the polypots or beds immediately. Keep shades until the roots have grown.
Species	Okhar, Oak, Katus, Pangar, Nimaro, Pakhuri, Dudhilo, Lapsi, Lankuri, Utis, Ipil Ipil, Khanyu, Gogan, Bakaino, Bhimal, Painyu, Siltimur, Cryptomeria, Bottlebrush, Eucalyptus	Badahar, Phaledo, Chiuri, Koiralo, Tanki, Ipil Ipil, Pines, Chuleto, Acacias, Siris.	Nimaro, Pakhuri, Dudhilo, Kabro, Phaledo, Koiralo, Asuro, Saruwa, Kandaful, Baish, Simali,
Tools and aterials	Tray, Spade, Knife, Jhari, Loose Pipe, Bamboo, Wooden Stick/ Brick Or Flat Stone, Binding Wire, Sieving Mesh, Straw/ Old Jute Bag/Green Or Dry Litter, Belcha, Forest Soil, Sand, Compost, Seed,	Polypot, Spade, Knife, Jhari, Loose Pipe, Bamboo, Wooden Stick/ Brick Or Flat Stone, Binding Wire, Sieving Mesh, Straw/ Old Jute Bag/Green Or Dry Litter, Belcha, Forest Soil, Sand, Compost, Seed,	Polypot, Spade, Knife, Jhari, Loose Pipe, Bamboo, Wooden Stick, Brick Or Flat Stone, Sieving Mesh, Binding Wire, Straw/ Old Jute Bag/Green Or Dry Litter Belcha, Forest Soil, Sand, Compost, Cuttings, Chemicals For Rootex
Special Consideration	Mycorrhiza mixed soil should be used while producing pine seedlings and rhizobium mixed soil for legumes as they have symbiotic relationship.		

Pricking out seedlings

What? : Taking seedlings out from seedbed or seed tray and to plant them in polypot without any physical damage to the plant.
When? : For most species, the best time of transplant is shortly after germination, when the seedlings have only three or four primary leaves in addition to the cotyledon. Pine seedlings can be pricked out three or four days after germination.
How? : -
o One day before, thoroughly water the polytops into which seedlings will be transplanted.
o Ensure shades are erected and in a good order, and lightly water trays/ beds just before transplant.
o Insert the flat stick beneath seedlings and gently lift, holding seedlings by the leaves or cotyledons.
o Make a hole, 2-3 cm deeper than the root length of the seedling and wide enough to contain the root of the seedling, in the center of the filled pot, with a pointed - wooden stick, little thicker than a pencil.
o Insert the seedling deep enough in the hole carefully without damaging the roots and pull up so that the root collar is just below the soil surface. Ensure roots of the seedling are not bending into a J or U shape, and then press the soil and water lightly.

Types of propagation techniques of grasses			
How the techniques are used?	From seed	From root cuttings	From stem cuttings
- Collect seed with old flower just before seed falls. - Dry flower head in the sun in sheltered place. - Store the seed in a cool place. Seeds can be directly sown in gentle slopes with less possibility to be washed away. - Generally sow 3 handfuls of seed for every sq. m. (If seed is fine mix the seed with fine sieved sand). - For seed bed preparation and sowing in nursery, follow the process as in tree seed bed preparation and sowing - Cover the seed with a thin layer of sieved sand. - Cover by mulch.	- Root cuttings are taken from grasses with rhizomes. - Plant rhizomes with buds, from where new shoots grow up well. - Dig plants, generally in Jan. /Feb. or at the beginning of the monsoon. - Cut back the shoots to about 12 cm. And split the rhizomes into sections, each of which has some good bud scarce. - Plant Cuttings directly into the ground, which are dugout at the beginning of monsoon, or in the nursery bed which are prepared in the dry season.	- Take cuttings in Jan./Feb. from 6-12 months old plants - Each cutting preferably has 3 nodes. - Set cuttings with one node above the ground. - Keep the bed shaded, mulched and watered. - Plant out the cuttings that have rooted at the beginning of the monsoon. - Cuttings can also be planted straight into the ground at the beginning of the monsoon.	- Slips are taken from large mature clumps with some roots and 1 or 2 shoots. - Cut back leaves of the slips, to 10 cm. or less to stop them drying quickly. - Dig up, split and plant them out at the beginning of monsoon. - If they are planted out in the beginning of the monsoon, and growing well after 6-8 weeks, they can be dug up and split again so long as enough of the monsoon is left for them to establish before the dry season.
Species	Phurke, Narkat, Khar, Babio, Sito, Kans, Vetiver	Dubo, Amliso, Vetiver, Dhonde	Narkat, Sito, Nepiar, Amliso
			Phurke, Narkat, Khar, Babio, Sito, Kans, Katara khar, Dhonde

Note : List of appropriate species is given in Annex 2.

Cultural operations: These are the operations carried out to provide all favorable conditions and to fulfill all requirements to prepare planting stock.

	Shading	Spacing	Root Pruning	Watering	Weeding
What?	~ Providing artificial and temporary shade to germinating seeds and immature young seedlings.	~ Placing seedlings apart with sufficient space.	~ Cutting / pruning roots that have grown outside polypots and inside ground.	~ Supplying water to a plant in a desired quantity and in an appropriate way.	~ Removal of unwanted plants/seedlings from a tray, bed or polypot.
Why?	~ To protect them from hot sun, heavy rain, hard frost and hail	~ To minimize competition for nutrient, moisture and sun light to allow them grow well.	~ To protect seedling from physical damage while lifting out from the bed. ~ To allow smaller roots to grow well. ~ To slow down unwanted growth of seedling.	~ To fulfill moisture requirement of a plant ~ To protect a plant from any physical damage.	~ To prevent from the competition for moisture, nutrient and sunlight in favor of desired plant.
When?	~ Regularly for germinating seeds and recently transplanted seedlings. ~ As per need for all seedlings to protect from heavy rain, frost, hail and too much sun.	~ Depends on the species, the time of year, polypot size. ~ Generally, when the leaves of some seedlings are growing over smaller ones next to them, and when the start of competition is noticed.	~ Check some larger seedlings on bed. ~ When they are difficult to lift out, may be the notice of time for root pruning. ~ Check pulling out some seedlings.	~ Only a little water for 2 or more times a day to the soil in seed trays, seed beds or in polypots with recently pricked out seedlings. ~ For larger seedlings, once in a day.	~ Regularly when weed starts to germinate and grow.
How?	~ Water proof shade for seedbed and seed trays. ~ 30 cm above the ground for recently pricked out seedlings and 75 cm. above for fodder plants. ~ Bamboo, wood or straight stick can be used for frame. ~ Straw, khar, bamboo mat, old jute bag can be used as shading material.	~ Sort seedlings first, put large seedlings one side and smaller to another. ~ Place seedlings in a single rows separated by a line of the empty polypots, or a line of stones, wooden slots or bamboo.	~ Pull out seedlings ~ Prune outgrown roots.	~ For seed trays, seedbeds, and recently pricked out seedlings, use fine spray. ~ For larger seedlings, water without any physical damage. ~ While watering in beds, soil should moist upto 15-20 cm depth.	~ Water the beds or pots before then - pull the weeds out with the roots.

Type of Nursery Based on Management Responsibility

	Office nursery	Community nursery	Private nursery
What	Office managed nursery and permanent in nature.	Nursery managed by community e.g. CDG.	Nursery managed by an individual.
Why (Characteristics)	~ To fulfill the seedling demand of communities / farmers from different parts of the district. ~ To produce seedlings of those species, which need specialized technique and close supervision. ~ To use the permanent nursery structure made before. ~ To fulfill the requirement of seedlings for its own program. ~ To demonstrate the nursery techniques.	~ To become a community independent and sustainable in necessary seedlings and technology as well. ~ To promote greenery by timely planning and producing appropriate species and required no. of seedlings. ~ To minimize the cost of seedling production. ~ To minimize the plantation cost by reducing the distance for transportation. ~ To promote community's ownership and thus making plantation successful.	~ To provide opportunity for income generation for the involved farmers, by selling the seedlings. ~ To become an individual independent for necessary seedlings and technology as well. ~ To minimize the plantation cost by reducing the distance for transportation. ~ To promote ownership.
Limitation	~ Generally, plantation cost will be high due to high transportation cost from distant place. ~ With limited budget, local demand will not be fulfilled, either in terms of no. or species. ~ Involvement of the local community will be low, therefore transfer of technology to the communities will be low and community's dependency on the office remains forever. ~ People may not take care after plants and plantation, as the plants are generally provided free of cost.	~ Seedling quality may not be achieved in the lack of technical input and regular supervision. ~ Roles and responsibility among the community members may not be defined well, thus supervision may be low. ~ Community may not be able to produce seedlings that demand specialized technique.	~ Farmers may not be ready for initial investment. ~ Farmers may produce only those seedlings, which can be easily produced. ~ Farmers may not be able to produce seedlings that demand specialized techniques.

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Promotion of Low cost Soil Conservation and Watershed Management

1. Introduction

Technology means nothing unless replicated by the intended target beneficiaries. Extension is defined as the process by which targeted beneficiaries replicate the technologies for their own and or community's benefits. Therefore, extension includes awareness building and creation of environment for replication by the beneficiaries. Farmers have faced a land management issue of one kind or the other. They have therefore sought ideas and possibilities to solve the issue and have developed and applied the idea in the way most suitable for them, given the prevailing conditions and resources available. Main objective of promoting LCSCWM is to bring change in farmers' or community members' behavior (towards SCWM) by persuading them to adopt LCSCWM. The challenges to meet the objectives are to identify those successful low cost conservation practices and to extend them in similar areas, or to teach people to learn from each other, or to persuade people to adopt them.

2. Strategies for the promotion of LCSCWM

Strategies to promote the LCSCWM are categorized into two. One is regarding the staff and second is regarding the farmers.

2.1. Strategies regarding the staff

Good results need quality service and inputs. For the quality service, extensionist / service provider needs competencies in the following areas:

- **LCSCWM technologies of economic and practical importance.** Extension worker should be able to provide useful information relevant to local situation. S/he should have thorough knowledge on LCSCWM so that they can give information on relative advantages in many dimensions. Such as rationale, cost, sustainability, multiple uses, simplicity of the technology etc. These are the perceived characters of LCSCWM so these characteristics should be the basis for the extension. People will adopt LCSCWM quickly if these characters are perceived as beneficial to them. If community members perceive that LCSCWM are simple to understand and use, they will adopt. The early adopters are more interested to test new technology by doing on small-scale trial. Extension worker should facilitate early adopters to try LCSCWM in small scale. Conservation activities of preventive nature are less understood (less observed) by community members and focus on curative measures, therefore extension worker should be able to link LCSCWM with other benefits to satisfy community's expectations.

- **Logical thinking on cause and effect relationship.**

It is said that "If anything can possibly go wrong, it will go wrong, of unintended result". Therefore extension worker should create environment to think and analyze the situation and act in appropriate sequence (facilitate how to think, not what to think). Attention should be paid in the process, which will ultimately bring the desired results. Extension worker should be able to facilitate community members to identify the real situation and their felt needs. They should be able to empower communities through stepwise processes and be able to facilitate them to organize in groups to solve common problems. This professionalism often depends on the personal skills of the individual extensionists.

- **Confidence in LCSCWM**

Extension worker should have confidence in LCSCWM that can bring about change in soil conservation and watershed management. Confidence can be built through training and practice.

- **Willingness and professional skill**

Extension worker should have willingness to work for the communities. They should have practical (professional) skill to execute LCSCWM and demonstrate in the field and then interpret the result. They should be able to provide various technological options as a solution to the issue. For this they should be able to analyze the issue from different perspectives for which they should update their professionalism (through learning from training / by doing / from farmers). Able to collect stories of successful activities and use them as the source of new information for further dissemination.

- **Effective Communication**

Effective communication is one of the essential elements to bring change in behavior of the communities. The success depends on the skill of extension worker to use relevant extension message in right time and communicated through appropriate channel. They should also know learning behavior of adult people. Note that conservation extension has been considered as a compulsory training to all the field staff.

- **Follow up and Feed back**

Extension worker should keep in touch with communities and get feed back from them for future improvement.

2.2. Strategies regarding the farmers/communities

Adoption Process

Five stages of adoption process have been widely recognized. These are: - i. Awareness, ii. Interest and motivation, iii. Evaluation, iv. Trial and v. Adoption.

Adoption is not an instantaneous act, rather it is a process that occurs over a period of time and consists of a series of actions.

Awareness Stage: The individual learns of the existence of the new idea but lacks information about it. At this stage an individual is aware of the idea, but lacks detailed information about it.

Interest Stage: The individual develops interest and is motivated in the innovation and seeks additional information about it. At this stage the individual develops interest in idea and tries to acquire more information about it. The person wants to know what it is, how it works and what its potentialities are.

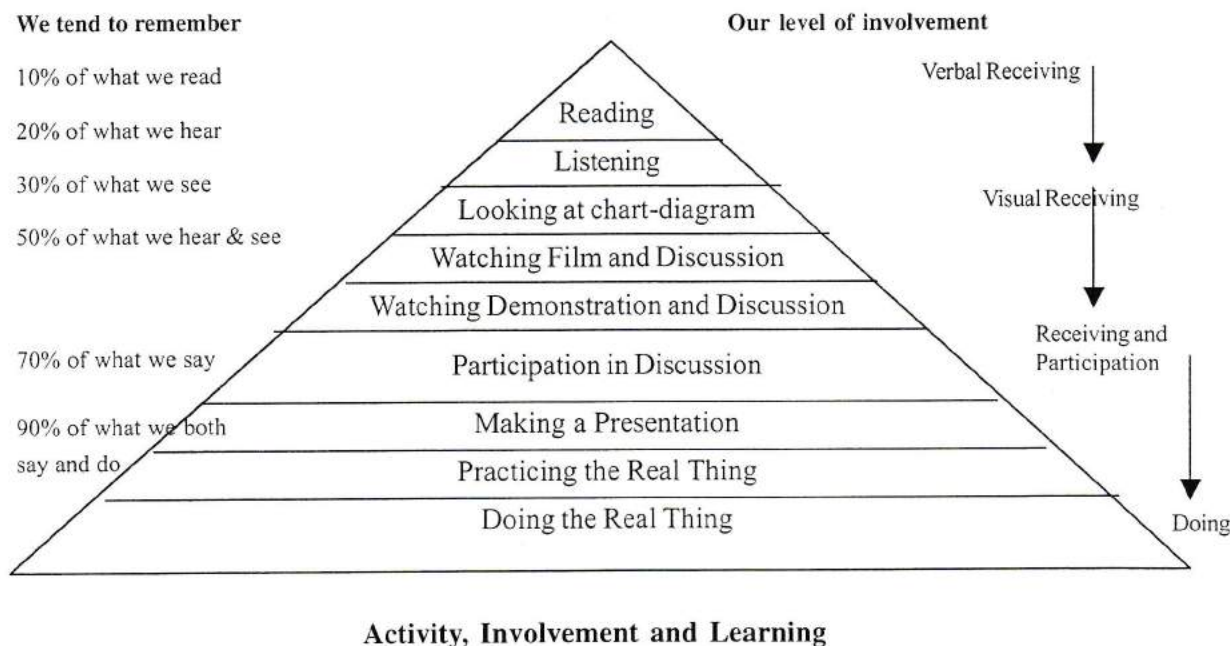
Evaluation Stage: The individual makes mental application of the new idea to the present and anticipated future situations and decides whether or not to try it. At this stage the individual judges the worth of the innovation. The person makes assessment whether the idea is applicable to own situation, and if applied what would be the result.

Trial Stage: The individual actually applies the new idea on a small scale in order to determine its utility in own situation. These are generally small-scale trials to test the effectiveness of the innovation in one's own situation. Apparently individual needs to test a new idea even though they have thought about it for a long time and gathered information concerning it.

Adoption Stage: Trial may be considered as the practical evaluation of an innovation. Being satisfied with the trial and considering the pros and cons of the situation, the individual takes a final decision and applies the innovation in a scale appropriate to own situation on a continued basis.

Effective Approach

Different extension activities have different effectiveness based on the level of people's ability to remember and the level of their participation. The following chart indicates the activity, level of their involvement and their learning level. Between the two extremes of "reading" and "doing the real thing" are a number of other ways through which people learn. As one moves downward from the pinnacle of the cone, increased involvement, and learning occur. Strategy should be based on this result.



Strategies

Based on the adoption stage and effective approaches of the extension, following strategies are adopted: -

- **Idea Catalogue:** Many good indigenous ideas and techniques exist in the area. As a facilitator, s/he must be aware of such things in the locality and also in the surroundings. For which thorough visit and understanding of the area must be made. Idea catalogue collected from different parts of the country could be an asset to promote the facilitation.
- **Awareness Building:** Raising the level of awareness and knowledge on LCSCWM (level of consciousness). Awareness is the first stage of adoption.

Following are some activities to create awareness: -

- Poster / flipchart development on LCSCWM techniques: Showing the advantage, limitation and construction steps.
- Film show
- Conservation day: Emphasize the need of the LCSCWM
- School conservation education: Communicate the need, roles of the LCSCWM techniques.
- Literacy: Communicate the need, roles of the LCSCWM techniques.
- **Stimulate Interest:** Stimulate interest among community members by providing relevant technologies in right time. Give one idea at a time and describe about the importance of the idea. Encourage farmers to seek

solutions to emerging issues in their immediate surroundings, i.e. enhance their analytical skills, enhance dialogue and idea sharing among farmers (contact farmer, farmer to farmer extension, etc.), enable them to identify and seek various sources for ideas and solutions. Following are some major strategies: -

➤ **Interaction** is one major activity to stimulate the interest between individual farmer and community. In the interaction technicians and motivators must accompany the group and facilitate to promote the learning environment. Following are some of the major activities: -

~ **House to house visits:** Field staff go on house-to-house visits. Farmers strongly favor mutual discussion. Mutual discussion can give more information, can increase trust and help farmers to clarify feeling, and can integrate farmer's needs in the implementation. The extension can make a very direct attempt to influence the farmers by suggesting improvement on what the farmers have been saying or doing, using their own standards as a reference point.

~ **Group Interaction:** Discussing in small groups is useful in raising awareness of farmers. Disciplined group discussion will help them to be more aware of the problem and their feeling. Group discussion can help farmers to specify their problems clearly and in more detail. Farmers may conclude that they should change their norms and do it. This can help participants to develop consensus on opinion about a specific issue or for action. Following could be appropriate floors for group discussion.

- o Group networking,
- o Monthly meeting,
- o Planning,
- o School conservation education,
- o Literacy class.

Successful stories and cases, comparative information on advantages and disadvantages, cost benefits of the different interventions could be some of the good tools for discussion.

➤ **Visits and Interaction:** "*Seeing is believing*". Therefore, stimulating interest through visits to the sites, where activities have been implemented. Where farmers can see and interact to build understanding and consensus among themselves. Following are some activities: -

- o Visit to activities carried out by individual farmer and community inside the sub-watershed,
- o Visit to activities carried out by individual farmer and community outside the watershed within the district, and
- o Visit to activities carried out by individual farmer and community outside the district.

• **Motivate for Action:** Motivate community members by stirring their desires towards action. People have desire for economy and for new experience. Therefore use this philosophy for motivation. Convince them by strong persuading to practice LCSCWM in real life. Once the farmers or community or students (in case of school conservation education) develop desires, persuade them to practice LCSCWM in real life. Following are appropriate floors for persuasion: -

➤ **Planning:** During the community's plan preparation, field staff must provide a number of alternative solutions to the issue and should explain the pros and cons of the alternatives. Persuade them to select and implement the selected activities through the LCSCWM techniques at individual and community levels.

➤ **School Conservation Education/Literacy Programme:** Students, if they express the desire to implement LCSCWM techniques around the school, should be persuaded to implement activity at demonstration scale. The same could be done with the literacy groups.

- **Demonstration:** It is the effective way of extension of the successful practices. People get the opportunity to observe the techniques and their benefits directly. Demonstration can be made as individual technique or several techniques as an integrated package. Demonstration can be made on the working process (method) and their results. Following are the suitable areas where the demonstration can be done: -
 - On School complex: In School through students after School Conservation Education Programs
 - On leader farmers' land through leader farmers
 - On Community land through community group
- **Rewards:** Rewarding the individual farmer, school or community implementing LCSCWM and doing best in the implementation of the LCSCWM technique could be very effective means of motivation. Reward not only provides the incentive but also recognizes the efforts made by them.
- **Adaptation (Technical Backstopping):** When people are convinced, they plan and implement LCSCWM. During the implementation, they need help and encouragement. At this stage, extension worker should provide in-situ timely technical backstopping. Field staff must be very sensitive and pro-active to provide service.
- **Replication:** After implementation, people observe the pros and cons, effectiveness and benefits, etc. and conclude and make final decision, whether to replicate or reject. Extension worker should help analyze the result in proper way.

Conclusion

People learn because of compulsion, desire, interest, needs etc. Therefore, Extension worker should be able to know the level of consciousness of the beneficiaries (Farmers / Community members) in the learning process so as to carry out appropriate extension method to enhance decision-making process.

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Annex 1. List of Species Used in the Text

Local Name	Botanical Name	Botanical Name	Local Name
Amala	Emblia officinalis	Acacia arabica	Babul
Amliso	Thysanolaena maxima	Acacia catechu	Khair
Arare	Acacia pennata	Acacia pennata	Arare
Assuro	Adhatoda vasica	Adhatoda vasica	Assuro
Babiyo	Eulaliopsis binata	Agave Americana	Ketuki
Babul	Acacia arabica	Albizia lebbek	Kalo siris
Badaam (ground nut)	Arachis glaberrata	Albizia procera	Siris
Badahar	Artocarpus lakoocha	Alnus nepalensis	Utis
Bains	Salix tetrasperma	<i>Alnus nepalensis</i>	<i>Utis</i>
Bakaino	Melia azedarach	Arachis glaberrata	Badaam (ground nut)
Bayer	Zizyphus mauritiana	Artocarpus lakoocha	Badahar
Bedulo	Zizyphus jujube	Arundinaria intermedia	Nigalo
Bhatwasi	<i>Flemingia macrophylla</i>	Arundo donax	Narkat
Bhimal	Grewia oppositifolia	Arundinella nepalensis	Phurke
Bhimal	Grewia optiva	Bambusa balcooa (Dhanu)	Dhanu bans
Bhuletro	Butea minor	Bambusa nutans / cupulata	Mal bans
Bihaya / Saruwa	Ipomoea fistulosa	Bassia butyracea	Chyuri
Casuarina	Casuarina	Bauhinia purpurea	Tanki
Centipede grass	Centipede grass	Bauhinia variegata	Koiralo
Champ	Michelia champaca	Brassaiopsis hainla	Chuletro
Chilaune	Schima wallichii	Butea minor	Bhuletro
Chuletro	Brassaiopsis hainla	Cajanus cajan	Rahar
Chyuri	Bassia butyracea	Casuarina	Casuarina
Dabdabe	Garuga pinnata	Centipede grass	Centipede grass
<i>Desmodium</i>	<i>Desmodium rensonii</i>	Chamaecrista rotundifolia	
Dhaincha	Sesbania grandiflora	Choerospondias axillaris	Lapsi
Dhanu bans	Bambusa balcooa (Dhanu)	Colquhounia coccinea	Namdi phul
Dhonde	Neyraudia reynaudiana	Cymbopogon microtheca	Khar
Dubo	Cynodon dactylon	Cynodon dactylon	Dubo
Dudhilo	Ficus nemoralis	D. Hookeri (kalo)	Kalo
Faledo / Phaledo	Erythrina arborescens	Dalbergia sissoo	Sissoo
Ghangharu	Pyracantha crenulata	Dendrocalamus hamiltonii	Tama bans
Gideri	Premna spp.	Desmanthus virgatus	
<i>Gliricidia</i>	<i>Gliricidia sepium</i>	<i>Desmodium rensonii</i>	<i>Desmodium</i>
Gogan	Saurauia napaulensis	<i>Dismanthus</i>	
Golainchi	Plumeria acuminata	Drepanostachyum intermedium	Tite nigalo bans
Ipil ipil	Leucaena leucocephala	Duranta repens	Nilkada
<i>Ipil-Ipil</i>	<i>Leucaena leucocephala</i>	Emblia officinalis	Amala
Kabro	Ficus lacor	Erythrina arborescens	Faledo / Phaledo
Kalo	D. Hookeri (kalo)	Eulaliopsis binata	Babiyo
Kalo siris	Albizia lebbek	Euphorbia royleana	Siuli
Kanda phul	Lantana camara	Ficus glaberrima	Pakhuri
Kans	Saccharum spontaneum	Ficus lacor	Kabro

Local Name	Botanical Name	Botanical Name	Local Name
Katara khar	Themeda species	Ficus nemoralis	Dudhilo
Ketuki	Agave Americana	Ficus religiosa	Pipal
Khair	Acacia catechu	Ficus roxburghii	Nimaro
Khanyu	Ficus semicordata	Ficus semicordata	Khanyu
Khar	Cymbopogon microtheca	<i>Flemingia macrophylla</i>	Bhatwasi
Khirro	Sepium insegne	Fraxinus floribunda	Lankuri
Khus	Vetiveria lawsoni	Garuga pinnata	Dabdabe
Kimbu	Morus alba	<i>Gliricidia sepium</i>	Gliricidia
Koiralo	Bauhinia veriegata	Grewia oppositifolia	Bhimal
Kutmiro	Litsea monopetala	Grewia optiva	Bhimal
Lahare papal	Populus deltoids	Himalayacalamus hookerianus	Padang bans
Laliguras	Rhododendron arboreum	Ipomoea fistulosa	Bihaya / Saruwa
Lankuri	Fraxinus floribunda	Ipomoea fistulosa	Saruwa/Bihaya
Lapsi	Choerospondias axillaris	Jatropha curcas	Sajiwan
Mal bans	Bambusa nutans / cupulata	Lantana camara	Kanda phul
Namdi phul	Colquhounia coccinea	Leucaena leucocephala	Ipil ipil
Napier	Pennisatum purpureum	<i>Leucaena leucocephala</i>	<i>Ipil-Ipil</i>
Narkat	Arundo clonax	Litsea monopetala	Kutmiro
Nigalo	Arundinaria intermedia	Melia azedarach	Bakaino
Nilkada	Duranta repens	Michelia champaca	Champ
Nimaro	Ficus roxburghii	Morus alba	Kimbu
Padang bans	Himalayacalamus hookerianus	Neyraudia arundinacea	Sito
Painyu	Prunus cerasoides	Neyraudia reynaudiana	Dhonde
Pakhuri	Ficus glaberrima	Paspalum	Paspalum
Paspalum	Paspalum	Pennisatum purpureum	Napier
Phurke	Arundella nepalensis	Pinus roxburghii	Sallo
Pipal	Ficus religiosa	Plumeria acuminata	Golainchi
Rahar	Cajanus cajan	Populus deltoids	Lahare papal
Sajiwan	Jatropha curcas	Premna spp.	Gideri
Sallo	Pinus roxburghii	Prunus cerasoides	Painyu
Saruwa/Bihaya	Ipomoea fistulosa	Pyracantha crenulata	Ghangharu
<i>Sesbania</i>	<i>Sesbania</i>	Rhododendron arboreum	Laliguras
Simali	Vitex negundo	Saccharum spontaneum	Kans
Siris	Albizia procera	Salix tetrasperma	Bains
Sisso	Dalbergia sissoo	Saurauia napaulensis	Gogan
Sito	Neyraudia arundinacea	Schima wallichii	Chilaune
Siuli	Euphorbia royleana	Sepium insegne	Khirro
Stylo-184	Stylo-184	<i>Sesbania</i>	<i>Sesbania</i>
Tama bans	Dendrocalamus hamiltonii	Sesbania grandiflora	Dhaincha
Tanki	Bauhinia purpurea	Stylo-184	Stylo-184
Tite nigalo bans	Drepanostachyum intermedium	<i>Tephrosia candida</i>	Tephrosia
Uti	Alnus nepalensis	Themeda species	Katara khar
<i>Uti</i>	<i>Alnus nepalensis</i>	Thysanolaena maxima	Amliso

Annex 2. List of Appropriate Species for Soil Conservation

Shrubs

Name	Character	Sites	Propagation Techniques	Cultivation and Maintenance	Uses
<i>Adhatoda vasica</i> (Asuro)	Shrub up to 3m forms a dense bush.	Up to 1000m. Shade tolerant best grows in damp, shady sites, also survives in dry and stony areas.	Stems cutting planted at any angle. Planted in dormant stage in moist and damp sites and just before monsoon in dry areas.	Regular weeding should be done. Protect from grazing. Thinning when it gets dense. It coppices or pollards heavily.	Technique: Brush layering, palisade, live check dams, fascines, compost making, hedgerows, etc. Activity: On farm conservation, natural hazard prevention, development infrastructure protection works. Other: Medicines, Green manure.
<i>Ipomoea fistulosa</i> (Saruwa/Bihaya)	Low-lying shrub with straggling stems up to 3 m long. Stems with few branches and clumps of leaves at the end. Mature clumps are extremely dense and impenetrable to animals.	Upto 1500 m. Invasive weed growing abundantly in wet, marshy depressions. Grows well when planted on hot, dry sites but only if the soil is loose. Good for fill material but may fail completely after a promising first season on cut slopes.	Grows very easily and rapidly from stem cuttings. Since there is such ready supply of material in the Terai, there is little point in collecting seed.	Depending on the site, Saruwa needs little maintenance. Grows vigorously and so does not require weeding. Protection from grazing when young. After the first growing season it is resistant to grazing. Thinning when get dense. Saruwa can be lopped heavily. It will die out completely if it is shaded.	Technique: Brush layering, fascines, palisades, live check dams, live fence. Activity: Gully / Landslide treatment, Stream bank protection, Road slope stabilization, Retaining Walls, etc. Other: Poor fuel wood, etc.
<i>Lantana camara</i> (Kanda phool)	Bushy shrub up to 2m high and forms a dense thickets.	Upto 1750m. Grows on dry, stony, and degraded sites.	Propagated from stem cuttings (10 to 30mm thick and 30 cm long usually more successful than normal cuttings). Although it seeds prolifically, the seeds are difficult to germinate under nursery conditions.	Slow to establish. Weeding may be required. Resistant to grazing and if used properly can make a thick hedge. It has no under storey and gully can start underneath even dense stands of bushes. Careful thinning and coppicing reduces erosion to some extent.	Technique: Brush layering, fascines, palisades, live check dams, etc. Activity: Gully / Landslide treatment, Roadside / Channel-side slope stabilization, Retaining walls, etc. Other: Poor ornamental, firewood, hedging, etc.
<i>Salix tetrasperma</i> (Bainsh)	Fodder tree high up to 15m	Better upto 2700m. Better grows in damp / north facing sites (along stream channels). Not used in dry areas below 2000m	Hard stem cuttings. Planted in dormant stage in moist and damp sites and just before monsoon in dry areas.	Weeding should be done. Protect from grazing. Thinning when it gets dense. It coppices or pollards heavily.	Technique: Brush layering, fascines, palisades, wattling, live check dams, agro-forestry etc. Activity: Gully, Landslide, Road / Channel-side slope stabilization, Stream bank cutting, on farm conservation, etc Other Uses: Fodder, Small timber
<i>Vitex negundo</i> (Simali)	Small tree up to 6m	Better upto 1750m, naturally occurs along the rivers and gullies. Preferable on moist, shady places, but grows on dry, stony sites and hot dry slope when planted.	Stems cuttings (10 and 50 mm in diameter) and 30cm - 1.2m long give excellent results. Planted in dormant stage in moist and damp sites and just before monsoon in dry areas.	Regular weeding should be done. Thinning when it gets dense. It coppices and pollards well.	Technique: Brush layering, palisade, live check dams, fascines, compost making, hedgerows, etc Activity: Gully, Landslide, Roadside / Channel-side slope stabilization, Stream bank cutting, etc. Other: Firewood, live fences, etc.
<i>Agave Americana</i> (Kettuki)	Large cactus with/out thorns. Fibrous, succulent leaves max. height of 1.5m.	Upto 2000m grows on dry, hot and south facing slopes. Not found in damp and shady sites.	Seeds are rare. Separating a section of rootstocks or a sucker can grow it. No need to grow in the nursery unless for large/strong plants.	No maintenance required once established. Resistant to grazing.	Technique: Hedging, brush layering, palisade, etc. Activity: Slope stabilization, Gully treatment Others: Live fence, rope making

Grasses: -

Name	Character	Sites	Propagation Techniques	Cultivation and Maintenance	Uses
Arundella nepalensis (Phurke)	Medium sized clumping grass, smaller in stature. Grows to a height of only about 1.5 m. The culm is hollow and only has branches from the nodes on material of two or more years in age. Clumps do not exceed 0.5m in diameter.	700 to 2000m, grows naturally on relatively damp south-west to north facing slopes. It is tough and colonises landslides, therefore growing in harsh, stony sites. It probably does not do well on hot sites in the full sun.	Easily propagated by splitting clumps into slip cuttings or by seeds. Seeds are collected between Mangsir and Magh. Direct seedings can also be done.	Depending on the sites, it also may need weeding and protection from grazing. It should normally be cut in Magh or Falgun.	Technique: Grass plantation, Strip planting, Palisade Activity: Integration with various natural hazard prevention activities Other: Thatch, fodder.
Arundo clonax (Narkat)	Large tall clumping and forest grass. The stem is hollow and similar in appearance to bamboo but less woody. Leaves are a pea green colour, thick, pointed and about 15 mm wide.	Upto 1500m. Grows on hot south-west facing slopes. In the Terai, it grows in Sal forest. It thrives most vigorously in wet and waterlogged sites.	Easily propagated from seeds, slip and stem cuttings. For stem cuttings, material more than two years old branches should be used. Seeds are collected between Mangsir to Magh.	Depending on the sites, it may require weeding and protection from grazing. It should normally be cut in Magh or Falgun.	Technique: Fascine, palisades, grass planting Activity: Degraded land rehabilitation, Gully / Landslide treatment Other: fodder
Cymbopogon microtheca (Khar)	Medium to large clumping tall grass (50cm diameter). Leaves are thin (<5 mm), pointed, have a channel running along them, and are rough to the touch. The plant turns brownish red as the seeds ripen.	Upto 2000m. Tough forest grass. It is often cultivated on marginal land by farmers. Grows well on hot, dry, south facing slopes. Although not really indigenous to the very driest sites, it grows well on many harsh, dry sites.	Easily propagated through splitting clumps into slip cuttings or by seeds. Seeds are collected between Mangsir and Magh. Direct seedings can also be done.	Depending on the sites, it may require weeding and protection from grazing. It should normally be cut in Magh or Falgun.	Technique: Grass planting Activity: Degraded land rehabilitation, Gully/Landslide Treatment Other: Thatch, Fodder
Cynon daetylon (Dubo)	Low short creeping grass, forming a continuous cover rather than producing clumps. Forms a tough lawn (sward). Leaves about 50 to 75 mm in length. Rarely stands more than 100 mm in height, or 50 mm if grazed	Upto 1800m. Good growth on fertile sites. Secondary coloniser and appears in moist areas that are regularly grazed. Dubo tolerates fairly intense grazing.	Most easily propagated by either root or stolon node cuttings. Seeds are very difficult to collect.	Requires little attention once it is established. Requires weeding in the first growing season. It does not need to be cut. Protection from grazing is not required.	Technique: Turfing Activity: In slopes, Retaining walls, Earthen Dams, Irrigation channels, Cut and natural slopes of gullies and landslides, Embankment of river training structures, etc. Other: Grass, lawn
Drepanostachyum intermedium (Tite Nigalo Bans)	Large spreading grass; Most resilient small-stature bamboo. Leaf sheaths are hairy and culm sheaths narrow from about half way up. A spreading, rather than clumping bamboo.	1000 m to 2500m. Common throughout the middle mountains. Found on relatively hot, dry, and exposed banks, and in rocky sites in its range. But it is not as resistant to drought as the larger bamboos and grows best in damp, shady sites.	Easily propagated either by the traditional bamboo propagation method i.e. vegetative propagation by clump division (off cut stumps) or by nodal cuttings. Seeding is very rare.	Depending on the sites, it may require weeding and protection from grazing. Bamboos should not be cut completely like other grasses, but partial cuttings can be done in Magh or Falgun.	Technique: Palisade, Grass planting Activity: Degraded land rehabilitation, Gully / Landslide treatment Other: Weaving, Fodder
Eulaliopsis binata (Babio)	Medium-sized clumping grass, having very strong fibers. Very thin and coarse leaves. Grows up to 750 mm tall. Droop, hanging down slopes as if laid on purpose as a kind of thatch.	Upto 1500m. Found in Terai, Churia and lower river valley. Grows well on very harsh, hot, dry sites and on steep slopes, even on very stony sites.	Propagated from slips (splitting of clumps). Can also be propagated from seeds. Seeds are collected between Poush and Falgun (January to February).	Weeding should be done regularly. Protect from grazing. It should normally be cut in Magh or Falgun for rope making. It also can be used as grass for livestock and can be cut once or twice in rainy season	Technique: Grass plantation, Agro-forestry Activity: On-farm conservation (Terrace edges), Degraded lands, Drainage edges, Gully / Landslide Treatment, Retaining Walls, etc. Other: Ropes, paper, fodder, etc.

Grass Continued.

Name	Character	Sites	Propagation Techniques	Cultivation and Maintenance	Uses
Himalayacalamus hookerianus (Padang Bans)	Large clumping grass and a small stature bamboo with blue culms and distinctive culm sheaths which narrow from the base upwards. It tends to form clumps rather than spreading like the other small bamboos.	1500 to 2500m. Prefers cool, damp sites with some shades and moisture. It is not as drought resistant as the large bamboos.	Easily propagated either by the traditional bamboo propagation method i.e. vegetative propagation by clump division (off cut stumps) or by nodal cuttings.	Depending on the sites, it may require weeding and protection from grazing. Bamboos should not be cut completely like other grasses, but partial cuttings can be done in Magh or Falgun.	Technique: Palisade, Fascines, grass planting Activity: Degraded land rehabilitation, Gully / Landslide treatment, Stream bank protection Other: Weaving, Fodder
Neyraudia arundinacea (Sito)	Large-stature clumping forest grass. Occurs under wetter climatic condition. Young shoots are poisonous to animals but are grazed when there is no other grass.	Upto 1500m common in the damper parts of Nepal. In areas of higher rainfall, grows in harsh sites, including south facing slopes. It grows in dry sites if planted.	Propagates readily from slips cuttings, culm cuttings or seeds. Seeds are collected between Mangsir to Magh. The seeds can be used for direct seedlings.	Depending on the sites, it also may need weeding and protection from grazing. It should normally be cut in Magh or Falgun.	Technique: Grass plantation Activity: Integration with other in various natural hazard prevention activities Other: Poor thatch, poor fodder.
Neyraudia reynaudiana (Dhonde)	Large clumping grass. Thin leaves but grows to about 400 mm in length. The stem is hollow like a bamboo and single small branch from every node. Forms clumps of at least 750mm in diameter and puts up rhizomatous shoots similar to those of bamboos.	Upto 1500m. Common in many dry forest types, particularly in eastern Nepal. Grows in dry south facing rain shadow areas where its natural sites are very harsh. Tolerates dry sites.	Easy to propagate from slip cuttings or from seeds. It can also be propagated from culm cuttings. Seeds are collected between Mangsir to Magh (December to January).	Depending on sites, it may need weeding and protection from grazing. It should normally be cut in Magh or Falgun.	Technique: Grass plantation, hedgerows, etc. Activity: In integration with other in various natural hazard prevention activities Other: Fodder, poor thatch
Pennisetum purpureum (Neptiar)	Exotic grass species, large and semi-clumping.	Found up to 2000m in all aspects. Needs more than 600 mm rain annually. We can plant it in any type of soil and even in eroded areas.	Easily be propagated through stems cuttings. Cuttings should be prepared from 5/6 month's mature stem. Prepared with a sharp weapon keeping 3 to 5 nodes per stem. Cutting can be stored for about 20 days if not be left to get dry.	~ If no fear of erosion, dig 8 x 10 cm pit and plant the cuttings horizontally, then cover with soil and press with foot. ~ If susceptible to erosion, make a hole at an angle of 8 to 10°, insert cutting and press. ~ 2-nodes of cutting inside and one just above the ground. 2/3 of the cutting inside the ground.	Technique: Grass plantation, Bio-terracing, Agro-forestry, Check dams, etc. Activity: On-farm conservation (Terrace Raiser), Degraded lands, Drainage edges, Gully / Landslide Treatment, in slopes, Retaining Walls, etc.) Other: Fodder, etc.
Saccharum spontaneum (Kans)	Large clumping and spreading grass. The appearance is similar to an enormous spider crawling across the ground.	Upto 2000m. Most widespread large indigenous grass. Occurs naturally on coarse alluvial soils, including very gravelly and stony areas beside rivers. Kans withstands water logging, inundation, and severe drought. Withstands grazing, but will not thrive if the shoots are eaten repeatedly. When planted, it survives well on very hot, dry and harsh sites. It is probably the toughest of the low altitude grasses, with a deep rooting system and widely spreading stolons.	Propagated most easily by slip cuttings. Easiest grasses to grow by cuttings. It can be grown from stolons, if they are available. It grows from seeds but not well. Seeds are collected between Kartik and Poush (November to December).	It may need weeding. Protect from grazing depending on sites. It should not normally be cut in Magh or Falgun.	Technique: Brush layering, Grass plantation, Bio terracing, Waterways, etc. Activity: Degraded land rehabilitation, Stream bank protection, Other: Poor fodder, poor thatch.

Grass Continued.

Name	Character	Sites	Propagation Techniques	Cultivation and Maintenance	Uses
Thysanolaena maxima (Amliso)	Shrub to 2m high. Has broad culm ~ 10mm in diameter. No branches from stem. The clumps can be a metre or more in diameter. Massive rooting system similar to a small bamboo.	Upto 2000m, common in the cooler and damper sites. Grows well on reasonably dry, stony sites, and in some hot but relatively humid areas. However it is not as tough as many other grasses.	Easy to propagate from rhizome cuttings, though success is much greater in hot locations. Better results from Rhizome planted with stem having two to three nodes. Success with Single node culm cuttings if carried out with care. Better on contour in slopes. Spacing: 50 to 60 cm, in line and 1 - 1.5m between lines above 85% in slope. 2m. and above in slope less than 85%. Seeds are very small and seem to be difficult to germinate in Nurseries. Seeds collection between Falgun and Baisakh (March to April). The best season to plant is rainy season.	Weeding should be done regularly. Protected from grazing. Normally be cut in Magh and Falgun. Cut regularly if grown on the terrace raisers. Dead ones should be replaced at once.	Technique: Grass plantation, Bio-terracing, Agro-forestry, Check dams etc. Activity: On-farm conservation (Terrace edges), Degraded lands, Drainage edges, Gully / Landslide Treatment, Retaining Walls, etc. Other Uses: Brooms, fodder, etc
Vetiveria lawsoni (Khus/Sinki)	A medium- large stature clumping grass with clumps up to 0.5 to 1.5 m long and forming a dense clump up to a maximum of 0.5 m in diameter. The roots are many and spongy in mass, with a dominant downward direction.	Upto 1500m. Grows naturally along rivers in areas prone to seasonal waterlogging. Grows well in dry sites on fill materials but does not grow so well on hard cut slopes.	Easy to propagate by root splitting. Can also be grown from seeds. Seeds are collected between Aswin and Mangsir (September to November).	Weeding should be done regularly. Protect from grazing.	Technique: Grass plantation, Bio-terracing, Agro-forestry, etc. Activity: On-farm conservation (Terrace Raiser, Degraded lands, Drainage edges, Gully / Landslide Treatment, In slopes, Retaining Walls, etc. Other: Fodder, poor thatch, etc.
Themeda species (Katara Khar)	A large tall clumping forest grass. The stem is thick usually up to 10 mm in diameter. The grey distinct from the smaller Khar.	Upto 2000m. Widely grows in many forest types in its range. Grows on dry, south facing slopes in wetter areas, but also tolerant to much drier sites.	It can be propagated from slip cuttings. It also grows from seeds. Seeds are collected between Aswin to Mangsir.	May require weeding and protection from grazing. Should normally be cut in Magh or Falgun.	Technique: Grass planting Activity: Degraded land rehabilitation, Gully/ Landslide Treatment Other: Thatch, Fodder

Trees

Name	Character	Sites	Propagation Techniques	Cultivation and Maintenance	Uses
<i>Alnus nepalensis</i> (Utris)	Large broad-leaved tree having nitrogen-fixing bacteria in root nodules.	Wide range from 900-2700m. Coloniser of gullies/landslides. Grows better on damp, shady and permeable site. Tolerates poorest and stoniest materials. Avoids waterlogged areas.	Direct seeding if the area is large and immediate establishment of vegetation is not so important. Preferably with polypot seedlings raised in a nursery. Seeds collection from Mangsir to Falgun (November to March). Viable for 18 months.	Weeding for first 2-3 years. Protect from grazing until it gets out of the reach of animals. Thinning when it gets dense. Branches can be pruned. It shouldn't be coppiced or pollarded except in very good growing sites. It is pioneer species so better to introduce other important species within 5 years to omit the unwanted succession.	Technique: Hedgerows, conservation plantation, agro-forestry etc. Activity: Gully, Landslide, Roadside /Channel-side slope stabilization, etc. Other: Fuelwood, timber, fodder, nurse plant for cardamom, etc.
<i>Leucena leucocephala</i> (Ipilipil)	A small nitrogen fixing tree or shrub, which is heavily lopped. Normally evergreen but will shed leaves in a drought. The fruit is in dry pod.	Upto 1300m. Requires inoculation with the nitrogen fixing bacteria, rhizobium. Grows best in full sun. It does not grow well in acid soil.	Propagated from polypot seedling. Seeds are collected by hand in January to February, when the pods turn brown. Should be dried thoroughly, viable for many years. The seeds should be immersed 2-3 minutes in 15 times its volume of boiled water (do not boil the seeds), followed by 24 hours cold water. Seeds are sowed in 2nd week of May in Terai and last 2 weeks of April in elsewhere. Nursery soil can be prepared at the ratio of 2:1:1 of soil, sand and compost respectively. But the soil must be composed of the inoculated soil from beneath Ipil ipil. Seeds can be sown directly in Polypots @ 2 seeds per pot. Germination starts in 3-4 days. Takes 8-12 weeks to get 20 to 30 cm higher which is the best planting size.	Seedlings can easily be killed by frost. It grows 2 to 4 m / year. Grows beyond browsing in 6 months in low altitudes. Produces 8-10 tonnes/ha in plantation. Can be lopped at 30 days intervals in monsoon and 45 days at other times. Has a distinct winter low growth rate.	Technique: Agro-forestry, Composting, Nurse tree in Alley cropping, Strip planting, Hedgerows, etc. Activity: On-farm conservation (Terrace Raiser), Degraded lands, Drainage edges, etc. Other: Fodder, Food, Fuelwood, Timber, Soil improver, etc.
<i>Ficus semicordata</i> (Khanyu)	Small stature fodder having heavy branching. 3 Types of species available in Nepal: Rai Khanu (Ficus montana), Khosre Khanyu (Ficus semicordata), Dudhe Khanyu.	Upto 2000m. Natural coloniser of bare and often very rocky sites. Often the first tree species to appear on disturbed ground. Can withstand considerable drought, but also grows well in damp sites. Like most colonisers, full light is required, and it cannot tolerate shade. Versatile trees for bio-engineering.	Propagation is normally done by polypot seedlings. Collected between Shrawan to Aswin. Viability is only for about 6 months. It can also be propagated by cuttings.	Weeding should be done in the first growing season. Protect from grazing until it gets out of the reach of animals. Thinning should be carried out when the plantation gets too dense. Khosre Khanyu can be lopped heavily and once the tree is established. It coppices or pollards heavily.	Technique: Conservation Plantation, Agro-forestry Activity: Other: Fodder
<i>Melia azedarach</i> Bakaino	Medium to large deciduous tree, with smooth straight trunk and branches. Branches are relatively few, thin, straight, and brittle. The leaves are similar to Neem (pointed with serrated edges) and come in composite groups.	Upto 1800m. Fast growing tree in many warm sites. Although it grows best in good soil, it survives well on shallow, stony, infertile and very dry soils. It does much better on fill material rather than on cut slopes.	Best propagated by Polypots seedlings. There are 1200 seeds / kg. Seed collected between Mangsir to Falgun. Viable for about 12 months. The seeds can directly be sown or broadcasted in the planting sites.	Weeding should be done in the first growing season. Protect from grazing until it gets out of the reach of animals. Thinning should be carried out when the plantation gets too dense. Can be lopped heavily, and once the tree is established. It coppices or pollards heavily.	Technique: Conservation Plantation, Agro-forestry Activity: Land Productivity Conservation Other: Timber, firewood

Name	Character	Sites	Propagation Techniques	Cultivation and Maintenance	Uses
Choerospondias axillaris (Lapsi)	Slow growing tree species especially in higher altitude, moderate to large, up to 20 m tall. The fruits are fleshy drupe, yellowish when ripe. Seed is a single stone containing up to 5 seeds.	950 to 1900m	Seedlings. Seeds are collected in October-January. After removing flesh from seeds, they are sown in late February in trays or beds, spaced at 5 cm * 5 cm and protected against rodents by mesh wire. One stone contains up to 5 seeds. Usually, germination starts 3-4 weeks after sowing and may continue for two or more months. Transplantation is carried out about two weeks after germination, when the seedlings are 4-5 cm tall. Root pruning will be necessary by April or May and should be repeated every 3-4 weeks. Below 1500 meter, stock suitable for planting, 20-30 cm tall can be produced in about five months; above this altitude 11 months will be needed.		Technique: Conservation plantation Activity: Fruit tree plantation Other: A very popular fruit tree. Fruit is eaten fresh or unripe made into a variety of chutney and sweetmeats. Inferior firewood, soft and light timber, etc.

References: - DOR, 1999. Kayastha, Baban P., 2002. Jackson, J.K., 1994.

Fodder Trees

Name	Character	Sites	Propagation Techniques	Cultivation and Maintenance	Other Uses
Artocarpus lakoocha (Badahar)	A medium sized occasionally large deciduous tree with a milky sap.	Found generally upto 1300 m, and occasionally to 1600 m in isolated well protected spots. In its wild state it often grows along the banks of streams. Young trees will withstand moderate shade but older trees grow best in full light. It grows best on deep permeable sites, and does not thrive on poorer sites.	Mainly propagated by seed. Short viability. Seeds should be sown within a week after its collection (preferably within 1-2 days) after removing all flesh. They can be planted after 11 months of stocking in nursery but the good quality can be obtained if they are kept for 2 years in nursery. Stumps and root cuttings from one year old seedlings are reported successful. Plantation is done at the onset of monsoon, or in June/July. Can be sown in raised seed bed (1 kg / sq. m.), transplanting 3-4 weeks later or directly in poly pot of size 4*7". Seeds are collected and sown in June/July.	Weeding, Protection from grazing.	Fruit
Bassia butyracea (Chiuri)	It is a tree species always of big size.	It grows well up to 1400 m. altitude.	Propagated by seeds. Seeds are collected in Jun/ July. After extraction seeds are washed with water, then dried in shade. Seeds should be planted within 1 week of collection. Seedlings after two years, it attains height about 30 cm and planted at the onset of monsoon. Seeds within 1 week of collection are washed with water then dried in shade. Seeds are sown in poly pot. While sowing care is taken that micropyle should be up and the seeds are laid horizontally and about 1 cm deep in the soil. Shading is not necessary.		Fruits. Fat extracted from seed is used in making soap. Cake from seeds is edible and sweet.
Bauhinia variegata (Koiralo)	It is a big tree. It is a light demanding species. The seedlings are frost tender, but older plants can withstand heavy frost, though they are defoliated. It coppices well. Young seedlings are susceptible to damage by browsing. It is vulnerable to fire.	It grows well up to 1900 m. It is reputed to grow on dry rather infertile sites, but growth is better on porous, well-drained sites. It will not withstand water logging.	Stocking seedlings for about 13- 14 months, seedlings of about 15-30 cm height can be planted in the plantation site in the monsoon. It also can be propagated by branch cutting and stumping. Seeds are collected during March to June. Soaking the seed for 24 hours, changing the water 3-4 times may help reduce fungal attack. Sow 2 seeds in each pot (preferably, 4*7" size) by laying them flat and covering with about 5 mm of soil in May June. Cover with mulch. It is sensitive to deep sowing, which reduces germination and causes distortion of the shoot. Germination starts after 5-10 days then remove mulch.	Regular weeding, protection from grazing and fire.	The buds and flowers are used for pickle.
Bauhinia Purpuria (Tanki)	It is a small tree. It is moderately light demanding. Frost tolerant. It does not have rhizobial nodules on the root, though it falls under Leguminosae family.	Found upto 1600 m. A common constituent of Shorea robusta and Schima castanopsis forest. Is tolerable to poor dry sites, but on such sites its growth is often slow.	Seeds of this species are collected in February to May. All techniques of propagation are as Koiralo.	As in koiralo	The buds and flowers are used for pickle. Wood is used in making agricultural tools. Bark is used as tanning agent.

Fodder Trees Continued.

Name	Character	Sites	Propagation Techniques	Cultivation and Maintenance	Other Uses
<i>Erythrina arborescens</i> (Phaledo)	Tree with rough ridged bark, stem and leafstalk with re-curved prickles, leaves with three leaflets. Leaves with brown velvety hairs when young, becoming hairless as they grow older.	Grows naturally well from 1000-1600 m elevation, preferably on sandy loam soils with an east south-east aspect.	Propagated easily by hardwood cuttings. Collect cuttings in Jan/Feb. They can be taken from mature trees or from a few stools kept in the nursery, which are coppiced every year. Propagated also from cuttings grown in the nursery. For raising seedlings direct sowing in polythene pots, with two seeds per pot, is recommended. At about 1500 m about four months in nursery will be needed; at lower altitudes this period can be reduced. Cuttings about 15 cm long, thickness of a pencil, with 3-5 buds are set in beds or 4"x7" polypots. Shade is required for 2-3 months after setting, until roots are well formed. The plants should then be spaced and root pruned.	Regular weeding and protection from grazing and fire.	Live fences post, as an ornamental plant.
<i>Fraxinus floribunda</i> (Lankuri)	It is a large tree with gray bark. Leaves opposite, pinnate, with 7 to 9 leaflets. The seedlings need full light, but older trees will withstand shade to some extent.	It grows well between 1200-2000 m often in Schima - Castanopsis forest, and also sometimes as an understory to <i>Pinus roxburghii</i> . Its growth is best on deep moist soils. It is said to be one of the species, which survives best on difficult sites. In Nepal it is frequently found on non-calcareous soils.	Sown immediately if winged fruit are collected when it is still green. If left until it has turned brown, the seed enters a dormant stage and will not germinate until the spring after it has passed through a complete monsoon season. Seeds are collected when they are brown and have a viability of three years. Whereas, green seed loses its viability. Green seeds should be kept moist and sown in polypot or raised seed bed, as soon as possible after collection in Sept-Oct. Seeds germinate within 2-4 weeks and before development of first primary leaves, transplant them in polypots. Plants will be ready with 20-30 cm height after 10-12 months.	Weeding, Protection from grazing.	
<i>Ficus roxburghii</i> (Nimaro)	Medium size tree; new branches are hollow. It is light demanding and frost sensitive.	It grows well up to 2000 m altitude.	It can be propagated from seeds and sometimes by hardwood cuttings. Seeds can be stored for 2 years in dry state. After fungicide treatment seeds can be sown on the seedbed either in line or broadcast, or 5-10 seeds in polypots. It takes 10-30 days for the germination of seeds and 2.5-4.0 cm tall seedlings can be transplanted in polypots. Seedlings can be planted after 12-14 months in nursery, immediately after the onset of monsoon. 30-45 cm long cuttings set in a bed containing 40% compost and 60% forest soil, mulched with litters and under partial shade will have good result.	Grows slowly, thus thorough tending (use of fertilizer, weeding) is necessary. Protect from grazing until it attains the considerable height.	
<i>Ficus nemoralis</i> (Dudhilo)	Small deciduous tree. It is comparatively more frost tolerant than other figs and it tolerates high pH.	It grows well between the altitude of 900 and 2200 m. Found growing with pH 6.8 at the topsoil, and 8-8.2 in the subsoil.	As in <i>Ficus glaberrima</i> .	As in <i>Ficus glaberrima</i> .	

Fodder Trees Continued.

Name	Character	Sites	Propagation Techniques	Cultivation and Maintenance	Uses
Ficus glaberrima (Pakhuri)	A tall tree.	It occurs mainly between 600 to 1500 m, but is not found growing naturally in eastern Nepal.	Propagated both by seed and hardwood cutting. Seeds are soaked in water for 12 hours then dried in the sun. As the seeds are tiny particles, sand is mixed in 1:1 proportion and sown in the same day of treatment on raised bed. 3 to 5 cm tall seedlings are transplanted in polybags. After stocking for a year in nursery, they can attain 20-25 cm height and can be planted in plantation site in June/July or at the onset of monsoon. Cuttings of 1 cm thick and 20 to 30 cm long are made during March/ April and transplanted into polybags. Shade is applied. They can be ready to plant in July of the same year.	Regular weeding, protection from grazing, fire.	
Ficus lacor (Kabro)	It is a small deciduous or nearly deciduous tree. It has some tolerance to frost, but the seedlings are very susceptible to damage by browsing and fire.	It is found in all regions of Nepal, up to about 1600 m. It grows on a variety of soils; however good growth is only obtained in moderately deep soil with an adequate moisture supply.	Commonly propagated by cuttings. Hard wood cuttings 1 - 2.5 cm thick, and 25 to 30 cm long, taken in February and rooted in polybags can be planted after 4-5 months on the nursery. Large cuttings (2m) are the traditional method of propagation used by farmers; air layering is also possible. Stumps can also be used successfully. Propagation from seed is also carried out but the germination percentage is very low. Seedlings of 20 to 25 cm tall can be planted in plantation site. The process of seedling production is same as in other Ficus species but the time of sowing seed is August.	As in Ficus glaberrima.	Fuel wood, making "pickle".
Garugo pinnata (Dabdbe)	A large deciduous tree. It is a strong light demanding species, sensitive to frost, but very resistant to fire.	It occurs up to about 1300 m. It is found naturally near streams, and grows in the Siwalik.	Propagated from large cuttings, 2 m long and up to 10 cm diameter, root cuttings and seedlings grown in the nursery. Seed is collected between June and September. Dried seed can be stored for about at least one year. After hot water treatment, seeds are sown in nursery bed and seedlings are pricked out into polybags as they appear. This will provide plantable seedlings by the onset of the monsoon.	Regular weeding, protection from grazing	Living fence pole
Grewia optiva (Bhimil)	It is a moderate sized deciduous, light demanding species. The tree is susceptible to fire and seedlings are to browse. It shows some tolerance to frost.	Naturally grows upto 1700 m, exceptionally 2200 m. The seedlings and saplings may survive for some years on dry hill slopes, but growth is very slow; for good growth an adequate water supply is necessary.	Propagation with stumps has been successful. Hardwood cuttings set in Jan/Feb are reported to root. Seedlings after 11 months in nursery they will grow 25 to 35 cm tall and can be planted. Seed sowing in April in bed 15 cm apart. In July 15 months after sowing the plant should be 1.5-2m tall. Select those with root collar diameters of 5-20 mm and cut their shoots back to 5-7 cm, and many fine roots to prepare cuttings. Seeds are collected in Nov.-Jan. Viability is about a year. Germination is difficult. Drying in the sun for a week before sowing may help. Sow the seed in raised bed after removing the flesh, 500 gm /sq. m. When they have 2-3 primary leaves, transplant them in 4" x 7" sized polybag.		Edible fruit, Firewood, to make tool handles. Inner bark for rope making.
Litsea monopetala (Kutmiro)	Evergreen tree.	It is found in most parts of the country, from Terai to 1450 m.	Mostly propagated by seeds. Partially green seeds are collected in late May or early August. Seeds are sown in raised seedbed or polybags within a week of collection. Germinate after two weeks. 1-14 months old seedlings can be planted, when they get 20-35 cm height.	Regular weeding, protection from grazing and fire.	Fuelwood

References: Jackson, J. K.: 1994, Napier, Ian and Marcus Robbins, 1989.

Fruit Plant Species

Name	<i>Zizyphus spp. (Bayar)</i>	<i>Musa spp. (Banana)</i>	<i>Ananas comusus L. (Pineapple)</i>
Plant Character	- Medium tall (8-10m), hardy plant and can grow in adverse soil and climate - Leaves fall during May-June	- Bush with pseudo stem (2-6 m plant height) - Surface feeder.	Perennial rosette type herb, short life.
Climate and soil	- Grows well in hot and dry climate. - It can tolerate up to 5 degree Celsius	Hot, humid and windless climate, well drained soils with 2000-2500mm rain	Tropical to sub-tropical
Propagation	- Direct seeding - Root cutting - Budding (Baishkh-Jesth)	- Suckers - Seedlings produced through tissue culture	- Sucker - Crown - Slip
Plantation	- Seed treatment with Sulfuric Acid or breaking or rubbing seed coat - Pit Size 75cm*75cm*75cm - Manure: @ 30-40 kg FYM, 2 kg bone meal and 5kg ash / plant - Spacing: 4-6 m * 4-6 m - Planting time: Jesth- Ashadh	- Pit size 50cm *50cm *50cm - Manure: @ 10-15 FYM / pit - Spacing: 2-3m* 2-3 m for tall and 2*2m for dwarf. - Planting time: When monsoon starts.	- Curing the slips in shade for 5-6 days before planting. - Single row: 60cm * 75cm - Double row: 30cm * 60cm - Between paired rows: 75cm-90 cm. - Time: In the beginning of rainy season 5:3:5 gm NPK/ plant (During planting)
Care and Maintenance	- Compost @ 40 kg and 500:200:200gm NPK/plant / year in Jesth for fruiting plant - Needs weeding, earthing up and round basin - Remove sprouts coming from below ground - Allow 4-5 branches to grow from 60 cm above the ground and give final shape to the plant. - Annual pruning during dormancy (May-June)	- Compost @ 25 kg and 200:110:250 gram NPK / plant/year. - Irrigation when dry, grass cutting and earthing up. - When the plant is 6 month, let 1st sucker grow and during flowering, let second sucker grow. - Remove mother plant after harvesting	- Compost @ 2500 kg and 180:80:160 kg NPK /ha/y (2 split – Chaitra and Ashadh) - Mulching with rice husk (10-15 cm) - Irrigation in dry season 5 ml ethylene+ 1 Liter water+200g urea solution @ 50 ml /plant in Nov to induce flowering
Harvesting Time and Yield	- Starts fruiting from 3-4 years of plantation - Harvesting in Falgun-Chaitra. - Yield: 9-12 ton /ha (75-100 kg / plant)	- Ready to harvest first crop after 18 months. - Yield = 75-100 fingers (local) / 150 fingers (improved) 15-20 ton /ha	- When fruit color changes - Yield 20-25 ton /ha in Chitwan
Conservation	- Permanent cover to reduce erosion - Use in Agro forestry - Small timber, fuel wood, leaf litter	- Permanent cover to reduce erosion - Use in Agro forestry, nurse crop, catch crop - Nurse crop for fruit saplings, Moisture conservation.	- Permanent cover to reduce erosion - Used as hedge row on slopes - Agro-forestry
Other Uses	- Consumption (fresh and dry fruit) - Cash income	- Consumption - Cash income	- Consumption - Cash income
Activity	Fruit Plantation	Fruit Plantation	Fruit Plantation
Varieties	- Banarasi: Mid season, oblong fruit - Gola: Round fruit, good quality, perishable. - Umran, Najuk, Chochal	Local Malbhog, Jhapali malbhog, Willium hybrid, Hrichhal and Robusta.	- Queen: Dwarf, medium yield, early - Kew: Large fruit, cunning, less crown - Local:

Fruit Plant Species Continued.

Name	<i>Mangifera indica</i> (Mango)	<i>Litchi chinensis</i> (Litchi)	<i>Psidium guajava</i> (Guava)
Plant Character	Evergreen, deep tape root system, long life.	Evergreen plant with 9-10 m height, round canopy, surface feeder.	Evergreen plant with 7-8 m height, hardy and easy to grow.
Climate and soil Requirement	- Four month rain and clean weather rest of the year with 1500-1800 mm rain and up to 600 m altitude. - Deep well drained soils with pH range 5.5-7 - Can tolerate various climate but frost free.	- Sub-tropical fruit that can be grown up to 1000m and cannot tolerate frost. - Deep loamy, well drained and slightly acidic soils with sufficient OM	- Can be grown from Terai to 1500 m having 1000-2000mm rain and tolerates dry but not frost. - Any soil with pH range 4.5-8.2
Propagation Methods	- Anarching - Vineer grafting	Air layering (Guti layering)	- Air layering - Anarching, budding and Seedling
Plantation	- Pit size 75cm *75cm*75 cm - Spacing 8-10 m on flat and 8 * 11 m on slopes 5-6 m8 5-6 m For Amrapali. - Plantation with the onset of monsoon (evening time) - Manure 30-40 kg FYM + 2 kg bone meal + 5 kg ash	- Pit size 75cm * 75cm *75 cm - Spacing: 10m*10m in general, in dry areas 8m*8m. - Plantation with the onset of monsoon (evening time) on slopes in triangular system. - Manure 30-40 kg FYM + 2 kg bone meal + 5 kg ash	- Pit size 75cm * 75cm *75 cm - Spacing 6-7 m * 6-7 m. - Plantation with the on set of monsoon (evening time) - Manure 30-40 kg FYM + 2 kg bone meal + 5 kg ash
Care and Maintenance	- Irrigate to young plant and during fruiting period. - Compost: @ 50 kg FYM and 730:180:680 gram NPK /plant / year (in Phalgun). Fruiting plant - Remove dead and criss-cross branches. - Intercultural operations and weeding as per need - Grow legume inter-crops. - Establish windbreak on windward sites. - In mango crop, plough during Kartik-Paush and Baishakh- Jeshth to produce fruits regularly.	- Frequent irrigation up to first 3 years and for fruit bearing plants, January to mid April. - Compost @ 50 kg FYM and 600:200:600 gram NPK /plant / year (in Paus-Magh) during fruiting stage.	- Compost @ 40 kg 7 300:150:300 gram NPK / plant for fruiting plant (in April). - Remove all branches up to the height of 45cm in 2nd year and allow 3-4 branches to grow. - Remove vertical branches and give open center shape to the plant. - Stop irrigation in Guava from Magh to get winter crop
Harvesting time and yield	- Harvesting time varies depending upon climate. (Jeshth- Bhadra) 10-12 year tree can produce 500-600 fruits / year and 20 year old tree 1200-1500 fruits (8-10 ton / ha).	- Grafted plants start fruiting from 3-4 years. - Harvesting: Jeshth- Shrawan. 9-10 year plant bears 55-65 kg fruits or 7-8 ton /ha	- Starts bearing from 3-4 years - Harvesting time: Shrawan - Kartik - Yield: 7-12 ton /ha (grafted bear more fruits)
Conservation	- Permanent cover to reduce erosion - Use in Agro-forestry - Timber / fuel wood / leaf litters	- Inter cropping with Banana and Pineapple - Timber / fuel wood / leaf litters	- Inter cropping with Banana and Pineapple - Timber / fuel wood / leaf litters
Other Uses	- Consumption: Fresh fruits, pickles - Cash income	- Consumption as fresh fruit - Cash income	- Consumption as fresh fruit / Jelly / Jam - Cash income
Activity	Fruit tree plantation	Fruit tree plantation	Fruit tree plantation
Varieties	- Amrapali and Mallika -Regular bearing - Daseri: Good quality and main season - Neelam and Chausa : Late varieties.	- Rose scented, Sahi: Mid season, - Seedless late: Late season, very sweet - Mazaterpur: Early season, good yield - Deharadun: Mid season, high yield, sweet	- Ilahabad Safeda: White pulp good yield - Lucknow-49: Dwarf plant, large fruit. High yielding. - Local

Fruit Plant Species Continued.

Name	<i>Carica papaya L. (Papaya)</i>	<i>Citrus reticulata (orange)/C. sinensis (sweet orange)/C. limon (Lime)</i>	<i>Prunus persica (Peach)</i>
Plant Character	Plant has 2.5 to 3 m height, straight stem, no branching, mono-sexual and short life plant.	Medium sized perennial tree. It has two types of roots, surface feeder shallow roots and deep roots.	Small to medium sized deciduous plant
Climate and soil Requirement	- Area with sufficient sunlight and irrigation facility is needed but low temperature and windy climate is not good for its growth. - Well-drained loamy soils with pH 6-7 are suitable.	- Sub-tropical, an altitude range of 750 - 1050m from sea level. Slope with North-East aspect is suitable. - Well-drained sandy loam deep soils with pH range 5.5-6.5 and stone free.	- Peach requires wet and humid climate with cold winter - Well-drained light sandy loam and sandy loam soils are suitable for growing peach.
Propagation Methods	- Seedlings are raised from seed (40-50 days). - Cuttings raised in nursery bed	- Seed - Shoot tip grafting: Sweet orange and orange	- Seed - Budding or Grafting (April- Sept)
Plantation	- Pit size: 50cm*50cm*50 cm - Spacing: 2m * 2m . - Manure: 15-20 kg / pit. - Transplant 15-20 cm tall seedlings in Baishakh-Jesth and give water. - Plant three seedlings per hill to avoid the chances of male plants	- Pit size: 1m*1m*1 m - Spacing: 5-6m Orange, 6-7m Junar and 4-5 m Kagati. - Manure: 30-40 kg / pit. - Planting: In the beginning of rainy season.	- Pit size: 75cm*75cm*75cm - Plantation during dormancy (winter) - Spacing: 5-6m * 5-6 m
Care and Maintenance	- Though it's drought-resistant, irrigation is required during dry season. Be aware that water should not touch the color (to prevent disease). - Compost @ 10-15 kg / plant after 6 months and 20-25 kg compost + 250:250:500 gram NPK / plant after one year. - Timely weeding, mulching, earthing up and drainage are needed. - Papaya fruit is not economical from 4th year onwards.	- Light pruning during winter to remove dead, diseased branches and water sprouts. - Compost @ 50 kg FYM + 500:250:500 gram NPK / plant for orange and Junar, @ 50kg and 400:200:33grams of NPK for Kagati in winter. - Weeding, irrigation, mulching and drainage as per need.	- Training and pruning is needed. These activities are carried out when the plant is in its dormant stage. - Compost @ 25 kg and 330:350:90 gram NPK /plant / yr for the fruiting plant.
Harvesting time and yield	6-month-old plant starts flowering and it takes another 6 months for ripening. Harvesting crop in winter and spring season in Terai. - Yield: 3 year plant produces 80-100 fruits weighing 0.5 to 2 kg Or 15-20 ton / ha	Yield: - Orange=9-12 tons / ha - Sweet orange= 10-14 tons / ha - Lime = 7-8 tons / ha.	- Fruit ripening between May and October depending upon varieties. (Jesth-Shrawan) - Yield: 6-7 tons / ha
Conservation	Agro forestry and cash crop	- Permanent cover to reduce erosion - Fuel wood and small timber	- Permanent cover to reduce erosion - Fuel wood and small timber
Other Uses	- Consumption: Fresh fruit, Jam /Jelly /candy - Cash Income: Fruit and extracted Papain.	- Consumption: Fresh fruit, dessert, juice, - Cash income: Selling fruits, juice, pickles.	- Consumption: Fresh fruit, dessert, juice, - Cash income: Selling fruits, Jam, Jelly.
Activity	Fruit plantation	Fruit plantation	Fruit plantation
Varieties	- Washington: Dwarf, large fruit, scented, oval - Honey Dew: Bi-sexual, medium height, high yield - Ranchi dwarf	- Sweet orange: Mosami, Dhankute Junar, Jafa, Orange: Dhankute suntala, Dancy, local - Mexican, Banarasi, Local Sun Kagati	- Orine, Spring time, - Cardinal= Baishakh-Jesth - Red heaven, Texas= Mid season - Alberta, Peri green = Srawan-Bhadra

Some Fruit Plant Species

Name	<i>Pyrus communis</i> (Pear)	<i>Juglans regia</i> (Walnut)	<i>Punica granatum</i> (Pomegranate)
Plant Character	This is an important temperate fruit. The indigenous species known as Mayal is found growing wild in Nepal. This species is used as rootstock for propagation.	Indigenous varieties are large size trees with hard-shelled fruit. Imported varieties (Dante okhar) have thin shelled fruits.	It is a medium size hardy plant. In low temperature areas it is deciduous but in tropical and sub-tropical its evergreen or partially deciduous.
Climate and soil Requirement	- Pear favors warm temperate climate - Pear thrives well in deep sandy loam soils and can survive in wet conditions compared to other fruit plants.	- Warm to cool temperature climate with sufficient rain or moist sites and above 1300 m. - Deep well drained, moist alluvium soils preferably near stream	- Can be grown in the plains as well as in hills up to 1850 m. Grows best in semi-arid climate with cool winter and hot summer. - The best soil is deep loamy alluvial for good yield but can thrive well in diverse soils.
Propagation Methods	- Grafting on Mayal is the most common method - Tongue grafting	- Whip Grafting or Patch Budding on local species - Seedlings raised from seed - Direct seed sowing	- Direct seeding (Low quality) - Hard wood cutting - Air layering
Plantation	- Pit size: 1m*1m*1 m - Spacing: 6-8m * 6-8m - Manures: 40 kg compost, 80:150 gram PK and 1 kg Lime / pit - Plantation is carried out during the dormant period	- Pit size: 1m*1m*1 m - Spacing: 10-12m * 10-12m - Manure: Usually 1.5- 3 year-old seedlings are planted during winter.	- Pit size: 1m*1m*1 m - Spacing: 5 m * 5m - Seedlings prepared by vegetative measures are planted for better uniform and good quality fruits
Care and Maintenance	- Start training and pruning after one year from the date of planting. Do not allow branches to grow up to 45-60 cm from the ground level. Remove dead, criss-cross and unwanted branches during dormancy. - Compost @ 50 kg and 400:200:40 gram NPK / plant /yr at the fruiting stage.	- For intensive production pruning, fertilizer application and other cultural operations are necessary. - Compost @ 50 kg and 400:200:200 gram NPK / plant at the fruiting stage.	- For good crop weeding and irrigation is needed. But it can grow with low maintenance cost. - Compost @ 25 kg and 500:250:250 gram NPK / plant at the fruiting stage.
Harvesting time and yield	- Harvesting time: Shrawan to Ashoj - Yield: 10-15 ton / ha	- Main harvesting time is September but some early variety ripe in July (Bhadra-Ashoj). - Yield: 3-4 tons /ha	- Harvesting time: Shrawan-Ashoj - Yield: 6-8 tons / ha
Conservation	Permanent crop to reduce erosion	Reduces erosion and adds OM	Reduces erosion (Grows even in poor soils)
Uses	- Consumption as fresh fruit and Jam - Cash income - Fire wood	- Wide commercial value - Cooking oil - Medicine (bark and leaves) - Good timber and fire wood	- Good commercial value - Fire wood
Activity	Fruit Plantation	Fruit Plantation	Fruit plantation
Varieties	- European: High chilling (>1000 hr)= Bartlett, Hardy, Anjou - Oriental: Low chilling = (<1000 hr) Havana, Pharping, Chojuro, Sinko	- Thin shell: Hartely, Payne, Asley and Franquette - Thick shell: Local	- Bedana - Muskot Red, Ganesh - Paper shell

References: - Thapa Saligram Kumar and Badri Bisal Karmacharya,- 2050 B.S. Kayastha, B. P., 2002. C. M. Shrestha, 2061 B.S., Sangraula et.al. 2054 B.S.

Annex 3. Users' Note

Case Observed in the Field (If any similar technique/activity is observed in the field, describe it including its impact): -

Drawbacks observed: -

Recommendations to solve the drawbacks: -

Recommended Survey/Design/Practical Tips or Considerations: -

Annex 4. Trainers' Training on Low Cost Soil Conservation and Watershed Management Measures for DSCOs: Training Schedule

Day	8:30-9:00 Start	9:00-11:30 (Session)		11:30-11:45	11:45-14:15 (Session)	14:15-15:00 Snack	15:00-17:30 (Session)
1	Registration	Opening • Introduction to training	Start • Introduction • Briefing on the facilities • Set training norm		Introduction to Low Cost Soil Conservation Measures		Conservation Techniques (Fascine, Palisades, Wattling)
2	Review of Previous day	Conservation Techniques (Bamboo planting, Grass sowing, Conservation plantation)			Conservation Techniques (Hedgerow, Live fence, Mulching,)		Conservation Techniques (Brush layering, Brushwood Checkdam, Riprap,)
3	Review of Previous day	Conservation Techniques (Agro-forestry, Nitrogen fixing, Compost and FYM)			Conservation Techniques (Grass waterways, Water harvesting: Conservation Pond)		Conservation Techniques (Conservation farming: Conservation tillage, Crop rotation, Multiple cropping, Cover crop)
4	Review of Previous day	Field Trip to observe some low cost soil conservation techniques					
5	Review of Previous day	Conservation Activities (Gully and Landslide treatment)			Conservation Activities (Torrent control / Stream bank stabilization)		Conservation Activities (Degraded land rehabilitation, Shelter belt / Buffer strip planting)
6	Review of Previous day	Conservation Activities (Irrigation canal improvement, Water source improvement)			Conservation Activities (Road slope stabilization, Trail improvement)		Conservation Activities (On-farm conservation, Fruit tree planting, Silvi-pasture improvement)
7	Review of Previous day	Promotion of Low Cost Soil Conservation and Watershed Management Measures			Conservation Activities (Nursery and Appropriate Species)		Closing

Training Coordinator:

Annex 4 Continued. Training on Low Cost Soil Conservation and Watershed Management for MLTs

Day	8:30-9:00 Start	9:00-9:45	9:45-10:30	10:30-10:45 Tea Break	10:45-11:30	11:30-12:15	12:15-12:30 Break	12:30-13:15	13:15-14:00 Lunch Break	14:00-14:45	14:45-15:30	15:30-15:45 Tea Break	15:45-16:30	16:30-17:15
1	Opening: Introduction, Briefing on facilities, Norm setting.	Introduction to LCSCWM			Fascine			Palisade		Wattling	Grass Sowing		Bamboo	
2	Review	Conservation Plantation			Hedgerow	Live-fence		Mulching		Brush Layering	Rip-rap		Brushwood Checkdam	
3	Review	Grass Waterways			Agro- forestry	N-Fixing		Compost and FYM		Conservation tillage	Crop rotation		Multiple Crop	Cover crop
4	Review	Gully Treatment			Landslide Treatment			Shelter / Buffer Strip		Degraded Land Rehabilitation			Conservation Pond	Fodder Tree
5								Field Trip to observe some low cost soil conservation techniques						
6	Review	Irrigation Channel Improvement			Water Source Protection			Torrent Control / Stream Bank Protection		Torrent Control / Stream Bank Protection	Road Slope Stabili- zation		Trail Improvement	Fruit Tree
7	Review	On-farm Conservation			Promotion of LCSCWM			Nursery Techniques		Nursery Techniques	Closing			

Training Coordinator:



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