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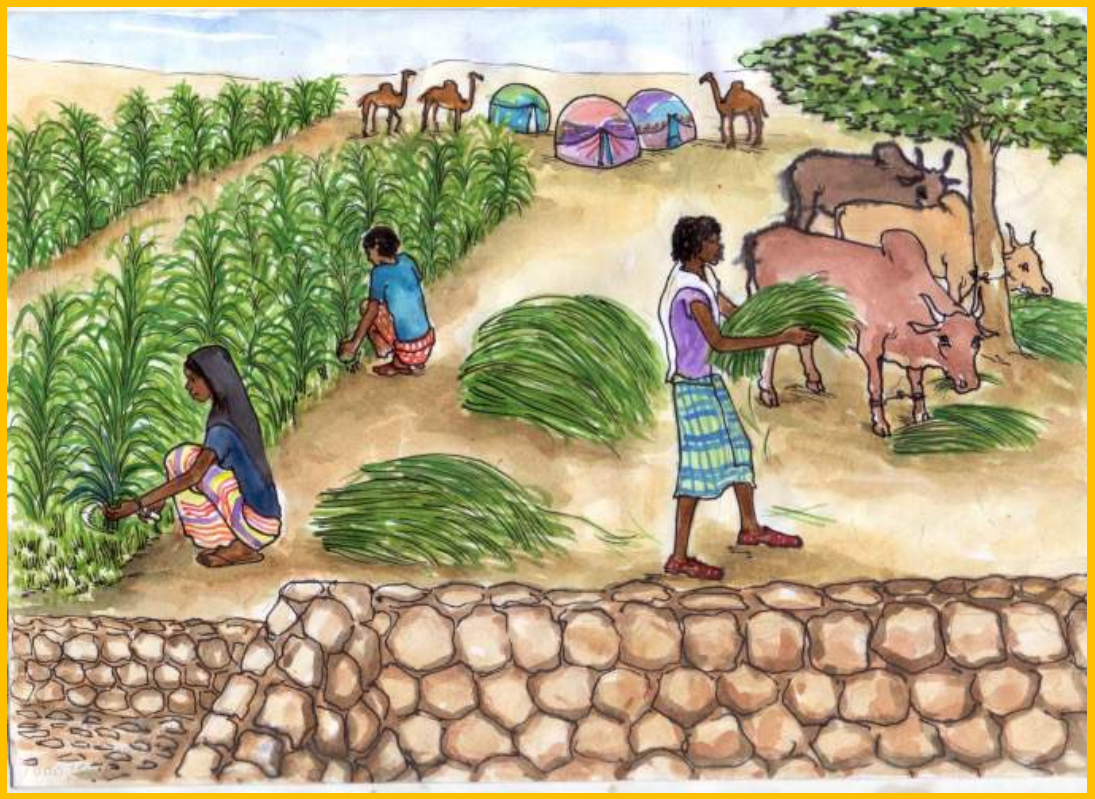
MINISTRY OF AGRICULTURE

Biological Measures



Training, Teaching, and Learning Material
First Edition

Contents

Instruction for using the learning and teaching material

This Teaching and Learning Guide is part of a series of three Teaching and Learning Guides on:

Theme 1	Construction of WSWs
Theme 2	Flood-based Farming
Theme 3	Biological Measures

The authors emphasise that comprehensive, gender-based community awareness creation and by-law development and implementation are crucial for optimal planning, construction, use and maintenance of biological measures. It is extremely important that development agents (DA) are confident and able in these areas when conducting community development activities. A solid understanding of the technology of biological measures is therefore invaluable. Teachers and learners should also familiarise themselves with these so-called ‘soft skills’ by beginning with the Teaching and Learning Guide on Creating Community Awareness, Gender Awareness, and By-Law Development before continuing with the guides on biological measures. This guide makes regular reference to the Teaching and Learning Guide on Creating Community Awareness, Gender Awareness, and By-Law Development, however, mentions only some aspects of community awareness and gender awareness creation that are specific to biological measures. Therefore, further information about social learning should be sought in this Teaching and Learning Guide. Similarly, the correct development and practical application of by-laws are crucial for the protection, utilisation and maintenance of biological measures.

Figure 1: Stable soils as a result of taking biological measures

This guide is arranged around four sections or Learning Outcomes (LOs):

Learning Outcome 1	Objectives and Benefits of Biological measures
Learning Outcome 2	Site Analysis
Learning Outcome 3	Biological measure strategies and Management
Learning Outcome 4	Maintenance & Harvest management
Learning Outcome 5	Strategies for controlling invasive species and their spread

Each of the five Learning Outcome comprises:

- Introduction with specific learning outcomes;
- An instruction sheet for teachers suggesting a teaching methodology, time needed and guidance through all worksheets;
- An instruction sheet for learners;
- Information sheets on the implementation steps, guiding questions for discussion and self-check test questions;
- Operational sheet, explaining, how to proceed to implement, what is described in the information sheet, indicating the required resources. Operational sheets always call for engaging the whole community. Therefore, sometimes, the procedure of operational sheets belonging to different Learning Outcomes can be merged;
- LAP-Test.

Be aware, the information sheets include guiding questions for discussion. These questions are used to enhance understanding, learning and reflection on the section's content as well as to serve as a form of self-evaluation.
As a whole, the guide is centred on active participation of students, integrating what they already know in accordance with key adult learning principles and detailing each topic with discussions, outdoor sessions and / or role plays.
A glossary of technical terms at the end of the document explains technical vocabulary and phrases.

Also, since many students of the ATVET colleges are future Development Agents (DA), the Teaching and Learning Guide focuses on their role and tasks.

Content that is especially relevant to development agents is marked throughout the document by this illustration of a meeting:

Small case studies in coloured text boxes illustrate the technical aspects and give examples of communities involved in Water Spreading Weir (WSW) construction, as well as use of the resulting rehabilitated land.

Hints and Tips for Training and Teaching

Adult Learning

Adults learn differently from children and so teaching techniques for adults therefore need to be different from those used with children. The main difference is that adults have considerably more life experience. As a result, adults are keenest to gain information that is most relevant to this lived experience and are inclined to be less interested in that which is not. Key points which help adults learn therefore include the following:

Meaningful information	Starting by helping the learners understand why the topic is important and how it can help them – see also Specific Learning Outcomes.
Experience	Recognising that the learners already have considerable knowledge and life experience (e.g., vegetative species understanding), and drawing out this experience as often as possible during learning.
Respect	Adults respond best when they feel that they are respected and that they are part of the learning process. Talk with them, not at them.
Self-exploration	Provide time for adult learners to explore ideas (on their own or in small groups). Let them consider how they might use and apply the learning material.

Teaching through facilitation

Facilitation is an important skill that takes practice and patience to improve. It is much easier for teachers to lecture and to give instructions than to facilitate. However, in order to make learning interesting and to get the best results, a

teacher facilitates effectively by assuming the following roles:

- The role of a mentor who assists students with empathy, understanding and encouragement;
- The role of a leader and organiser who initiates, demonstrates, sets goals as well as boundaries;
- The role of a coach who listens, comments, gives feedback and inspires.
- Conducting an activity
- Communicate clearly and confidently with your students by speaking and writing clearly.
- Make eye contact and try to be calm and confident with your body language.
- When a student asks a question or makes a point, listen carefully, do not interrupt them, and repeat or summarise what you have heard for everyone before responding - or asking others to respond - to it.
- When explaining ideas, regularly cross-check whether your students have understood what you have said by asking them to summarise, either as individuals or collectively by contributing points.
- As often as possible, elicit information from your students by asking open questions – Why? What? How? – rather than closed Yes-No questions.
- Try to encourage everyone in a group to participate and avoid individuals dominating.

Brainstorming ideas

A brainstorm is a bit like a real storm: it happens quickly. Participants pour out their ideas as soon as they come into their heads, like rain falling. Brainstorming is a particularly effective teaching method for adults because it draws out students' existing knowledge and experience as a starting point for the learning exercise. It is student-centred and if it is a written brainstorm rather than a verbal one, all of the ideas that have been contributed can be ordered, prioritised and / or reworked from their position on the blackboard or on cards.

Figure 2: Group discussions to share ideas and learn from others.

Group work

Some of the most productive adult learning takes place during group work. Working in groups places both responsibility for learning and empowerment for self-discovery onto the student, making them active learners rather than passive consumers of information. Before breaking into groups and starting a given task, it is essential to clarify both the objective and the time frame. Breaking into groups can be done randomly across the class (such as by using a counting system of say 1-2-3-4-5 or by height order), or in a more structured way by grouping friends, neighbours or regular working partners.

Leaders almost always emerge from group work, and so it is often helpful to select a group moderator whose responsibility is to steer the work towards the objective as well as encouraging all members, recording and summarising information.

Groups should never be left alone, rather the facilitator should circulate between groups, observing how each group manages the activity and making suggestions or asking helpful questions if necessary. If a group is off track from the topic, give support and guidance to try and lead the group back toward the objective.

Role Plays

A role play brings a slice of reality into a session. By directly simulating reality, the role play discussion, drama session or game raises questions which require discussion, assessment, negotiation and understanding of real scenarios. In this way role plays are learning experiences for both the actors and the observers.

Evaluation

The Self-Check Test at the end of each Information Sheet, and the LAP-Test after each Operational Sheet, are designed to help the student reflect on the overall content of a given section. Completing both Self-Check Test and LAP-Test will reinforce what is understood and learned as well as underline what needs further reflection, reading, discussion or study.

Introduction to the DVRPU approach

The lowlands of Ethiopia are primarily inhabited by agro-pastoral communities. Climate change is causing longer drought spells and increased incidences of intense floods. This, combined with increased population pressure and intensified demand for livestock grazing land, has contributed to the overexploitation of natural resources. With the widespread degradation of the land now evident in poor vegetation cover and low soil infiltration capacity, the once-replenishing floods from the highlands have become a force of destruction. This is most apparent in the formation of deep gullies along the escarpment floor. The floods no longer nourish the earth but destroy it, along with the livelihoods of millions of people.

This process has begun in most dry valleys, which used to be covered with tall grass in the past. They have lost their resistance to drought, and in most rainy seasons, water does more damage in the form of erosion than it contributes to regeneration. In this situation, Dry Valley Rehabilitation and Productive Use (DVRPU) is a game-changer. It has proven its potential to transform degraded dry valleys into flourishing fields that provide livelihoods for its people.

At the heart of DVRPU is a comprehensive set of measures that address multiple dimensions: social, technical, biological, economic, institutional, and governance, ensuring the successful rehabilitation of entire dry valleys. The core technology employed is a cascade of Water-Spreading Weirs (WSWs). These structures, combined with Dry-Stone Measures (DSMs) and biological measures, work together to slow down the flow velocity of floods. By doing so, water can infiltrate into the soils, increasing groundwater levels and allowing fertile sediment to settle, creating highly productive land and, thus, food security.

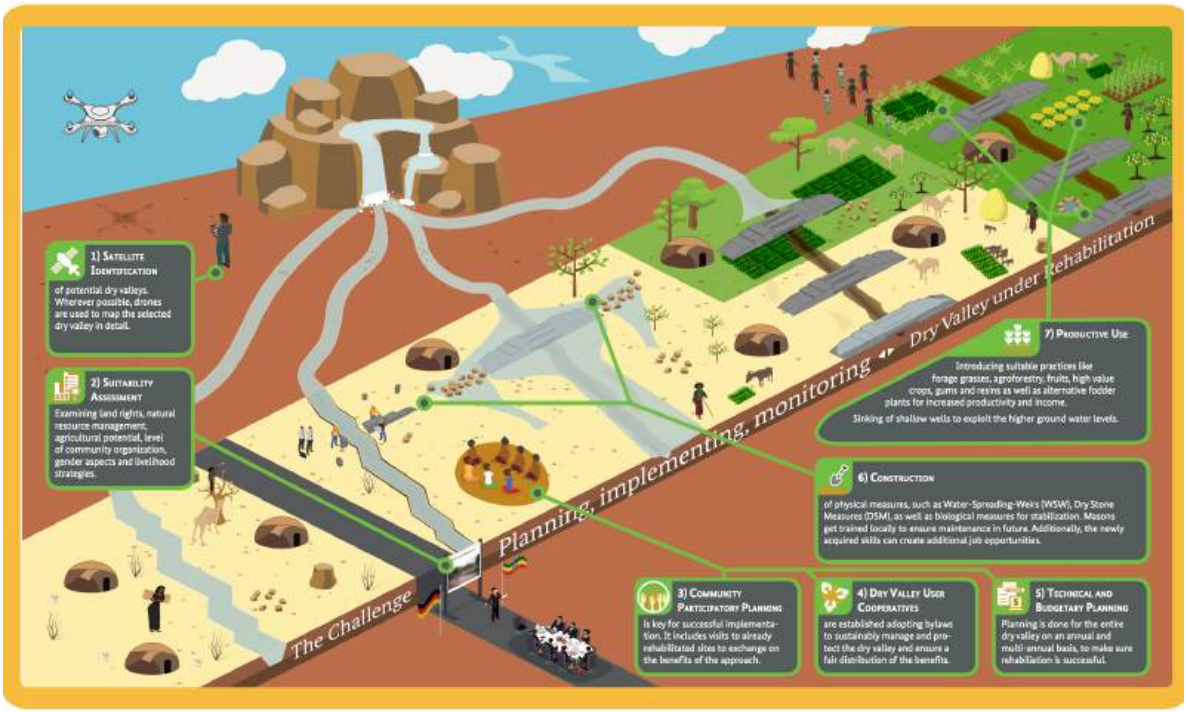
The DVRPU approach is defined in seven crucial steps for the sustainable rehabilitation of dry valleys:

1. Satellite Identification and Dry Valley Delineation
2. Suitability Assessment
3. Community Participatory Planning
4. Dry Valley User Cooperative Societies (DVUCS)

5. Technical and Budgetary Planning
6. Land Rehabilitation Measures
7. Productive Use

One of the key factors for success is the acceptance and active participation of local communities. Their engagement is supported by technical expertise and regulatory frameworks provided by local governments. This collaboration between communities, technical experts, and local governance is vital for the long-term sustainability of the intervention, fostering their active involvement in the planning, implementation, maintenance, and utilization of the rehabilitated lands.

The DVRPU approach offers a sustainable solution that not only rehabilitates the land but also empowers local communities to take charge of their own development and create prosperous futures for themselves.



This TTLM focuses on the critical role of biological measures (step 6) in stabilizing physical structures within the context of dry valley rehabilitation. When implementing biological measures, two key aspects are imperative:

1. Identifying Suitable Species: It is crucial to identify and propose appropriate plant species for planting in the dry valley, considering their availability and compatibility with the local ecosystem.
2. Accurate Quantity Determination: Accurately determining the quantity of each selected species needed is essential to ensure efficient resource utilization.

One effective biological measure is the use of grass strips in conjunction with physical measures to protect against erosion. This technique has proven successful in reducing erosion and maintaining soil stability. Typically, these grass strips are 1 to 3 meters wide and planted along the contours of the physical measures. They serve multiple purposes, including stabilizing and reinforcing the structure itself. Additionally, these grass strips provide valuable animal feed through the biomass they produce. Agro-pastoralists who rely on fodder grasses for livestock production have recognized and utilized suitable grass species. These species are carefully selected for their resilience to local climate conditions and their positive impact on soil and water conservation. Due to their adaptability to the region's environmental factors, they can be implemented relatively easily.

While specific grass species may vary depending on location and climate, several grasses are generally considered suitable for stabilizing physical measures and reducing water velocity. These include:

- Napier/Elephant Grass (Pennisetum purpureum)
- Bermuda Grass (Cynodon dactylon)
- Guinea Grass (Panicum maximum)
- Sudan Grass (Sorghum × drummondii)

Active community involvement in the implementation of grass strips and all other biological measures is critical. This participatory approach allows local community members to utilize their knowledge of the landscape, making their contribution invaluable in identifying the right species, proper planting, and continuous maintenance of biological measures. Such a level of participation strengthens the sense of ownership and contributes to the long-term success and sustainability.

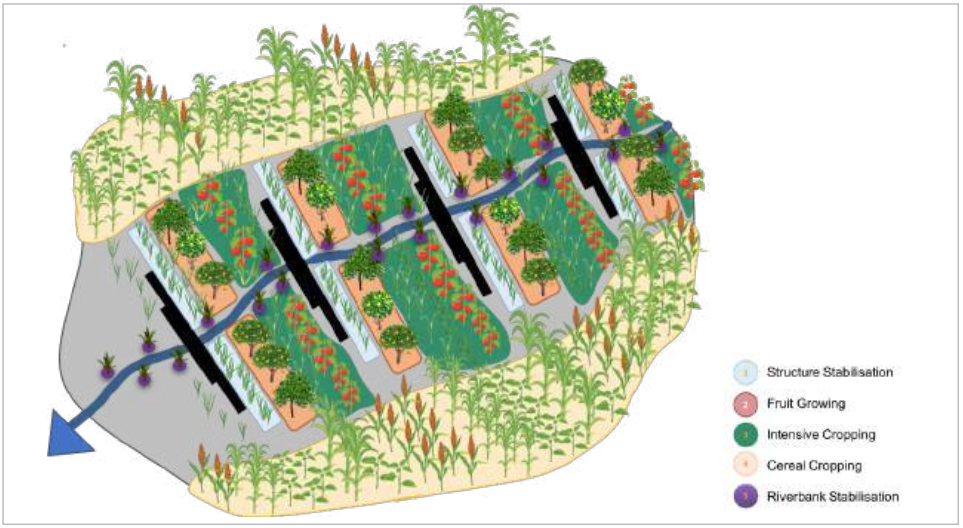
Productive use

The productive use (step 7) of a dry valley covers biomass production for food, fodder, fuel, and fibre crops. It also involves utilizing residual moisture for crop and fodder production and providing drinking water for both livestock and humans. To fully and sustainably harness such productive uses, it is essential to stabilize the upper part of the dry valley thereby reducing the velocity floods, increasing water infiltration, and preventing further erosion. Effective rehabilitation efforts will only be fully realized when physical measures (check dams, dry stone structures, and WSWs) are adequately complemented by biological measures, such as the use of grass strips, as described above.

In fact, as outlined below, all the zones delineated within a dry valley under the DVRPU approach are developed to fulfil a function in protecting the valley from erosion and degradation through a combination of biological and physical measures, while also transforming the valley into a productive land contributing to improved livelihoods of agro-pastoral community and socio-economic development of the region.

- **Zone 1** serves as the foundational element, focusing on stabilizing physical structures with biological measures, primarily using suitable grasses. It occasionally experiences waterlogging, which is essential for flood mitigation.
- **Zone 2** thrives as a fruit-growing area, benefiting from abundant water availability, creating ideal conditions for fruit-bearing plants to flourish.

- **Zone 3** is an intensive cropping area characterized by ample water availability, making it a prime location for cultivating high-value crops.
- **Zone 4** functions as a cereal cropping area accustomed to intermittent dry spells and is primarily utilized for growing crops like maize and sorghum.
- **Zone 5** plays a pivotal role in riverbank stabilization and features rich water availability. This zone encompasses a mix of grasses and fruit-bearing plants, contributing to both land stability and agricultural diversity.



Specific learning objectives

After you have finished working through this guide you should be able to:

- Explain the principles and importance of the biological measures in combination with the physical WSW and DSM structures
- Make a vegetative selection, based on the local site conditions and aim of the biological measure
- Prepare a suiting biological measure mechanism
- Have a knowhow on the harvesting strategy of the biological measure
- Understand how to deal with unwanted and/or invasive vegetation species

Learning Outcome 1: Objectives and Benefits of Biological measures

Introduction

Every Learning Outcome has a similar structure. In this Introduction you find the specific learning objectives of Learning Outcome 3. The Instructions sheet(s) for both the Teacher and the Learner tell what is expected from both groups. Following is an Information sheet that provides background information, guiding question, and a self-test. Finalizing, when applicable, an Operational sheet tells you how to proceed with implementation of what is described in the information sheet.

At the end of Learning Outcome 1, you should be able to:

- Understand the aim of biological measures
- Mention different benefits of biological measures
- Explain which factors are important for a successful implementation operation

Instruction Sheet for Teachers

1. As you go through this Learning Outcome together with your class, do not start by lecturing them about the objectives and benefits of biological measures from the Information Sheet. Instead, read the learning outcomes mentioned above with them and brainstorm ideas about the first things that pop-up when thinking about biological measures and/or the different biological measures that they already know and their main benefits.
2. Write these ideas down on a large paper in the form of a mind-map.
3. Work through the Information Sheet.
4. Ask students to suggest examples of where DSMs might be most suitable. Ask them to explain why.
5. Discuss the Guiding Questions
6. Let the Learners go through the Self-test and support when needed

Teaching Methodology

Brainstorming, interactive teaching and learning, group work (listing), discussions

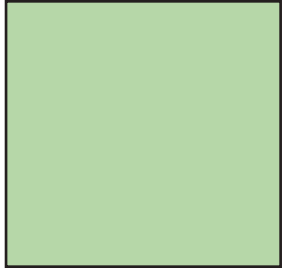
Session Plan

- 15 minutes looking at the introduction, brainstorming developing a mind-map (the idea that this is short and quick, to stimulate the first ideas that pop-up when talking about biological measures);
- 45 minutes for the Information Sheet;
- 20 minutes for the Guiding Questions;
- Total time: 80 minutes

Figure 3: Absence of vegetation can lead to erosion, which can weaken the Water Spreading Weir structure

Instruction Sheet for Learners

1. Read the introduction with the specific learning objective for Learning Outcome 1. Familiarise yourself, as a potential future development agent, with your role in the process.
2. Read the Information Sheet on objectives and benefits of biological measures.
3. Write down any questions you have.
4. Ask your teacher for support and seek answers to your questions.
5. Try to answer the guiding Questions and discuss them with classmates about the advantages, disadvantages and other factors regarding biological measures.
6. Test your knowledge by completing the Self-Check Test.
7. When questions pop-up, do not hesitate to ask the teacher again.



Information sheet

With the construction of the physical Water Spreading Weirs (WSW) and Dry-Stone Measures (DSM) structures, biological measures are recommended to strengthen, stabilize, and flourish the landscape around the structures. In practice, biological measures primarily involve the stimulation of plant growth (grasses, bushes, or trees) over a denuded measure area. The roots of these plants securely bind the soil and increase the water-holding capacity of the soil. the stabilization of the soils, erosion is reduced, which in its turn leads to less degraded land. So, although having a bit of a different technique, the outcome of the physical WSW and DSM structures and the biological measures are similar. Both reduce soil erosion in the (semi-) arid lowlands of Ethiopia. That is why a combination of the two measures, also called biophysical measures, is smart and lead to multiple benefits.

In the (semi-) arid landscapes, biological measures' ecological benefits are:

- preventing splash erosion;
- reducing the velocity of surface runoff;
- facilitating the accumulation of soil particles;
- increasing surface roughness which reduces runoff and increases infiltration;
- the roots and organic matter stabilize the soil aggregates and increase infiltration;
- dead organic material improves the soil's structure and fertility;
- windbreaks.

Additional to the improved ecological functions in the landscape, biological measures also serve some socioeconomic benefits:

- Harvest: either in the form of living (fruits, legumes) or dead material (straws that can be used as fodder). Be aware that animals do not damage the biological measures too much by grazing directly of the biological measure.

- Low-costly when maintained properly
- Fencing
- Shade and resting place during extreme hot days
- Stabilizes the physical structure for a long time

Figure 4: Reduced gully formation as a result of taking biological measures.

So, different from Flood-based Farming practices (see Theme-3 of the Teaching and Learning Guide), biological measures' main objective is not to increase agricultural productivity. Biological measures operate as a biological assisting tool to the physical structures in place, helping in conserving soil and water. Therefore, biological measures aim to give year-round ecological benefits, while

Flood-based Farming crops are grown in a short period (growing season) to give productive outcome. Nevertheless, used strategically; biological measures can create above mentioned socioeconomic benefits.

Figure 5: Initial gully formation

However, when carrying out a successful & appropriate biological measure operation, there are some important factors you have to consider and discuss with the community before and after the implementation:

- specific objective to stabilized & rehabilitate the WSWs / DSM area,
- specific strategy for planting the biological measure,
- merit of the vegetation to meet multiple needs of local communities,
- commitment and willingness of local communities to protect and manage the planted vegetation covers (including the harvest potential),
- suitability of the selected vegetation, considering soil, climate, available moisture and other circumstances
- Variation in the slope percentage.

Figure 6: The area behind the DSM can be used to plant biological measures.

This Teaching and Learning Guide will connect you with the following **biological measure strategies**:

- Grass strips
- Hedgerows of shrubs and/or grasses
- Stabilization of physical structures/ river-banks
- Biological check dam
- Live fencing

Similar to the physical structures (e.g., cascade of WSWs), one singular strategy will often not lead to the expected water and soil conservation benefits. A combination of different vegetative covers and strategies will help strengthening each other, resulting in bigger impacts. The biological measure strategies will further be discussed in Learning Outcome 3.

Learning Outcome 2 will focus on a basic site analysis. This Learning Outcome will address site characteristics that you should consider before selecting a target vegetative specie. Learning Outcome 3 will give you a better understanding of different planting strategies together with the management and preparation of the biological measures. Learning Outcome 4 focuses on harvesting strategies accompanied with the biological measures. Lastly, with biological measures, precautions should be taken against invasive species. Learnings about this will be treated in Learning Outcome 5

Guiding questions for discussion

- Can you mention other benefits of biological measures than the ones that are mentioned in this Information Sheet?
- What are potential disadvantages of biological measures?
- Could you explain the objective of a biological measure to a classmate?

Self-Check Test

Name	
Date	
Time started	
Time finished	

Instructions

Answer the question that are listed below. At the end, you can see whether you have a satisfied score.

Multiple choice questions:

Which measure is more important, physical or biological measure (1 pt)?

1. 1Physical measure
2. Biological measure
3. A combination of the two

What is the main function of plant roots in the context of biological measures (2 pts)?

1. Stimulate plant growth
2. Stabilizes the soil
3. Use as fodder
4. Fencing

Short answers:

At the start of the biological measure implementation, list 3 points that need to be considered (3pts)

Next to ecological benefits for the landscape, biological measures have multiple socioeconomic benefits, name 3 (3pts)

Name 3 biological measures strategies that will be explained in this Learning Guide (3pts)

Rating

Satisfactory rating points 7.5 and above. Unsatisfactory points below 7.5.

You can ask your instructor for a copy of the correct answers. If your answer differs from that of your instructor for a very single point do not proceed to the next learning, rather better work on the same information sheet until you acquire all the necessary information.

Score: (insert number of points)

Learning Outcome 2. Site Analysis

Introduction

Every Learning Outcome has a similar structure. In this Introduction you find the specific learning objectives of Learning Outcome 3. The Instructions sheet(s) for both the Teacher and the Learner tell what is expected from both groups. Following is an Information sheet that provides background information, guiding questions, and a self-test. Finalizing, when applicable, an Operational sheet tells you how to proceed with the implementation of what is described in the information sheet.

By the end of this Learning outcome section, you should:

- know the different factors that are important for a specific site characteristic
- be familiar with the relation between site characteristics and specie selection
- be able to make a basic site analysis that corresponds to your location

Instruction for Teachers

- Ask one of your students to read aloud the Introduction of Learning Outcome 2. Ask your students what their expectations are from the Learning Outcome after reading the introduction.
- Inform your students what is this step about and what they will learn and understand, when working through the second step.
- Subsequently, ask your students what they already know about the site conditions of the current location. What do they see as important factors in the site analysis regarding biological measures?
- Complement with the information of the Information sheet on site analysis.
- Discuss the Guiding Questions. Ask one or two students to take notes.
- If clarification is needed with the Self-Test (not content wise), assist the students
- Continue with the Operational Sheet. Sit outside the classroom under a tree, pretending a community awareness creation meeting. Work with

your students on the procedures. What comes first? What follows? Work through the text.

Teaching Methodology

Brainstorming, interactive teaching, and learning, group work (listing), and discussions.

Session plan

- 10 minutes for looking at the Specific Learning Outcome and the brain-storming;
- 55 minutes for the information sheet, including Guiding Questions;
- 60 minutes for the Operational Sheet.
- Total: 125 minutes.

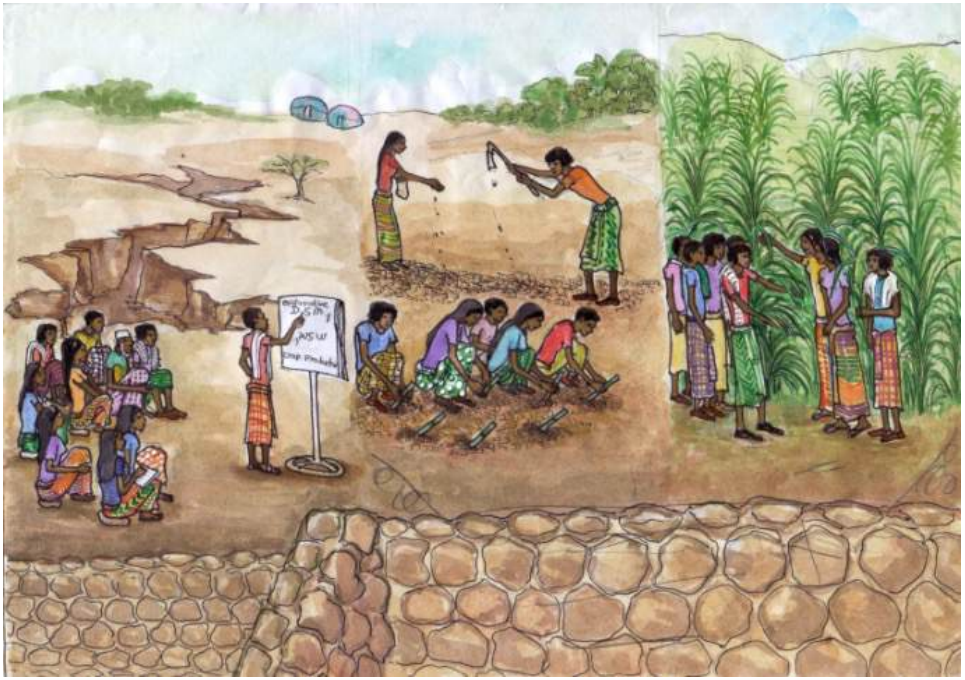
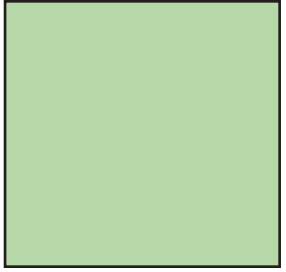


Figure 7: Steps in to establish biological measures



Information sheet

- Climate information
    1. Rainfall (frequency, distribution, and amount)
    2. Temperature (average temperature, minimum/maximum temperatures)
- Soil Structures
    1. Types of soil structures
    2. Impact of soil structures on different plant growth
    3. Strategies to identify soil structures on site
- Vegetation (Species Selection)
    1. Procedures
    2. Identify the suitability of native or exotic (introduced) plant species
    3. Grass species
    4. Leguminous /fodder plants
    5. Tree species

Site analysis - Introduction

Before determining on a biological measure, a careful site analysis should be done. Afar and Somali region as well as parts of Oromiya and SNNP both have (semi-) arid lowlands landscapes. However, this does not mean that all measure site has similar conditions, as every location is unique regarding climate, soil structures, and water sources. A site analysis helps you in deepening an understanding of local conditions regarding climate, soil structures, and water sources. This is important, as doing a good site selection helps in choosing a biological measure that has high surviving chances. Besides, with changing climate conditions, having a good understanding of current site conditions helps in recognizing changes. Based on these changes, vegetative species might need to change accordingly in the future.

The following site characteristics are important:

- Climate
- Altitude
- Soil type and structure
- Availability of moisture.

This Learning Outcome gives you the average site conditions of the two regions. However, as mentioned in the introduction, always realize that local conditions might differ from these average conditions. When this is the case in your area, be aware and adapt accordingly.

Climate

Two important climate factors that impact plant growth are water availability and temperature. A mismatch between plant requirement and local climate conditions leads in low survival chances of the biological measure. The lowlands of Ethiopia are known for their large extremes, especially around high temperatures and long-period of droughts.

Water Resources:

Floods generated by high-intensity rainfall in the highland areas serve as the primary source of water for plant growth and water supply for people and livestock in the Ethiopian lowlands. While there is wide variability in the amount of rainfall across different regions of the Ethiopian lowlands, it is generally limited and, on its own, insufficient to fully support plant growth. It is important to note that the rainfall pattern in different highland regions is also highly variable.

The biological measures, which are the focus of this TTLM, primarily depend on floods for growth, with rainfall serving as a supplementary source, which may occasionally be substantial. When these biological measures reach maturity, they contribute to stability and enhance strengthen the capacity of WSWs and other physical measures to reduce damage from excessive floods and harness significant floodwater for productive use. A solid understanding of the rainfall patterns in the highlands can provide valuable insights into when floods are expected, their likely size, and the timing of peak periods. Such insight can inform adequate operational preparations, leading to more effective flood damage mitigation. It can also help in determining which biological measures (plant species) to select and when to initiate their growth, as certain species are more susceptible to flood

damage and waterlogging than others.
Rainfall in the highlands and lowlands of Ethiopia generally follows similar trends and is characterized by a bimodal distribution, featuring two distinctive rainy seasons: the Kiremt, the primary rainy season extending from June to September (often peaking in July and August), and the Belg, the secondary rainy season covering the period from March to May (usually peaking in April). This rainfall pattern implies that the lowlands have two distinct seasonal cycles: the ‘floods and wet’ season when substantial soil moisture should be harvested using physical and biological measures, and the ‘hot and dry’ season when most plants grow largely based on residual moisture.

Lastly, it is essential to note that while modern rainfall forecasting is critical for gaining insights into the timing and volume of floods, traditional knowledge is equally invaluable. In several Ethiopian lowlands, communities often rely on a group of experienced elders who are considered reliable sources of information regarding flood occurrences.

Temperature

Similar to water requirements (minimum, maximum, and optimal), plant species also have temperature requirements (minimum, maximum, and optimal). Temperatures in the lowlands of Ethiopia typically range from 20 to 40 degrees Celsius, with an average of around 30 degrees.

Soil

With the floods from the highlands, large amounts of nutrient rich sediments are deposited behind the WSW and DSM. These soils can be used to grow crops and support the biological measures.

Species overview

After finishing the site analysis, a selection of the vegetation species can be executed. Every specie, whether it is a grass, a shrub, or a tree, has its optimal growing requirements. To be sure that the requirements are met, they should match with the site conditions. This can be done by comparing the specie requirements with the site conditions. If after comparing, hypothetically, you can answer 'Yes' to all the requirements needed, then there is a potential match to use the specie as biological measurement. Important to note is that the match-up is independent to the aim for which you want to use the biological measure.

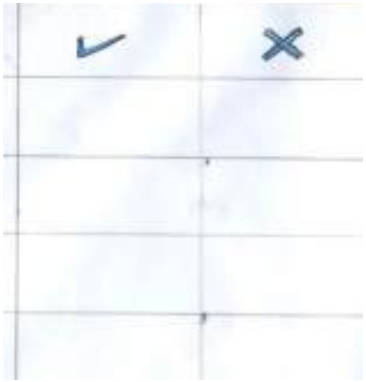


Table 1: The growth requirements and remarks of grass plant species

Species	Given Name	Growth requirement of the target species[1]			Remark / Uses
		Soil	Altitude (m)	Water demand (mm)	
Andropagon	Beard grass, bluestem grass, broomsedge	sandy clays, sandy loams to loamy sands, sands to black cracking clays	Below 980	400 – 1500	Erosion control and fodder grass
Setaria	Foxtail, bristle grasses	Adapted to a range of soils, especially those with a good water-holding capacity	600 – 2700	>550	Erosion control, fodder grass and grains can be used as food (after boiling)
Phalaris aquatica	Bulbous canary-grass, and Harding grass	best suited to high-fertility, deep, heavy-textured soils	400 – 450	>400	Erosion control and fodder grass
Elephant grass	Napier grass, Uganda grass	Deep, friabl Fertile soil (not tolerant against floodings)	2000	200 – 4000	Erosion control, fodder grass, pest management (push-pull)
Panicom	Panic Grass	Does best on fine textured and organic soils	Up to 2100	400 – 2000	Erosion control, fodder
Chloris gayana	Rhodes grass	Light texture, well-drained	600 – 2000	650 – 1200	Strip along the WSWs, fodder, intercropping, improve soil nutrients
Sorghum × drummondii	Sudan grass	From light loams to heavy clays, at least moderately well-drained	0 – 300	300 – 2000	Erosion control and fodder. May accumulate toxic levels of nitrate if fed for a long period of time

[1] Compiled from: USDA, FAO, TropicalForages.info, feedipedia.org and worldfloraonline.org

Chrysopogon zizanioides	Vetiver	Well-drained soil	Up to 3000	300 – 2000	Erosion control, pest management, animal feed, oil extraction (from roots), ropes, roof thatch
Megathyrsus maximus	Guinea grass	Well-drained, moist and fertile soils	0 – >2000	1000+	Erosion control, it is well suited for cut-and-carry (fodder) systems and can be used for making silage and hay
Paspalum spp.	Paspalum Grass	Sandy and other friable, free-draining soils, also been grown successfully on hard-setting sandy clay loams	0 – >1700	800 – 1500	Permanent pasture, with possible application for hay and silage

Table 2: The growth requirements and remarks of leguminous non-woody plant species

Species	Given name	Growth requirement of the target species[2]			Remark / Uses
		Soil	Altitude (m)	Water demand (mm)	
Alfalfa	Lucerne	Deep fertile & well drained	500 – 3000	600 – 750	Erosion control, forage for livestock, green manure
Stylo Stylosanthes guianensis	Stylo	well-drained, open-textured soils from sands to light clays	0 – 2,000	700	Fodder, palatability increases with maturity
Siratro (Macroptilium atropurpureum)	Purple bushbean	Varity of soil	up to 1600	up to 2900	Erosion control, fodder. Can become an invasive specie

Desmodium	Tick-trefoil or tick clover	Varity of soil	300 – 2500	700 – 3000	Push-pull technology, erosion control, green manure
Vigna unguiculata	Cow pea	Varity of soils, prefers sandy soil	Up to 2000	400 – 700	Tolerant for waterlogging. Erosion control, suitable for human consumption
Lablab	Hyacinth bean, lablab-bean and others	Deep sandy to clay loam soils	Up to 2000	700 – 2000	Erosion control, forage for livestock, human consumption (if boiled)
Vigna radiata	Mung bean	Well-drained, loam-sandy soil	Up to 2000	600 – 900	Water in blooming period important, sensitive to extensive water logging. Nitrogen fixation, cover crop, human consumption
Cajanus cajan	Pigeon pea	Varity of soil	500 – 1800	600 – 1000	Erosion control, animal feed, human consumption
Vicia	Vetch	Versatile	1500 – 3000	400	Erosion control, animal feed

[2] Compiled from: USDA, FAO, TropicalForages.info, feedipedia.org and worldfloraonline.org

Table 3: The growth requirements and remarks of shrub/tree species

Species	Given name	Growth requirement of the target species[3]			Remark/ uses
		Soil	Altitude (m)	Water demand (mm)	
Acacia albidas	Apple-ring acacia and others	Prefers deep sandy soil	0 – 1800	450 – 800	Bee keeping, seeds for livestock, nitrogen fixation
Acacia Eherenbergiana	Vachellia flava	Sandy soils	0 – 1500	50 – 400	Livestock feed
Acacia mellifera	Black thorn	Prefers loamy soil with hard surface, sandy soils & rocky hillsides	0 – 1500	250 – 700	Livestock feed, building material
Acacia nilotica	Gum arabic tree, thorny acacia	Wide range	0 – 600	200 – 1000	Young trees do not compete well, so weeding is important. Provide fodder, firewood, charcoal. Good on river banks.
Acacia oerfota	Orfot	Silty alluvial soils	100 – 1600	50 – 1200	Fodder
Cassia sturtii (Senna artemisioides)	Silver cassia or Sturt's pea	Wide range	100 – 1600	200 – 500	Larval food plant
Leucaena leucocephala	Jumbay, pearl wattle and others	Wide range	600 – 1400	600 – 2000	Fencing, soil fertility, firewood, fiber, and livestock fodder
Parkinsonia aculeata	Jerusalem thorn, jelly bean tree and others	Sandy/Light-medium	600 – 1400	200 – 800	Can become invasive species. Not liked as fodder due to the spines
Atriplex nummularia	Saltbush	Wide range (can grow on marginal lands and salt affected areas).		150 – 500	Fodder (mineral rich), erosion control, hedge, windbreak and other uses

Sesbania sesban/ Cassia siamea	Cassia tree	Wide range	0 – 400	600	Tree legume, fodder, erosion control, medicinal value
Ziziphus abyssinica	Large jujube	Wide range	200 – 2500	200 – 500	Erosion control.
Sanseveria	Devil's tongue	Sandy loam soils	0 – 800	250+	Erosion control, fibres (ropes)
Moringa stenopetala	Moringa, cabbage tree	Rocky or sandy soils, with good drainage	0 – 1900	500 – 1400	Human consumption, can provided shade for other crops
Jatropha	Physic nut or nettlespurge	Well drained sandy and clay soils	400 – 1200	300 – 1.000	Can be highly toxic Basket (hand crafting) making. Animal feed (if detoxified)
Lawsonia inermis	Henna tree	Prefers sandy soils but can tolerate clays and poor, stony, sand soils	0 – 1000	200 – 4200	Used for dye
Entada abyssinica	Tree entanda	Prefers sandy loam soils	0 – 1350	500 – 1500	Erosion control, fodder, fuel wood, timber, live fencing

[3] Compiled from: USDA, FAO, TropicalForages.info, feedipedia.org and worldfloraonline.org

Table 4: The growth requirements and remarks of other non-forage plant species

Species	Given name	Growth requirement of the target species[4]			Remark/ uses
		Soil	Altitude (m)	Water demand (mm)	
Opuntia ficus-indica L. MILL	Cactus pear	Wide range	600 – 2200	200 – 250	Live-fencing, fruit, erosion control.
Agave sisalana	Saisal / sisal	Loose well-drained sandy soils	0 – 2000	600 – 1500	Live-fencing, fiber for multiple uses, bee keeping
Opuntia ficus-indica	Beles	Sandy and deep	0 – 1500	200 – 400	Soil erosion, fodder
Aloe Vera	Aloe	Chalky, Clay, Loamy, Sandy	0 – 3500	350 – 400	Drink (juice), medicine (sap), skin ointment (sap), cosmetic (sap).

[4] Compiled from: USDA, FAO, TropicalForages.info, feedipedia.org and worldfloraonline.org

Self-test

Name	
Date	
Time started	
Time finished	

Instructions

Answer the question that are listed below. At the end, you can see whether your score is satisfying

Question

Multiple choice

What is the main aim for a proper site analysis to determine biological measure (2pnts)?
A. Because (semi-)arid landscapes can have different characteristics determining biological measures selection
B. Creates community awareness, resulting in more incentive
C. To know the climate of a specific site
D. To explore if the area is suitable for biological measures

Open questions:

- The vegetative tables 5 includes one species of which the requirements do not match with the site conditions of the Somali and Afar region, which one and why (2pnts)?
- Name 2 characteristics that a species should match in a flood-prone area in the Afar region (2pnts, one point per right answer).
- Name 3 different species type groups (3pnts, one point per right answer)

Rating

Satisfactory rating points 5 and above. Unsatisfactory points below 4

You can ask your instructor for a copy of the correct answers. If your answer differs from that of your instructor for a very single point do not proceed to the next learning, rather better work on the same information sheet until you acquire all the necessary information.

Score: (insert number of points)

Operational sheet

As the development agent (DA) of the kebele, you have an important role in assisting communities in the site analysis. If right, you have been present in the construction of the WSW and/or the DSM. If not, please use the previous Learning and Teaching Guide to make ourself familiar with the procedure of first meeting with the Kebele and the community.

During the site analysis process, carefully listen to the way that the community describes the site. After listening to their initial site analysis, provide additional (if needed) technical information. For the purpose of biological measures, pay special attention to the above-mentioned site characteristics.

Objective

A clear site analysis is done together with the community so that together a fitting biological measure can be selected.

Procedure

- Together with the kebele or clan leader, call for a community meeting as soon as construction of the physical structures are finished. In terms of timing, make sure to consider the growing season of your specific location. Ideally, you start the discussions well-before the first biological measures should be implemented. This requires some planning from the DA's side.
- Brainstorm: sit and discuss the rainy seasons
- Discuss how much is flooded
- Transact walk (determine where erosion is most (even after construction of DSM and WSW))
- Determine the soil (see soil texture exercise)
- Discuss what vegetation might be suitable (use list as inspiration)

Figure 9: Recognizing the site through a transect walk

Soil texture exercise

During a transact walk, some location might pop-up as potentially interesting to apply biological measures. To get a rough understanding on the soil texture, some easy-to-use methods can be applied.

A soil texture triangle is used to classify the texture class of a soil. The sides of the soil texture triangle are scaled for the percentages of sand, silt, and clay. Clay percentages are read from left to right across the triangle (dashed lines). Silt is read from the upper right to lower left (light, dotted lines). Sand from lower right towards the upper left portion of the triangle (bold, solid lines). The bound-

aries of the soil texture classes are highlighted in blue. The intersection of the three sizes on the triangle give the texture class. For instance, if you have a soil with 20% clay, 60% silt, and 20% sand it falls in the “silt loam” class

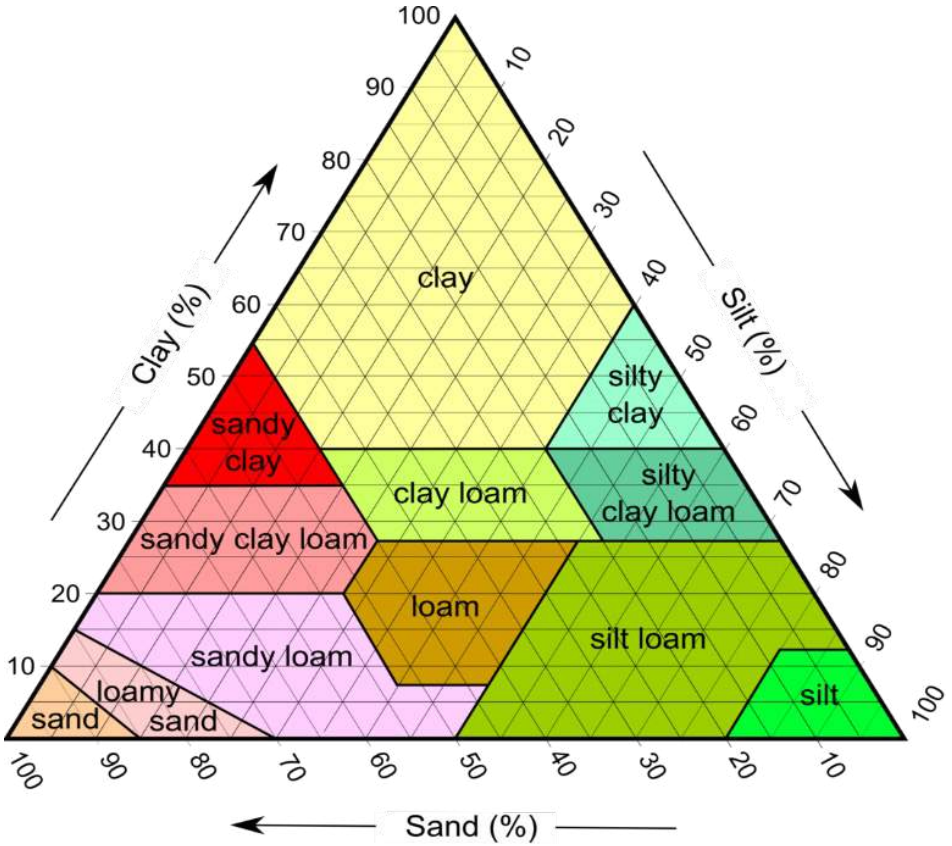


Figure 10: Soil Texture Triangle

Hand Method to Estimate Soil Texture

In applying the 'hand method' to determine or estimate soil texture and identify the texture class using the soil texture triangle, the following five steps need to be followed:

Step 1: Sieve Your Soil. Use a 2-millimeter sieve to remove stones, gravel, and break down soil lumps, making it easier to work with. If your soil is damp, it needs to be dried before sieving. To dry it, place about 1 kilogram of broken-up soil in a location exposed to the sun for an extended period.

Step 2: Estimate the Percentage of Stones or Gravel in the Soil. Visually estimate the percentage of stones and gravel in the soil obtained from step 1. This estimation is helpful if you intend to calculate the plant-available water capacity of the soil.

Step 3: Hand Texturing. Take a small handful of soil sample that comfortably fits in the palm of your hand.

Step 4: Add Water to the Sample. Add enough water to create a bolus or ball. Knead the bolus for 1-2 minutes, adding more water or soil until it stops sticking to your fingers. Notice how the soil feels while kneading: gritty (sandy), silky (silty), or plastic/sticky (clay). If you can't create a bolus, the soil is very sandy.

Step 5: Form a Soil Ribbon. Gently press out the soil between your thumb and index finger to form a hanging ribbon. The ribbon should be only 2-3mm thick. The more clay in your soil, the longer the ribbon will be. Indication of ribbon length for various soil types:

Top of Form

Soil type	Length of ribbon
Loamy sand	5 -10mm
Sandy loam	12 – 20mm
Loam	25 – 30 mm
Clay loam	35 – 45mm
clay	50 – 75mm

LAP-test

Species selection exercise

An exercise using the table 1, 2, and 3.

Identify the percentage of Clay, Sand, and Silt of a specific soil requirements for 5 specific crop types. You can do so by linking the soil type under growth requirements (mentioned in tables 3, 4 and 5) with the Soil Texture Triangle in figure 10. Every soil texture class resembles a combination of percentages of Clay, Silt and Sand.

Learning Outcome 3. Biological measure strategies and Management

Introduction

Every Learning Outcome has a similar structure. In this Introduction, you find the specific learning objectives of Learning Outcome 3. The Instructions sheet(s) for both the Teacher and the Learner tell what is expected from both groups. Following is an Information sheet that provides background information, guiding question, and a self-test. Finalizing, when applicable, an Operational sheet tells you how to proceed with implementation of what is described in the information sheet.

By the end of Learning Outcome 3, you should:

- be able to mention different biological measure strategies
- be comfortable in explaining the different strategies with their specific benefits
- have a knowhow on the management aspect of the different biological measure strategies

Instruction for Teachers

1. Start by discussing the learning objectives for this Learning Outcome. Ask what they the students think is meant with the word ‘Strategy’ in the context of biological measures and why a strategy is important when applying a biological measure.
2. Let the student go through the Information Sheet, when questions are raised, answer them immediately. When every student is finished with the Information Sheet, discuss the guiding question in a plenary session. After that, let the students make the Self-Test.

Teaching Methodology

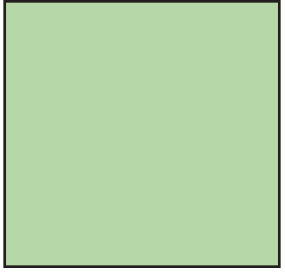
Brainstorming, interactive teaching and learning, discussions.

Session plan

- 15 minutes for the Introduction with discussion on objectives
- 60 minutes for the Information sheet 1
- 30 minutes for the Information sheet 2
- 15 minutes for the guiding questions within the Information sheet
- Total 2 hours minutes

Instruction for Learners

1. Read the Introduction ones more and make yourself familiar with the Learning Objectives of this Learning Outcome.
2. Go through the Information sheet. If anything is unclear, raise a question to the teacher.
3. If time left, already try to formulate answers to the guiding question, so you can actively participate in the discussion.
4. Make the Self-Test. After checking the Self-Test, critically reflect on your performance and check with yourself if you understand the reasoning behind the right answer. If not, discuss this with the teacher.
5. Work through the Operational Sheet and follow the tasks in the sheet.
6. Perform the LAP-Test



Information sheet 1 – Biological measure strategies

To create sustainable (Agro-)pastoral livelihoods, utilizing biological measures without a clear strategy and community incentive often does not lead to the expected outcome, both for the communities and for the ecological effect of the biological measure. Over time this would mean that communities are not actively involved, leading to the discontinuation of the biological measures. Clear strategies, accompanied with pros and cons are therefore essential in sustainable Biological Measures's. The vegetative species mentioned in Learning Outcome 2 can be utilized in different biological measure strategies. In this Information sheet, you will familiarize yourself with some strategies and how communities become comfortable with the application of the strategy. The application includes the general lay-out, vegetation species, and preparation. To remind you from Learning Outcome 1, the biological measures do not necessarily aim to increase productivity (that is mentioned in Theme 2), but aim to lift the total ecological value of the surrounding together with some additional socioeconomic benefits.

The biological measure strategies introduced in this Learning Outcome, which can be applied around physical structures are the following:

- Grass strips
- Hedgerows of shrubs and/or grasses
- Stabilization of physical structures/ river-banks
- Biological check dam
- Live fencing
- Area enclosure/ re-vegetation
- Cover crop
- Grass strips along WSWs (with elephant grass)
- Sansevieria strip along DSM
- And others

Figure 11: Biological check dams contributing to the stabilisation and restoration of gullies

Grass strips

Strategy

Grass strips along WSWs are common stabilization mechanisms that conserve both soil and water, by decreasing soil erosion, surface run-off (and sometimes wind erosion with high grass). They also help in increasing water quality, and biodiversity ((micro-) organisms that improve soil quality), and periodically provide fodder. Within the landscape, vegetation strips can be present in different locations (most efficient on gentle slopes, 5-8%) and sizes (length and width).

For example, the strips can be placed parallel (on the contour lines) with the wings of the WSW or DSM to make them more stable and less exposed to damage. Another option is to place the contours strips alongside the basin of the weir, which reduces the erosion of fertile soils. For agropastoral, placing vegetative strips around or within the field gives great benefits to soil fertility and water holding capacity. Do consider that the vegetative strip should not compete with the crops for water, nutrients and light.

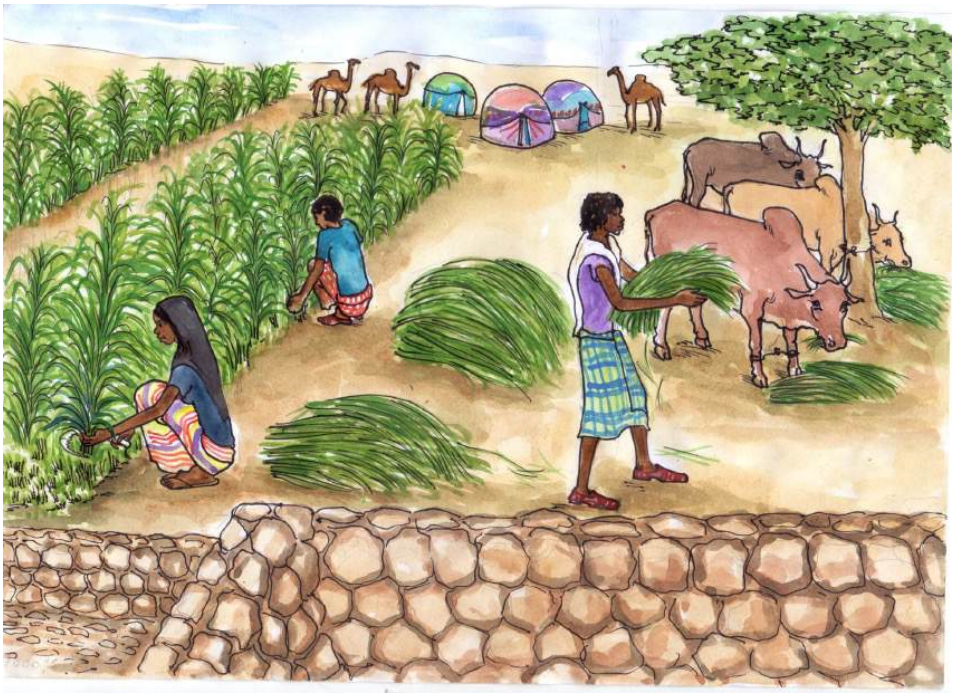


Figure 12: Grass strips planted in combination with WSWs. Besides the benefit of soil stabilisation it can be a source of fodder for livestock. When the main purpose of the grass strip is the erosion control, the grass strip should be planted along the WSW for a maximum result in terms of erosion control. When the strip is planted perpendicular, the main purpose is fodder.

Application:

To successfully apply grass-strips, the following lay-out is recommended:

- Grass strips should be placed along WSWs alongside contour lines (parallel to the physical structure)
- The slope depends the distance between two strips (the lower the slope, the larger the distance. E.g., at 3% slope distance around 30 meters, at 15% slope distance around 7 meters). Grass strips should not be applied on a slope higher than 8% for the Afar and Somali region.
- Width of the strip is around 0.5 – 1 meter. Planting can be done by sowing/broadcasting or splitting/cutting (in multiple lines two or three, with a legume in the middle line)
- Seed bed preparations before start of rain season, so that grass can root directly.

Similar to other biological measures, the chosen grass species should be perennial, drought tolerant, in some occasions waterlogging tolerant, compete with weeds, good dens ground cover, reduce run-off, and preferably provide an extra incentive in the form of fodder. Some species that might be beneficial in the Afar and Somali regions are Rhodes, Andropogon, and Vetiver. Additional, legumes like Stylo, Sirato, Desmodium can be combined.

Like mentioned, there are two general preparation techniques for grass strips: sowing and splitting/cutting.

Sowing requires seedbed preparation. During seedling preparation, be sure to take careful actions, as the seedlings are sensitive and vulnerable for changes in living conditions.

1. Prepare a mixture of fine sand, forest soil and farm yard manure,
2. Prepare seedbed/s with 1m width and 10m length by locating it against slope,
3. If the situation forces you to have more than one seedbed, leave 0.5m space between each seedbed for appropriate management,
4. Carrying out smooth and fine seedbed preparation for small sized seeds (grass seeds), generally 0.5-1.5 cm depth is optimal,

5. Ensuring the avoidance of big clods and soil movement during the seedbed preparation,
6. Watering the seedbed, a day before planting to stabilize the seedbeds and to avoid the burying of seeds due to soil movement.
7. Use small stick make a line with 30cm space and of 2cm depth against the length of the seedbed,
8. Mix the seeds with filter to have uniform plant population,
9. Slowly drop the seeds within the prepared line,

The steps above can also be applied in nurseries.

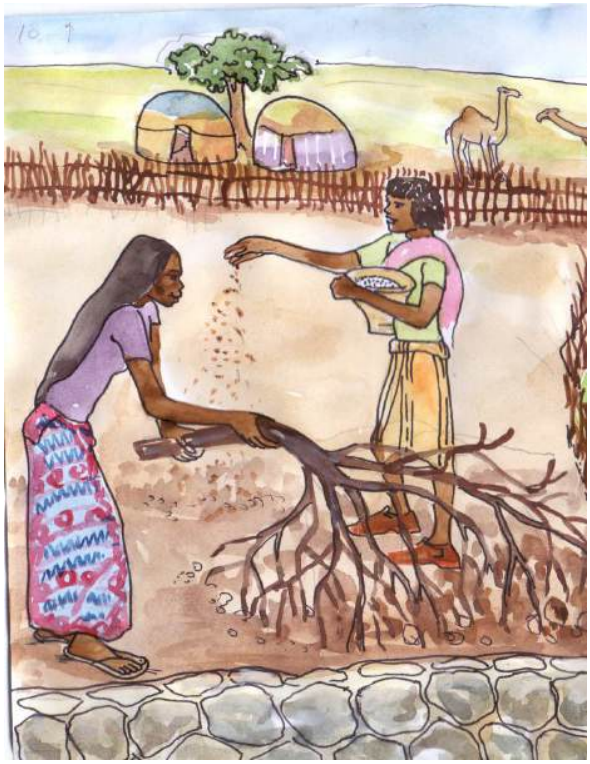


Figure 13: Preparing the soil before planting the grass strip

The other technique is splitting and cutting. Splitting and/or cutting of the biological measure (especially with grasses) can improve the time efficiency of the preparation because the biological measure does not have to start growing from seed. However, with this preparation method, a careful approach is important, as you don't want to damage the biological measure.

If using grass splits/cuts for planting, the following steps should be executed:

1. Grass is cut at about 12 cm above the ground;
2. Clump is uprooted and transported to the planting site;
3. Clump is split into pieces, including 2 to 3 tillers each to ensure good establishment;
4. Supervise plantation of grass splits in planting holes with a stick, ensure that the contact with the soil is good by putting a bit of pressure:
5. Spacing between cuttings/splits should not be wider than 5-10 cm to guarantee effective dense grass strips. 2 to 3 rows per meter of width (consider the option of legumes as middle row).
6. Depending on the vegetative specie, shading and the provision of wood are additional socioeconomic benefits.

Hedgerows of shrubs and/or grasses

Strategy

Hedge rows have similar characteristics and benefits as grass strips; however, they can consist of all kind of different species sorts. As often they are a bit higher, they better reduce the effects of wind erosion. Hedgerows can vary in length and height sizes. Be aware that they could attract birds and compete with other vegetation, so do not locate them too closely to crop fields.

Application

For good implementation, take care of the following tasks:

- Make sure the shrubs (branches in the shrubs) and grasses are dense and compactly grown.
- When moisture levels allow, even make double rows, with spacing around 30-40 cm. This gives added benefits for soil and water conservation as plant residues accumulate in the space between the hedgerows.
- Sow seedlings in a staggered patterns (10-20 cm, when using more shrubs than 20 cm, with grasses a bit smaller).
- Examples of shrubs that are suitable are Leucaena and Sesbania.

Stabilization of gully banks

Strategy

Due to overgrazing and vegetation removal gullies carve deeper and deeper in the landscapes of the Afar and Somali region. With the physical structures of WSW and DSM, a first step is taken in the reduction of soil and water conservation. Accompanied with this, biological measures can serve as stabilizers of the gully banks. This is important as the area around the gullies contain generally most fertile soils. Additionally, gully bank erosion might damage roads and bridges, or pastoralist migration routes. Stabilization of the gully banks differ from the previous two as they are implemented on the contour lines, while gully bank stabilization is parallel along the gully.

Application

A combination of trees, shrubs, and grasses can be done to stabilize the gully banks. During the first year (and especially first flood), protection of the vegetation from the flow of the water must be considered. This can be done with the help of wooden stakes or if finance resource allows erosion math placement. When the gully is carved in such a way that the gully bank slope is high, also remove soil to reduce this to a stable angle.

Accompanied with the vegetation growth, some tricks can temporary be applied to strengthen the gully beds at vital places where vegetation growth is needed:

- Tree recycles: rows of cut and/or dead trees that cannot be used for valuable processing practices (timber, fodder, etc) can be anchored to the foot of the bank (lowest part). Here they trap sediment flows. Make sure that the stems cannot flow away during the floods and damage the physical structures downstream.
- Use freshly cut branches to cover the slope of the bank. Make sure to tighten them so that they are kept together in times of floods.

Biological check dams:

Strategy

To apply physical structures (WSW and DSM) for every gully is costly and time intensive, because of to the required construction and maintenance. In a landscape where small side gullies (leading to the main gully with a physical structure) are present, biological check dams can function as useful stabilization method, in combination with WSWs and DSMs. Just like a concrete or stone check dam, a biological check dam is placed horizontally across the gully. When implemented correctly, the check dam reduces the flow of the water in the gully. This leads to a reduction in soil erosion. There are a few points to consider with the biological check dam.

1. Recognize how much water is logging in the gully bed. Tolerant vegetation specie should be chosen when waterlogging is high
2. Make sure that the biological measure is deep and strongly rooted into the soil before the flooding. This way you make sure that the measure does not get damaged and flow away
3. Take care of the density of the biological check dam compared to the depth of the gully. A large biological density with a shallow gully could divert the water to the sides and create gullies here. An optimal density ensures that water velocity is reduced evenly across the gully without stopping the water fully. With high flow velocities this can damage the crops (see point 2).

Be aware that for every specie, these points need to be re-considered, as for example grass dams (e.g., Elephant grass) result in different circumstances than a tree dam (e.g., Acacia tree). A combination of different vegetative species can be beneficial, as they strengthen each other.

Application

At the start of biological check dams, conditions should be optimal for quick and fierce rooting of the biological measure. That is why it is advised to start biolog-

ical check dams at the beginning of the rainy season. The following procedure can be used for the construction of a woody check dam:

- Use live cuttings from a desired species with a diameter of 2-4 cm and a length of 70 cm for the establishment
- Insert the cuttings 20 cm deep in a horizontal line across the gully floor and space them 50 cm apart;
- Make sure that the whole gully bed is covered
- Fill space in between the rows with smaller dead stems from any species, woven together to form a dam. Be aware not to make the weave too dense so that water cannot flow through, as this could lead to the destruction of the dam large run-off flows.

Figure 14: Inserting the cuttings in the flood of the gully, to start the biological check dam

Reinforced bundling/wattling, used in between woody check dams to create growing strips, reducing speed of water and as such erosion

- Bind fresh stems of the selected plants (e.g. elephant grass, Moringa or Jatropha) together.
- Plant horizontally and cover with soil;
- Optional: use other organic material (e.g. straw, tree branches);
- Fresh vegetative material are placed in between two rows of reinforcing materials (such as loose branches and cut shrubs) inserted in the soil as described for woody plant boxes.

At some point after the initial semi-permeable check dam, sufficient amounts of sediments have accumulated to plant an additional layer consisting out of fresh stems (e.g., elephant grass). Eventually, when applying layer after layer, small gully bed plantations can be created. These plantations can consist of waterlogging tolerant grasses or even legumes (after floods are receding).

Importantly: Always check whether the biological check dam has the expected beneficial effect with the floodings. If not, adjustments should be made accordingly.

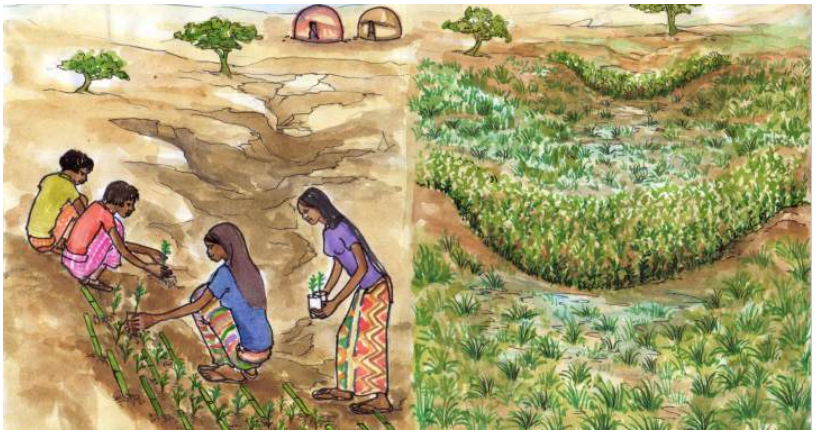


Figure 15: The first steps of the biological check dam and a fully grown and functional biological check dam

Live fencing:

Strategy

In Theme 2 of the Teaching and Learning Guide, livestock challenges within Flood-based Farming are acknowledged. That is why there is a potential need for live fencing, to protect areas from livestock, but also human and wildlife interactions. Next, live fences can protect homesteads or wind sensitive (like cereals) crops against strong winds. Depending on the size of protected land, live fencing requires quite some investment cost and time (maintaining of gaps). Therefore, live fencing should especially be applied around high potential and/ or productive patches of land (gardens, recently rehabilitated land, crop fields). Also be aware of permanent enclosure of common land, as this could result in conflicts. Therefore, before the implementation of live fences, good communication and by-law are important.

Application

For the application of live-fences, you can use one or more rows of trees, shrubs. When you decide to plant more rows, make sure that the distance between planted seedlings are minimal 30-40 cm apart (depending on species type, in a staggered pattern. When using a single row, the distance can be a bit smaller, as it is important that there are no gaps in the fence. The type of species determines the design and spacing. It helps to use nutrient fixating grasses/ legume sat the inside of the fence as this optimized the biomass production of the fence itself, meaning that no unwanted gaps are occurring. Instead of direct sowing, use seedlings to get quick outcomes for the fences.

Species that are found suitable for live fencing are: Jatropha curcas, Senegalia mellifera, Acacia nilotica, Lawsonia inermis, Ziziphus spp., Beles, Agave sisalana, Entada abyssinica.

In choosing the species, consider the type of fence (not a poisonous fence) and fill gaps with dead branches to ensure the fence is closed.

Figure 16: Live fencing can help protect the trees and bushes

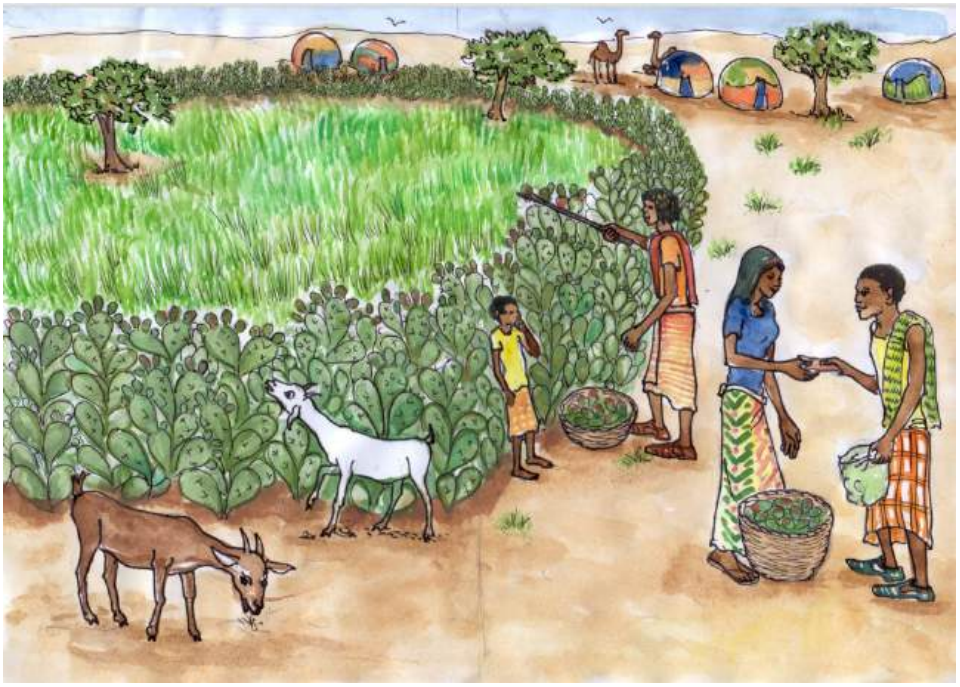


Figure 17: Live fences can also be used to grow edible fruits

Self-test:

Name	
Date	
Time started	
Time finished	

Instructions

Answer the question that are listed below. At the end, you can see whether your score is satisfying

Questions

Multiple choice

What is the main aim of biological measures (2pnts)?
1. Lift productivity
2. Create awareness of regreening among communities
3. Create windbreaks against wind erosion
4. Lift the ecological value of the landscape

A vegetation strip is always made from grass (1pnt)?
1. True
2. False

Out of the following statement regarding biological check-dams, which one(s) are correct (2pnts)?
1. Choose a vegetative specie that can tolerate waterlogging
2. Start building the check-dam in the dry period, so that it can function during the wet
3. Built directly multiple layers of vegetation so that the run-off decreases
4. Regularly check if the check-dam vegetation density is suitable with the run-off

Open question

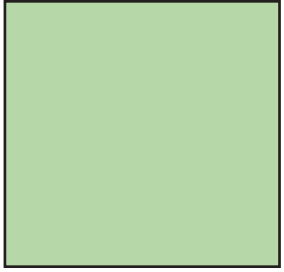
Mention two ways of grass preparation methods. Mention with each method a pro and a con (4pnts, one point for every right answer).

Rating

Satisfactory rating points 5 and above. Unsatisfactory points below 5.

You can ask your instructor for a copy of the correct answers. If your answer differs from that of your instructor for a very single point do not proceed to the next learning, rather better work on the same information sheet until you acquire all the necessary information.

Score: (insert number of points).



Information sheet 2 – Do's and Don'ts for biological measure strategies

Do's for Biological Measures near a Water-Spreading Weir

1. **Native Plant Selection:**
   Do choose native plant species that are well-adapted to the local environment, as they will require less maintenance, provide better habitat, and promote biodiversity.

2. **Root Systems and Soil Stabilization:**
   Do select plants with deep and extensive root systems to stabilize the soil and prevent erosion around the weir area.

3. **Planting Density and Spacing:**
   Do ensure an appropriate planting density and spacing to maximize plant growth, cover, and effectiveness in preventing soil erosion.

4. **Monitoring and Maintenance:**
   Do regularly monitor the health and growth of planted vegetation and perform necessary maintenance, such as weeding, to ensure their successful establishment.

5. **Consideration of Water Levels:**
   Do choose plant species that can tolerate fluctuations in water levels, especially in areas affected by the water spreading weir's operation.

Don’ts for Biological Measures near a Water-Spreading Weir

1. **Avoid Invasive Plant Species:**
   Do not use invasive plant species for revegetation, as they can outcompete native plants, disrupt the local ecosystem, and create long-term management challenges.
2. **No Chemical Pesticides or Herbicides:**
   Do not use chemical pesticides or herbicides near the weir area, as they can harm non-target species and contaminate water sources.
3. **Avoid Monoculture Planting:**
   Do not rely on a single species for revegetation, as it can lead to reduced biodiversity and decrease resilience to environmental changes.
4. **Minimize Disruption to Existing Vegetation:**
   Do not unnecessarily remove existing vegetation unless it poses a direct threat to the weir’s structure or operation.
5. **No Planting in Flood Zones:**
   Do not plant vegetation in areas prone to flooding, as it can be detrimental to the survival of plant species and may contribute to downstream sedimentation.

By following these do’s and don’ts, the biological measures for a water-spreading weir can be implemented in an environmentally responsible and sustainable manner, supporting the overall health of the ecosystem.

Operational sheet

Using biological measures means developing a strategy. As Development Agent, you have to facilitate in the discussion to decide on the strategy based on the needs of the community. You will give technical advice on the benefits of certain strategies but also on how to apply the strategy.

When decided on the strategy, you will assist in the preparation and application of the strategy to ensure that everything goes according to plan.

Objective

To have all stakeholders (community, PADO, clan leader and kebele leader) on the same page regarding the specific strategy and application plan. This also includes that everyone is aware of the value of the biological strategy, so that it can serve as long-term sustainable measure.

Procedure:

To decide on a strategy, full community awareness and involvement is necessary as they are the ones that have to maintain the biological measures. With biological measures, this is tricky, as unlike with Flood-based Farming (theme 2) the direct productivity of biological measures is low. Nevertheless, if there are clear strategies, biological measures can be low-costly, not labour intensive, and have high rewards. Additional to the community, the kebele leader and other DA's need to be involved.

Learning Outcome 4. Maintenance & Harvest Management

Introduction

Every Learning Outcome has a similar structure. In this Introduction you find the specific learning objectives of Learning Outcome 4. The Instructions sheet(s) for both the Teacher and the Learner tell what is expected from both groups. Following is an Information sheet that provides background information, guiding question, and a self-test. Finalizing, when applicable, an Operational sheet tells you how to proceed with implementation of what is described in the information sheet.

By the end of Learning Outcome 4, you should:

- have an understanding of the maintenance procedures of biological measures
- recognize when and how to control damaging biological measures
- be able to recognize when and what to harvest from biological measure
- know on how to take care of biological measures that are damaging the physical structures

Instruction for Teachers

1. Go through the Introduction of Learning Outcome 4 and discuss the learning objectives. Ask why they think that maintenance of biological measures is so important and in what ways the maintenance of biological measures differs from the physical structures. What is an extra benefit from maintaining the biological structure?
2. Let the students discuss for a few minutes and discuss in a plenary discussion the answers of the students
3. Read together with the students through the Information sheet. If students have questions related to the text, make sure to answer them immediately (if it is an important question, do this plenary).
4. Now go to the guiding questions and reflect on the discussion of point 1. Did the view of the students regarding maintenance change?

5. Provide the students help if the Self-Test is unclear
6. Go through the Operational Sheet

Teaching Methodology

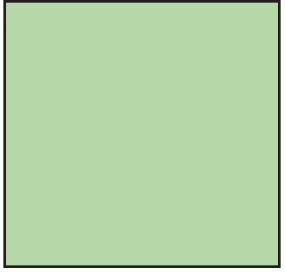
Brainstorming, interactive teaching and learning, discussions.

Session plan

- 15 minutes for the Introduction with discussion on objectives
- 30 minutes for the Information sheet
- 15 minutes for the guiding questions within the Information sheet
- Total 60 minutes

Instruction for Learners

1. Go through the Introduction and make yourself familiar with the learning objectives of Learning Outcome 4.
2. After a plenary discussion about the objectives, go through the Information sheet. If you have any questions, make sure to ask (or note down) questions if they arise to the teacher.
3. Create answers around the guiding questions at the end of the Information sheet.
4. Make the Self-Test. Be self-critical, so if questions are wrongly answered, try to figure out the right answers and why this is the right answer. For example, ask your teacher about this.
5. Go to the Operational sheet and perform the LAP-test. This sheet together with the LAP-test tries to imitate a real-life situation so be focused during this session.



Information sheet – Maintenance

- Part of the plant to harvest, to maintain the soil stabilizing characteristics of the plant
- Use of harvest/plant products, at home and commercial
- Tools for harvesting
- Preparing the field after harvest
- Seed production

Like all organic material, biological measures will grow when having suitable site conditions. This asks for proper maintenance of the measure. If applied smartly and adequately, this can be done time-efficient and can even go hand in hand with small harvest outcomes from the biological measures.

Management of biological measures

Learning outcome 3 of this Teaching and Learning guide presented some biological measure strategies. If right, you know by now how to apply them and where. This section will discuss some general and specific management tasks that should be done to maintain the strategies.

In general, as maintenance should be done regularly it requires planning and thus a maintenance plan. Therefore, after implementing a biological measure, you always have to build some community expectations around a maintenance as this is as important as the implementation itself.

Grass strips

Applicable species: Rhodes, Andropogon, and Vetiver. Additional, legumes like Stylo, Sirato, Desmodium can be combined.
Suitable locations: parallel to the wings of the WSW or parallel to the DSM, if the erosion control is the main aim of the measure

To proper manage grass strips, consider the following:

- Grass strips are vulnerable and should preferably be protected from

livestock (e.g., farmlands with grass strips can be protected by live-fences). This is especially the case with recently planted grass strips that are yet to develop a strong root system.

- Replace or replant when seeds or seedlings do not grow (sufficiently). This must be done to ensure erosion control. Replanting can be done in between the existing plants.
- Do not cut the grasses too often, as this will weaken the grasses. See the chapter on harvesting of grasses for the applicable interval.

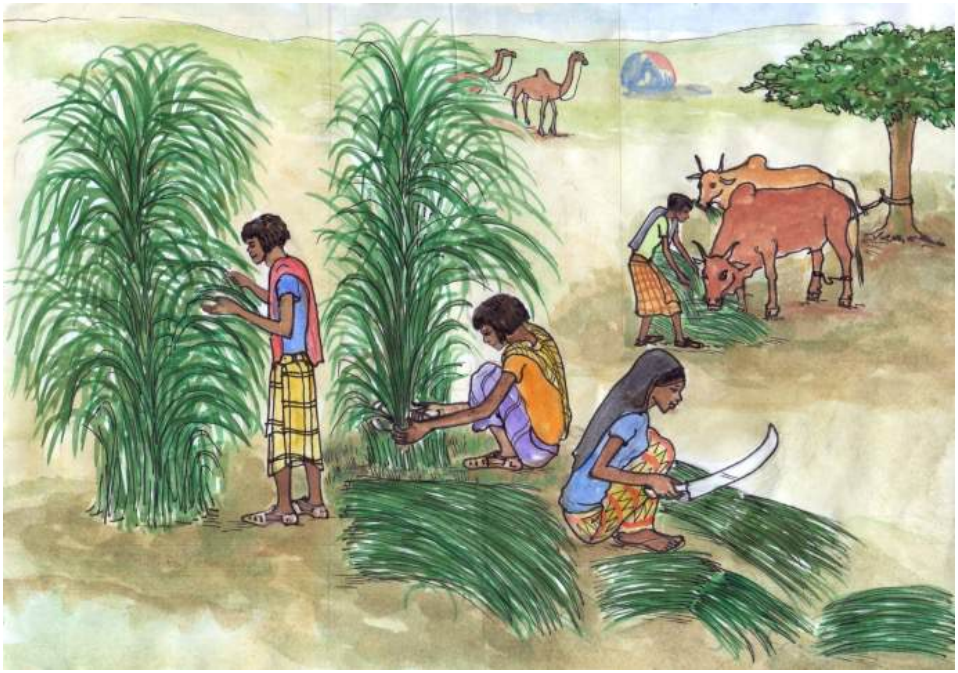


Figure 18: Only cut the grasses once they have grown sufficiently high

Hedgerows

Applicable species: Suitable shrubs are Leucaena and Sesbania. Also most grasses are suitable for hedge rows, combined with shrubs.

Suitable locations: similar to grass strips (parallel to the WSW or DSM). The hedge rows can also reduce effects of wind erosion, thus applicable with soil types vulnerable to wind erosion.

To proper manage grass strips, consider the following:

- Regularly trimming hedges stimulates the growth and thus also biomass control. When the hedge is cut too often or too little it can cause dieback. This means that the plant will die from the tip of its leaf backwards. To prevent this, a certain percentage leaves should always be maintained.
- For the first trim, seedlings should reach a base stem of around 6 cm.
- Cut the hedge about 10-15 cm height above the lowest branch
- Hedges have a good permanent height (species specific) when they reach around 70-100 cm above the ground.
- Trimming species slightly under their permanent height, prevent them from seeding and thicken their stem (and thus reduce soil erosion).
- Pruning frequency depend on the variety. Fast growing shrubs like Leucaena and Sesbania require pruning every 1,5 to 2 months under optimal conditions.

Gully bank stabilization

Applicable species: a combination of trees, shrubs, and grasses, combined with wooden stakes/branches of dead trees.

Suitable locations: at gully banks, combined with WSWs and DSMs. The gully bank stabilization is applied parallel to the gully.

For gully bank stabilization, there is no definite management procedure. Make sure to regularly check whether everything is still stable and will not be washed

away during flash floods. So especially check before the flood season. Fix problems immediately when needed to avoid further damage.

Biological check-dam

Applicable species: the biological measure should be deep and strongly rooted. For example elephant grass, acacia tree species, Jatropha, Moringa. A combination of species can strengthen each other.

Suitable locations: where small side gullies are present, in combination with WSWs and DSMs.

Revegetation of gullies takes time and labour, especially the first year(s). At the beginning, fast water flows can damage the vegetation, so always be careful for this. Important is to keep livestock away from the biological check-dam as it is a fragile structure and trampling with the hoofs can uproot the plants.

Live-fence

Applicable species: a row of trees or shrubs such as Jatropha curcas, Senegalia mellifera, Acacia nilotica, Lawsonia inermis, Ziziphus spp., Beles, Agave sisalana, Entada abyssinica.

Suitable locations: live fencing should especially be applied around high potential and/or productive patches of land (gardens, recently rehabilitated land, crop fields).

During early establishment, make sure that livestock does not affect the fence too much. After establishment, make sure that gaps within the fence are fixed to avoid development of gaps. This can be done in two ways: with pruning and waving branches together, you can train the plant to grow in a certain direction to fill the gap. The other way is to replant another plant at the place where there is a big gap.

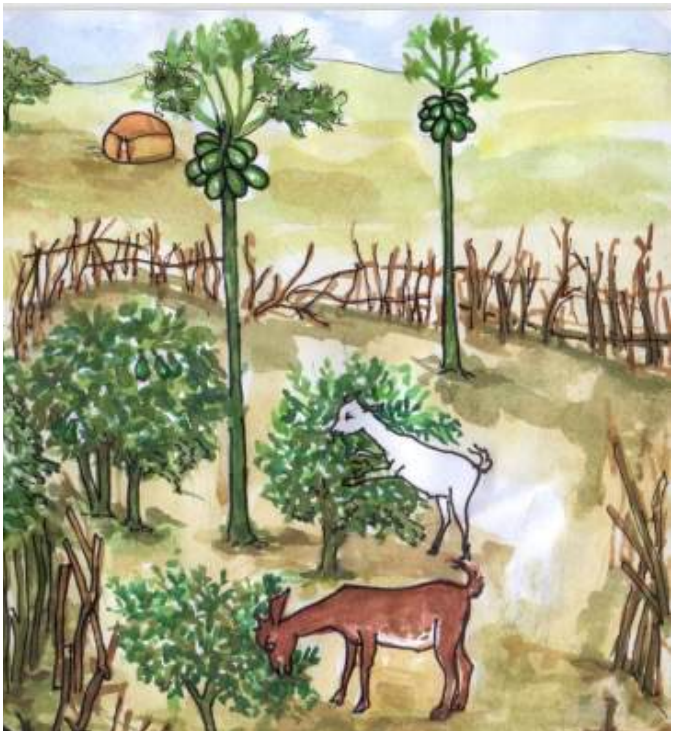


Figure 19: Ensure the live fence remains closed to avoid livestock from entering the area.

Control of constructing damaging plants

Most of the time, biological measures lead to benefits for soil and water conservation together with the physical structures (WSW, DSM). However, (potential) damage by the biological measure to the structure should carefully be managed. Both the roots and branches of biological measures (especially from trees and shrubs) can result in damage. Therefore, action should directly be taken when the measure grows too close or on structure walls. There are a few actions that can be done:

1. Pulling the biological measure out of the structure (be aware to not damage the structure by pulling out rocks as well)
2. Cutting and drilling. When the tree is growing in the structure and it cannot be removed by pulling, make flush cuts (cuts as close to the trunk or main branch as possible) or drill holes in the stump. This way, the biological measure will start rotting. Sometimes, the cutting and drilling should be done repeatedly for the biological measure to die.
3. When you see that the biological measure has become part of the structure without damaging it (this is often when the measure has been part of the structure for a long time), the measure can be left there. This is because trying to remove it might damage the structure more than leaving the biological measures in the structure.

Harvest

Like mentioned, maintenance and harvest of biological measures can go hand in hand. Harvesting at the right timing denies species to grow and/or spread uncontrolled. The following sections give specific harvesting techniques for the different vegetative groups.

Harvesting of grasses, legumes: Forage crops should be allowed to produce seed during the first year of planting. If there is excessive growth then it should be harvested in advance of flowering so that flowing and seed production is not affected.

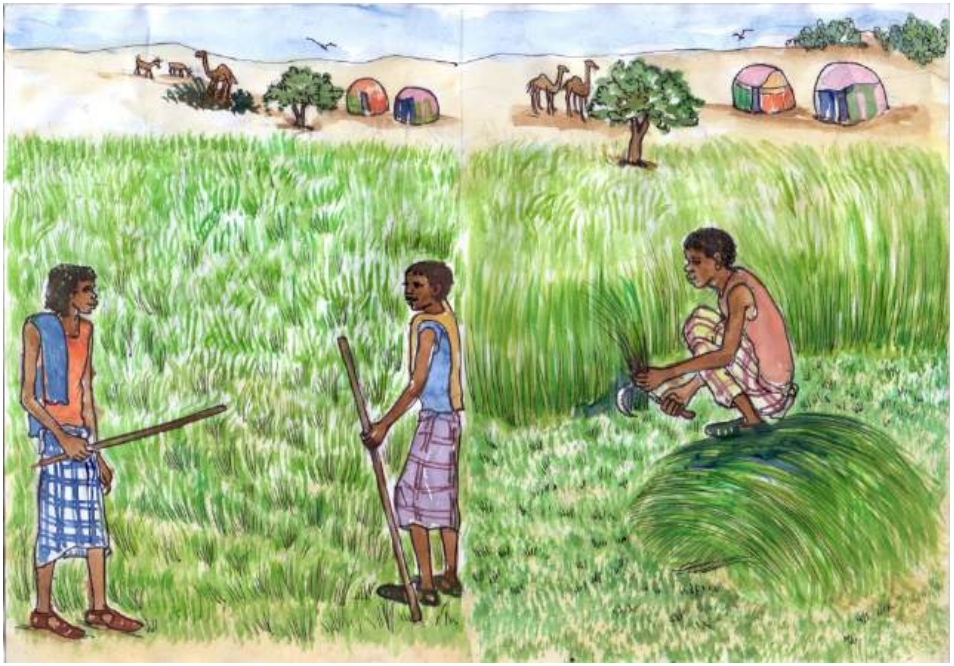


Figure 20: Harvesting grasses at the right time ensures their survival for the next season.

Forage should be harvested before or at flowering stage to harvest nutritious feed. Harvesting should be done about 10 cm above ground level so that re-growth is encouraged and plants do not die. This biomass can be used for feeding livestock as green or dry feed in the form of hay. Good quality hay should be made on time. Under the dry conditions, depending on the rains, one or two harvesting per year may be possible.

Grasses should be harvested before flowering, when their nutritional value is high. Harvested grass can be used as green fodder immediately or kept for a longer period through hay making. At harvesting time any crop growing on the

embankment should be harvested by cutting the stem and not by pulling them out so that the stability of the soil would not be affected. Pulling out the grass comes with the risk of damaging the roots and reducing the stabilizing benefits of the grasses.

Harvesting of grasses: Depend from their use and inner characteristics. Some grass should be cut frequently and at a young stage, other at flowering or filling time etc. If used as forage usually the first harvest is after 3-4 months from establishment, before flowering and cutting grass 10-15 cm above the ground.

Harvesting of fodder trees: To root deep and create stabilization, fodder trees should be allowed to grow strong in the first year. One exception in this is that the trees should be pruned at the top to allow side branching to produce more biomass. During harvesting after this first year, only young leafy branches should be cut with sharp knife and the old branches should not be damaged. The frequency of harvesting will depend on the weather conditions. Fodder trees provide high protein green feed and therefore, should be harvested during dry season. The green leaves should be mixed with dry grass while feeding livestock.

Harvesting of fruits: Fruit plants take time to grow and produce fruits. Timely pruning enables the farmer to produce more fruits from the same plants. Some plants may start flowering in the first year but this should be discouraged to allow the plant to grow strong to bear more fruits.

Management of crop residues: Efficient management of crop residues on the farm is very important especially in dry areas. It should be either used as livestock feed, mulching material or making organic manures such as compost. This will help to maximize the benefits of the biological measures.

Figure 21: Growing fruit trees, besides contributing to soil conservation, contributes to availability of nutritional foods

Self-test:

Name	
Date	
Time started	
Time finished	

Instructions

Answer the question that are listed below. At the end, you can see whether your score is satisfying.

Questions

Multiple-choice

Which of the following damaging control options is not an option (2 pnts):
A. Leaving the biological measure when it does not damage the physical structure
B. Pulling the biological measure out of the structure
C. Cut and drill the biological measure when it is not easy to remove
D. Removing the physical structure to remove the biological measure, then placing the structure back

Open questions

What is a side benefit of maintaining biological measures (1 pnt)?

Learning objectives/outcome 5. Strategies for controlling invasive

Introduction

Every Learning Outcome has a similar structure. In this Introduction you find the specific learning objectives of Learning Outcome 5. The Instructions sheet(s) for both the Teacher and the Learner tell what is expected from both groups. Following is an Information sheet that provides background information, guiding question, and a self-test. Finalizing, when applicable, an Operational sheet tells you how to proceed with implementation of what is described in the information sheet.

By the end of Learning Outcome 5, you should:

- understand the role of invasive species (with focus on Prosopis juliflora, Parthenium and Lantana) in the landscape
- be able to develop a clear plan on how to control Prosopis juliflora
- be able to mention different utilization techniques of removed Prosopis juliflora

Instruction for Teachers

1. Discuss the learning objectives of the Introduction, ask what the students know about invasive species and in special Prosopis juliflora.
2. Go through the Information sheet together with the students. If questions are raised, try to answer them immediately. End the Information sheet by discussing the guiding questions. Do this when all students finished reading.
3. Assist the students in the Self-test. This means that you help with needed clarifications around the questions and not content specific.
4. Operational sheet

Teaching Methodology

Brainstorming, interactive teaching and learning, discussions.

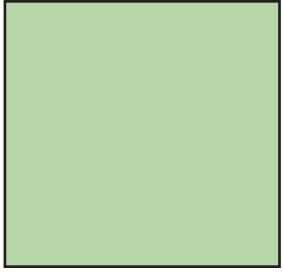
Session plan

- 10 minutes for brainstorming about invasive species in the Introduction
- 60 minutes for the Information sheet
- 20 min for guiding question within the Information sheet
- 30 minutes for the Self-Test
- 60 min for the Operational sheet

Total time: 3 hours

Instruction for Learners

1. Read the Introduction ones more and make yourself familiar with the Learning Objectives of this Learning Outcome.
2. Go through the Information sheet. If anything is unclear, raise a question to the teacher.
3. If time left, already try to formulate answers to the guiding question, so you can actively participate in the discussion.
4. Make the Self-Test. After checking the Self-Test, critically reflect on your performance and check with yourself if you understand the reasoning behind the right answer. If not, discuss this with the teacher.
5. Work through the Operational Sheet and follow the tasks in the sheet.
6. Perform the LAP-Test



Information sheet

Create awareness

With the use of any biological measure, there is a change that a specie finds the opportunity to outcompete other vegetation for natural resources like water, nutrients, and light. When this has negative affect for the socio-ecological environment, this specie is called an invasive species. In Ethiopia, a clear example of such an invasive species is the Prosopis juliflora. Other examples are Parthenium (Parthenium hysterophorus), Lantana (Lanrana camara) and Calotropis procera. In this chapter we will first focus on the prosopis and how to manage the species and then on Parthenium , Lantana and Calotropis.

Prosopis

In Ethiopia, Prosopis juliflora was distributed as a biological soil and water conservation intervention during the late 70s. Additionally, this specie was promoted to improve livelihoods by being a source of fuelwood, biomass, charcoal, and timber.

While the benefits are there, due to aggressive invasive character, it has led to decrease of native vegetation, grazing lands and agricultural land. Prosopis juliflora invades land and even worse encroaches on river beds and canal beds – blocking them and causing drainage patterns to uncontrollably shift. Particularly in areas where there is livestock grazing, Prosopis juliflora spreads rapidly: the seedpods cling to the animal skin. Prosopis juliflora germinates easily and once it has settled in an area it is difficult to get rid of it. It takes over the natural vegetation, does not allow undergrowth (the specie releases a chemical that blocks seed germination of other plants) and hence greatly reduces the grazing value of land. It also tends to creep into waterways – including dry riverbeds – choking them in the process and causing flood rivers to run wild. The Prosopis juliflora thorns are poisonous and can even cause blindness. Livestock, particularly cattle, can become ill when they are almost exclusively fed with pods of Prosopis juliflora.

Because of all these effects, this Learning Outcomes wants to create awareness around this species. Additionally, you should always be aware that other species might pop-up in the future as well. Controlling of invasive species is a dynamic work.

Complete removal of Prosopis juliflora is difficult (and attempts have been done in the past), because of its cost and time constraints. That is why it is best to look for ways to control the growth of the species so that negative effects are minimized and explore ways to benefit from the Prosopis juliflora that will be present in the landscapes. This way of dealing with Prosopis juliflora can be seen as control by utilization.

This method was introduced the Horn of Africa in 2014 and although it has shown the multiple uses of Prosopis juliflora, efforts are/were often not sustained. The main reason is the absence of ongoing support for training in technical and business skills plus the lack of markets and appropriate processing machinery. That is why the role of DA is important in facilitation of the whole process.

Control by utilization

To control Prosopis juliflora in a sustainable way, some actions need to be taken. Although the word control by utilization suggests that Prosopis juliflora is beneficial (which is true and should be done), controlling the specie should be central, especially around high valuable land. Therefore, this section first focusses on the main elements to control the spread of Prosopis juliflora and secondly how to use the remaining Prosopis juliflora that is still present in the landscape.

Control

The main elements in a controlled use strategy:

- Focus on removal of Prosopis juliflora from or around water ways, bio-

logical measures, highly productive land or land important for local food security.

- Prosopis juliflora main spreading technique is by pod attachment on animal skin. Therefore, keep the following in mind: never (or minimal) allow cattle movement between areas with Prosopis juliflora and important areas mentioned in point 1. Fencing (see Learning Outcome 3) could help with this.
- Land using communities should be encouraged to uproot Prosopis juliflora seedlings when they are still easy to remove.
- Governmental: combating and utilizing Prosopis juliflora in communal lands should be supported. Strong governance institutions and regulations are needed for this. Ways must be found to empower communities to make joint efforts with governments and authorities and private sector (for instance in biomass conversion, charcoal, poles for fencing and construction, see “Utilization strategies”), which until now is often discouraged.

Figure 22: Uprooting the prosopis

Figure 23: Burning the stumps of the proposis

Figure 24: Burning the proposis bushes

Utilization strategies

As mentioned, converting Prosopis juliflora into a valuable resource can also presents opportunities to the communities. However, for this, full participation of local communities is necessary. To remind, utilization should be done next to appropriate control measures in the previous section. Some strategies are presented here, the Operational sheet contains the techniques of the different strategies.

- **Charcoal production**

  Converting Prosopis juliflora into charcoal can create rehabilitation of land and/or be used in local market chain. By spreading charcoal and using it as bio-char, acidic degraded land can be rehabilitated and yields can be increased. Charcoal improves the physical, biological and chemical properties of the soil by releasing and storing nutrients, increasing the bulk density, improving the overall porosity and creating favourable conditions for micro-biological activity.

  Besides, charcoal with good properties and can easily be traded on markets. In Ethiopia farmers are trained in labour efficient charcoal production techniques using metal kilns instead of traditional kilns.

Figure 25: Bags with charcoal, made from prosopis

- **Fodder**

  In terms of fodder, it is important to recognize the control aspect of Prosopis juliflora. Grazing livestock is the major spreading way of the specie (see control strategies). Therefore, never let free ranging animals eat Prosopis juliflora pods directly from the tree. Alternatively, the pods can be collected and afterwards ground with hammer mills to produce flour which can be included in the animals' diet. The percentage of the flour in the mix should be kept below 50% in order to avoid digestion disorders among the livestock. Flour can also be used on the local markets.

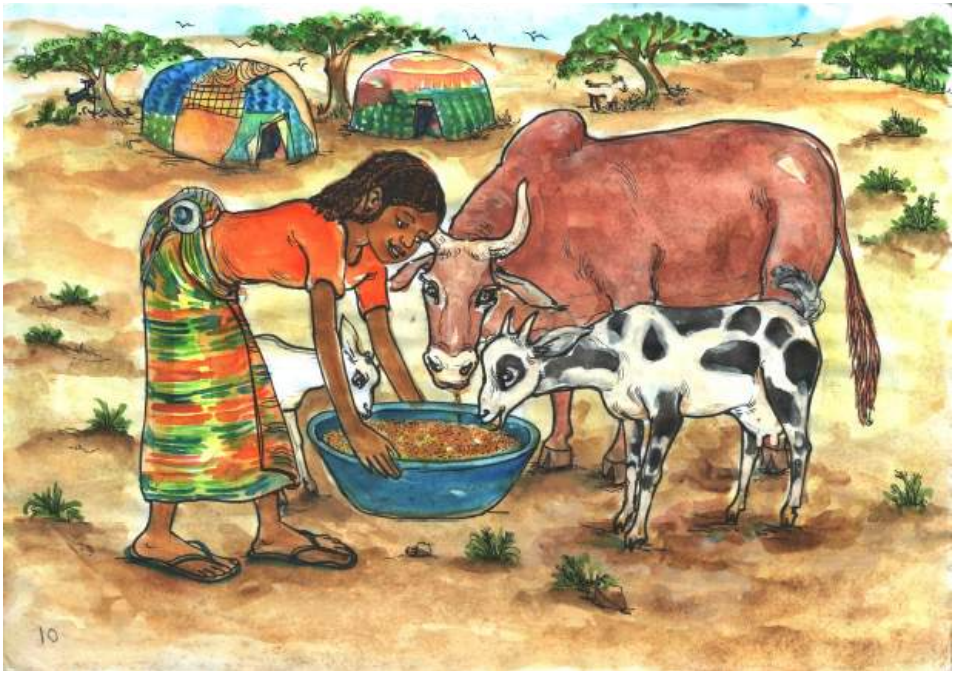


Figure 26: Feeding the prosopis to the livestock

- **Bio-Fuel**

  Prosopis juliflora wood is hard, burns slowly and has excellent heating properties. Prosopis juliflora is an underestimated source of sugars that can be converted into ethanol.

- **Timber**

  Prosopis juliflora wood is extremely hard and durable. It also has an appealing coloration that makes it ideal to make furniture with. The wood matures quickly and stems become dark inside when the plant

is trained as a tree. The mature timber is resistant to pest attack and weathering and thus can be used for furniture making and other useful purposes especially housing. It is also used as parquet flooring wood. However particularly in stressful conditions of dry areas, Prosopis juliflora trees remain craggy, crooked and small, which makes using them to make furniture or charcoal less attractive.

- **Wood chips**

  Wooden residues from Prosopis juliflora can be chipped off and used as mulch on the crop fields. The mulch is effective in reducing evapotranspiration. Consequently, it also reduces the plant water consumption. The chips have also been successfully proceeded into wooden pulp, which is the primary raw material for paper production.

Although these utilization and control strategies all sound promising, there is a few essential elements. To make a sustainable control by utilization strategy, community support is required to mobilize, train groups the appropriate process techniques, improve local governance, and of course create local market chains to develop new enterprises.

Guiding questions:

- What is an explanation of the meaning of control by utilization?
- Why is it important to know different utilization techniques of Prosopis juliflora for the communities?

Parthenium (Parthenium hysterophorus)

Parthenium (Parthenium hysterophorus) is a highly invasive and toxic weed that originated in the Americas, but has spread widely to many parts of the world, particularly in Africa, India, Australia, and Asia. Below is a description of Parthenium, its impacts on humans, livestock, agriculture, pasture land, and some of the promising management measures.

Characteristics:

- Parthenium is an annual plant with leaves that have deep cuts, green stems, and small white flowers. It typically grows to a height of 0.5 to 2 meters.
- It reproduces primarily by seeds, with a single plant capable of producing thousands of seeds. The seeds are easily spread by wind, water, animals, and human activities.
- The weed thrives in various environments, including floodplains, agricultural areas, and overgrazed pastures. These characteristics have made many arid flood-dependent agricultural and pasture areas across Ethiopia and African lowlands highly vulnerable to invasion by this weed, which, as explained below, is harmful to the health and well-being of local communities and their livestock (see details at: Effects and management of Parthenium).

Impacts on Humans:

- Health risk: Inhaling Parthenium pollen or dust from infested areas can lead to various significant health issues, including liver infections increasingly prevalent in the Ethiopian lowlands.
- Serious Allergies: Pollen grains, airborne dried plant parts, and roots of Parthenium can cause allergies like hay fever, asthma, and bronchitis.

Impact on Livestock:

- Health risk and mortality: Consumption of Parthenium can cause mouth

ulcers (painful wound) with excessive salivation. If a significant amount (10–50%) of this weed is included in animal feed, it can result in poisoning, especially in cattle, which are among the common livestock in Ethiopia and various African lowlands.
- Allergies: Animals may develop skin allergies and respiratory (breathing) problems when exposed to Parthenium.

Impacts on Agriculture and Pasture Land:

- Outcompetes most plants: Parthenium is a highly competitive weed that can quickly invade agricultural fields and pastures, outcompeting desirable crops and forage plants for nutrients, water, and sunlight.
- Reduces yields: Studies have shown that Parthenium causes yield declines of up to 40% in agricultural crops. For instance, Sorghum (Sorghum bicolor L. Moench) grain yield losses between 40 and 97% have been reported in Ethiopia if Parthenium is left uncontrolled throughout the season.
- Impedes germination: Parthenium contains chemicals such as Parthenin, which prevents the germination and growth of many types of plants including food and fodder crops.
- Inhibits nitrogen fixation: It hampers nitrogen fixation by leguminous crops, negatively affecting natural soil fertility enrichment.
- Reduces fruit setting: The vast quantities of pollen (an average of 624 million per plant), which are carried by the wind for a short distance in clusters of 600–800 grains, and settle on the reproductive sections of the plant's leaves and flowers, hinder the development of fruits in crops like tomatoes, beans, and capsicum.

Management Measures:

There are various promising and some proven biological, chemical, mechanical, and farming practices to manage and control Parthenium (see, for example, Effects and management of Parthenium). The most relevant and effective measures for the arid lowlands across Ethiopia and the Horn of Africa (the focus of this TTLM) include the following:

- Farming and grazing practices: Avoid, as much as possible, keeping agricultural land fallow (unutilized) for more than one season, as this increases the opportunity for invasion by Parthenium. To maintain and enhance soil fertility, adopt intercropping and crop rotation practices. Likewise, implement controlled grazing and similar methods to prevent overgrazing, which can result in the extensive growth of the opportunistic Parthenium.
- Mechanical control: Physically uprooting Parthenium before flowering and seed setting. Uprooting the weed after seed setting will increase the area of infestation. To mitigate health hazards, the best practice is to plough the land as soon as the weed is spotted and before it seeds. This should be followed by cultivating the desirable plants. If tillage or machinery use is not feasible and manual uprooting is necessary, wearing protective gloves and boots is essential. Additionally, using a face mask (or a clean piece of cloth if masks are unavailable) is recommended to minimize health risks.
- Biological control: promote the aggressive cultivation of the few multipurpose plants that have the capacity to suppress the growth of Parthenium. Examples of such drought-tolerant plant species include Cassia auriculata, Cassia tora, Cassia tora, and Cassia sericea. A study in India found that Cassia sericea reduces the accumulation of Parthenium by 70% and the Parthenium population by 52.5%.

Effectiveness of Burning as a Management Method:

Burning, which is a commonly practiced weed control and agricultural land preparation method, is not effective against Parthenium.

Lantana (Lantana camara)

Lantana camara, an invasive perennial shrub native to the Americas, has spread to arid and semi-arid regions in Africa, including Ethiopia. Despite its initial ornamental appeal and certain benefits, its negative impact on human and livestock health as well as agricultural production, has led to its diminished favour among the local communities.

Below, we outline the characteristics of Lantana camara, its negative impacts on human and livestock health, and agricultural lands. Following that, we present some implementable management methods. Finally, we will touch upon some of the benefits including the medicinal values of Lantana camara, emphasizing the need for caution when considering their use.

Characteristics:

- Grows 3-5m tall with a pungent scent from thorny stems and toothed leaves.
- Produces brightly coloured flower heads and seeds.
- Thrives in all environments including agricultural as well as in woodlands, forming dense, impenetrable thickets.
- Exhibits prolific seed production, germinating throughout the year, and having seeds that remain viable for 2-5 years.

Impacts on Human and Livestock:

- Toxicity: Contact or ingestion of Lantana camara causes skin irritation and digestive issues in humans and animals.
- Livestock Health Issues: Consumption by cattle and goats can lead to liver damage, posing severe health risks and potential fatality.
- Wildlife Shelter: Dense growth provides shelter for predatory wild animals, posing risks to rural communities and livestock.

Impacts on Agriculture and Pasture Land:

- Reduction in Crop Productivity: Studies show that Lantana camara significantly diminishes the growth and productivity of staple crops like teff, maize, and haricot beans. Land Transformation: Rapidly colonizes fallow lands, rendering them unsuitable for agriculture and grazing, transforming productive land into wasteland.
- Impact on Natural Ecosystems: Invades natural forests, competing with and reducing the population of multipurpose trees.
- Waterways and Irrigation: Chokes irrigation canals, resulting in poor water delivery and agricultural productivity.

Management Options:

- Prevention measures:
  - Community Engagement: Educating local communities about the negative impacts of Lantana camara and promoting alternative ornamental plants can discourage its intentional planting and spread.
  - Mapping of Infested Areas: Creating maps of known infested areas facilitates effective monitoring. Enforcing strict quarantine laws to prevent the weed's transportation from infested to non-infested areas within the country can effectively control its spread.

- Mechanical control:
  - Physically removing the plant by uprooting, slashing, or digging proves effective, especially for smaller infestations. To mitigate health risks, it is crucial to wear protective boots and gloves, and if possible, cover the mouth and nose with a piece of cloth in the absence of proper masks. For larger affected areas, machinery like bulldozers, tractors, or oxen-ploughing may be necessary.
  - It is important to promptly repurpose cleared areas for crop or pasture production to prevent the weed from resurfacing.

Effectiveness of Burning as a Management Method:

As is the case with Parthenium, burning is not a dependable or effective control method. While Lantana camara might readily burn during hot and dry conditions, even when green, moderate or low-intensity fires can actually encourage the persistence and spread of its thickets rather than diminish them.

Caution in Usage:

In certain parts of Ethiopia, Lantana camara is used by traditional healers to address various ailments like headaches, general malaise, diarrhea, and fungal issues. However, this traditional treatment poses several of the health risks mentioned earlier. Thus, the strong recommendation is to avoid it as much as possible to minimize potential health hazards.

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- Kidane, B., Van Andel, T., van der Maesen, L. J. G., & Asfaw, Z. (2014). 'Use and management of traditional medicinal plants by Maale and Ari ethnic communities in southern Ethiopia.' Journal of Ethnobiology and Ethnomedicine, 10.

Calotropis procera

Calotropis rocera, known as the apple of Sodom, thrives in arid and semi-arid regions. Indigenous to Northern Africa, the Arabian Peninsula, the Middle East, and southern Asia, including countries such as Algeria, Egypt, Libya, Sudan, and Kenya, it was once cultivated as an ornamental garden plant in Ethiopia, but has now lost favour due to its poisonous nature and classification as a weed.

Characteristics:

- A tall shrub with waxy stems and milky sap-containing leaves.
- Large greyish-green leaves (5-20 cm long and 4-10 cm wide) borne in pairs embracing the stem.
- Flowers with five white petals ending in reddish tips and a purplish crown-like centre.
- A sizable bladdery ‘pod’ (8-12 cm long) that releases countless seeds, each topped with long, white, silky hairs upon maturity.

Impacts on Humans and Livestock:

- The milky sap is highly toxic to humans and, in high doses, can be fatal as it interferes with heart function.
- It can cause eye injury and vision loss if parts of the plant get into the eye.

Impacts on Agriculture and Pasture Land:

- Aggressively grows outcompeting all major and desirable crops such as teff, maize and beans and reducing their productivity.
- It forms dense thickets, competing with native grasses, altering plant communities, and impeding pastoralism by reducing pasture yields and complicating mustering.

Management Measures:

- Eradication proves challenging due to deep roots and resistance to herbicides. Mechanical weeding is commonly used, akin to the preventive measures outlined for Lantana Camara.
- In Ethiopia and similar regions, the primary method is cutting trees to ground level, alongside strict adherence to precautions to minimize health risks as outlined in the case of the above two invasive species.

Caution in Usage:

- Traditional medicinal applications are discouraged due to associated health risks.
- For erosion control, it should only be utilized in barren areas, avoiding high-yield agricultural and pasture lands.
- Dead weed stems can be safely utilized for firewood, fiber, and rope productio

Effectiveness of Burning as a Management Method

There is limited conclusive evidence supporting burning as an effective management strategy for Calotropis Procera.

References

- https://keyserver.lucidcentral.org/weeds/data/media/Html/calotropis_procera.htm (Weeds of Australia- fact sheet)
- https://apps.worldagroforestry.org/suitable-tree/Ethiopia

Self-Test

Name	
Date	
Time started	
Time finished	

Instructions

Answer the question that are listed below. At the end, you can see whether your score is satisfying

Questions

Multiple-choice question

What was the government's main reason to introduce Prosopis juliflora in Ethiopia (2pnts)?
A. Improve livelihoods as being a source for bio-fuel, charcoal, etc.
B. As biological soil and water conservation intervention
C. It wasn't introduced, but came as an invasive species by itself
D. To grow vegetation in (semi-) arid landscapes, what no other vegetation can do

Open question (Short-answers)

What is the main spreading way of Prosopis juliflora (2pnts)?

Name 3 negative effects of Prosopis juliflora (3pnts, one point per right answer):

Explain the two main components in “control by utilization” (4pnts, two points per right answer)?

Give 4 utilization strategies of Prosopis juliflora (4pnts, one point per right answer):

Rating

Satisfactory rating points 11 and above. Unsatisfactory points below 11.

You can ask your instructor for a copy of the correct answers. If your answer differs from that of your instructor for a very single point do not proceed to the next learning, rather better work on the same information sheet until you acquire all the necessary information.

Score: (insert number of points)

Operational sheet

Control of Prosopis juliflora is essential for having a flourishing landscape. At the same time, the control is something that needs to be agreed on by the whole community. Therefore, as DA, you have the task to make all stakeholders aware of this, including the kebele or clan leader, PADO, and the community itself. The DA also needs to provide technical advice on how to control Prosopis juliflora and regularly check if the agreements are followed. If everything went well, by the time you discuss the control of biological measures, you have established good connections with the PADO, other DA(s), kebele or clan leader, community, and potential other stakeholders.

Objective

A clear control plan that is supported by all stakeholder is developed.

Procedure

1. For the control of Prosopis juliflora, all stakeholder needs to be involved. Therefore, call for a meeting.
2. Give everyone a say (including woman and youth) in the initial meeting. What is the view of everyone on the growth of Prosopis juliflora? How does everyone envision the control of the specie? What is the potential the utilize the specie (young or women entrepreneurship in the management)? Are there any current regulations for common areas in place? Did the community get previous training?
3. Discuss preferred control method and specific needs for this method
4. Is there place to install any by-laws for violating rules regarding the spread control of Prosopis juliflora.
5. Follow-up on the decisions that are made during the meeting.
6. Plan a second meeting in which some utilization techniques are presented.

During the whole meeting(s), notes should be taken by someone so that follow-up actions and meetings can be executed efficiently.

Utilization strategies

Charcoal

Resource requirement

- Storage bags/ sacks
- Labour force
- Optional: burn pit with metal roof

The following steps should be done to make charcoal:

1. Cut – a common rule is that all roots and branches that have a thumb thickness or larger (preferred) can be used for making charcoal.
2. Clear – make sure to completely deal with the remaining of the tree. So also, the stumps in the ground, as they will grow back quick. Pile a bunch of small branches on top of the stump and burn it or remove the stump from the ground making sure to remove all roots.
3. Processing – charcoal is produced under oxygen-scarce heating of the branches. This can be done in two ways: making a pit and cover it with a metal roof or built a tower of branches and cover it with soil. The further you go inside, the larger the stumps and branches should be. Afterwards, light it with small branches and control everyday whether the process is still running.
4. Store/ transport – After the burning process (generally takes a few days for smaller pits and 10 days for larger ones), leaf the coals for a few days to cool. Load into bags afterwards and take the product to the local market.

Fodder

Resource requirements

- Collecting bags
- Dry space
- Mill
- Storage bags/sacks

Figure 27: Bags with charcoal, made from prosopis

Processed Prosopis juliflora pods have great nutritious and economic value. Therefore, the following steps have to be taken to make Prosopis juliflora flour:

1. Collect – After flowering, the Prosopis juliflora makes golden-yellowish pods. These need to be collected (preferably direct from the tree). Make sure you collect undamaged, clean pods. In the collecting process, no sand or stone should be included as this will damage the quality of the flour.

2. Dry – Spread the pods on rooftops, plastic sheet and/or concrete floors (not on the ground as infected pots might sicken the animals!). Sun-dry the pods, when fully dried, they can be stored for over a year.

Figure 28: Drying the prosopis pods

3. Grind – Use a mill to grind the pods. Only use clean and dry pods. Additionally, somewhat moisture pods will damage the mill, so consider the moment of the day in which the air is dry. After grinding, directly put the flour in sacks and seal off.

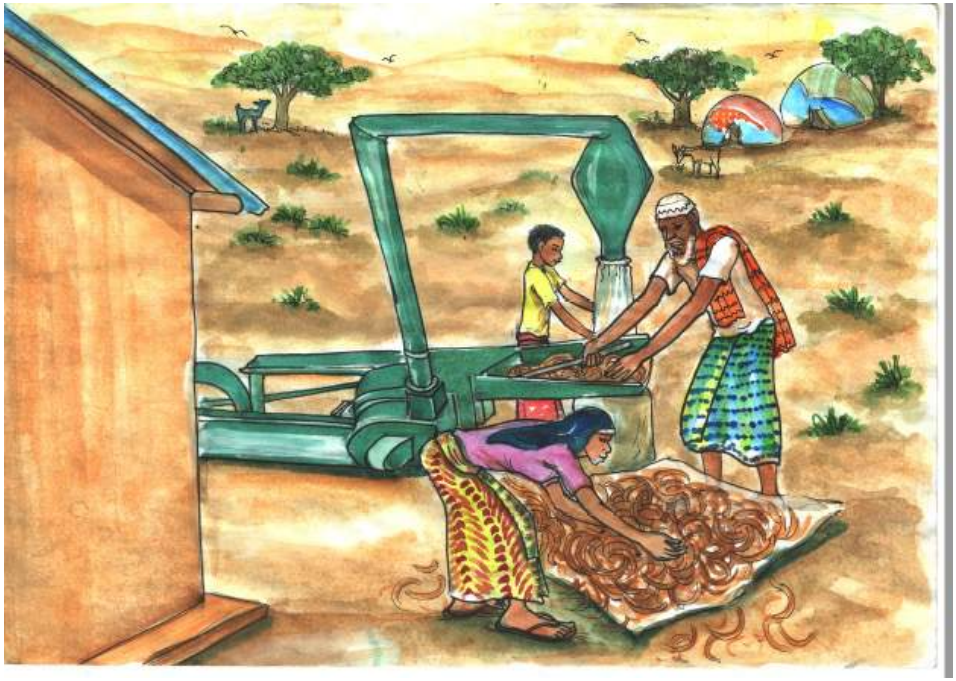

Figure 29: Grinding the prosopis pods for livestock feed

4. Mixture – as mentioned in the Information sheet, mixing 50% Prosopis juliflora flour with other fodder is best for the animals.

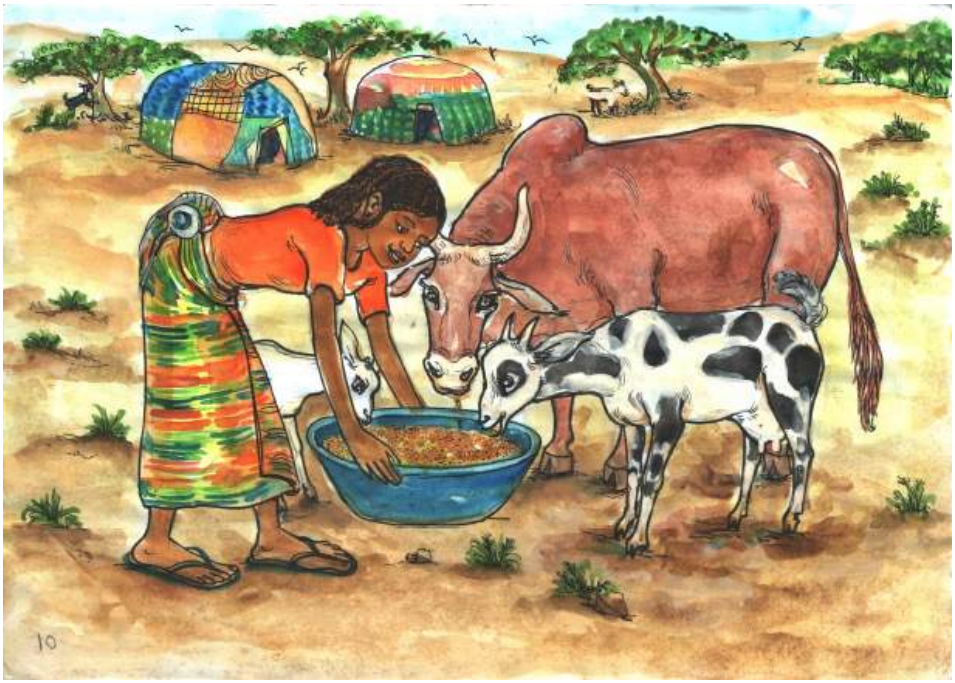

Figure 30: Feeding the prosopis to the livestock

Glossary of the technical terms

Area under rehabilitation:	An area where interventions are implemented designed to improve soil, water and vegetation conditions by reducing land degradation.
Area under protection	Defined as area, which is managed by a community under the governance of a participatory land use plan at community level with corresponding by-laws. The adherence should result in observable improvements of used natural resources, e.g., through cultivation area.
Available Water Capacity (AWC).	The water available for plant growth held between Field Capacity and Permanent Wilting Point
Bare land	It is land of limited ability to support life and in which less than one third of the area is covered by vegetation or other cover. It may be constituted of bare exposed rock, strip mines, quarries and gravel pits. In general, it is an area of thin soil, sand or rocks.
Basin	Any area draining to a point of interest
Cascade	A cascade is a series of Water-Spreading Weirs that reinforce themselves creating optimal growing conditions over an area of 200 to 800 hectares by increased infiltration of flood waters and the sedimentation of fertile sediments from the highlands. The area of a cascade is measured from the first upstream weir up to the last downstream weir. The upstream weir will be located in an area where erosion of the dry valley starts. The final weir will be at the area where there is no longer a change for high erosion (i.e. relatively flat areas, rocky areas, etcetera).
Catchment area	The area from which rainfall flows into a river, lake, or reservoir.

Climate	Also known as the “average weather” over a long period of time (generally 30 years). Within climate different variables (temperature, precipitation, and wind) can be identified.
Community	People who are living within or outside of the dry valley and utilizing the available natural resources within that dry valley. The contribution of community be considered for developing sense of ownership and as a checkpoint to know how the system is functioning properly and necessary to the target communities.
Counter Wall	The end of the wall of water spreading weir; party wall
Cropland	is defined as land used primarily for production of food and forage whether rain fed or irrigated; this category includes both cultivated and non-cultivated lands.
Discharge	Runoff excluding offsite flows, leaving the proposed development through overland flow, built conveyance system or infiltration facilities
Downstream	The direction of a stream or river flows
Dry Forest	Any vegetation found in areas with limited water resources and low annual precipitation which fall within an altitude range of 500 to 1500 meters above sea level. These forests are composed of several tree species adapted to limited water conditions including forage, timber, charcoal and gums and resins producing species

Dry Stone Measures	are structures constructed from loose stones laid along the contour lines. They are constructed in a series, and the measures can be used to fill smaller gullies (up to 1.5 m depth) feeding into the dry valley and disperse runoff in flatter areas. They are designed to reduce the speed of water flow, retain organic matter and deliver a water-spreading effect (although less than a water-spreading weir). DSMs function best in combination with biological protection.
Dry Valley:	A dry valley is defined as a segment of a dry river valley receiving seasonal floods from the highlands. The dry valley upper and lower boundaries are defined by a non-erodible base made up of stones or an intact floodplain. The dry valley includes all run-off areas within the upper and lower boundary towards the dry valley. It includes all the natural resources in a basin, especially water, soil, and vegetative factors. At the socioeconomic level a dry valley includes people, the farming system (including livestock) and interactions with land resources, coping strategies, social and economic activities and cultural aspects.

Field Capacity (FC)	Refers to the relatively constant soil water content reached after 48 hours of drainage of water from saturated soil. Drainage occurs through the transmission pores (greater than about 0.05 mm diameter, but note that field capacity can correspond to pores ranging from 0.03 to 0.1 mm diameter). The FC concept only applies to well-structured soils where drainage of excess water is relatively rapid; if drainage occurs in poorly structured soils, it will often continue for several weeks, and so poorly structured soils seldom possess a clearly defined FC. FC is best determined in the field by saturating the soil and measuring its water content after 48 hours of drainage have elapsed. Soil at field capacity feels very moist to the hands.
Flood Based Farming	the process of utilizing excess runoff (floods) for growing food, fodder or fuel in areas where no other options are possible
Gabion Check Dams:	are placed and anchored in gullies, function similarly to masonry check dams but with some distinct features. These dams, reinforced by sturdy mesh wire known as gabion, are designed to be lower in height compared to traditional masonry check dams. They are particularly effective in stabilizing deeper gullies and controlling the flow of water. So that soil can settle behind the gabion wall, and allow water to flow over it, mitigating the force of floods.
Gully erosion	A gully is a landform created by running water eroding sharply into soil on a hillside or slope.
Harvest	The season/ process of gathering crops, leaves, fruits from a specific target species
Infiltration	The penetration of water through the ground surface into subsurface soil

LAP-test	Learning Accomplishment Profile Test, examined by an assessor.
Leguminous plant	A plant that is able to fixate the nutrient nitrogen. This increases the fertility of the soil.
Live Check Dams	These are innovative structures designed to combat erosion while minimizing the costs of establishment. This method involves strategically planting suitable species to form a horizontal barrier across the gully bottom. By effectively reducing the velocity of flowing water in the gully, live check dams serve as a defence against erosion.
Maintenance	Making sure that over time the desired effect of a measure (in this case a biological measure) is still intact.
Masonry Check Dams	are a non-permeable, low-based masonry structure that span the entire width of a riverbed. Masonry check dams are constructed at deep, preferably stony gullies with a depth of up to four meters. If necessary, they can be increased in height after each rainy season to fill the gully. The final stage, once level, check dams can be upgraded to a WSW.
Pasture land	Pastureland/Rangeland: Extensive area of land on which the vegetation is predominantly grasses, shrubs and is managed as a natural ecosystem. It is a significant source of livestock feed and of livelihoods for stock raisers and herders.
(Agro-)Pastoralism:	is a traditional system that combines agriculture and livestock management. Communities practice both crop cultivation and animal rearing for sustenance and livelihoods. This approach maximizes resource utilization and is commonly practiced in arid or semi-arid regions.

Permanent Wilting Point (PWP)	Refers to the water content of soil that has been exhausted of its available water by a crop, such that only non-available water remains. The crop then becomes permanently wilted and cannot be revived when placed in a water-saturated atmosphere. At this point the soil feels nearly dry or only very slightly moist.
Primary users	People living within the delineated dry valley or using area within the delineated dry valley permanently
Productive Use	is the utilization of a delineated dry valley for biomass production like for food, fodder, fuel and fibre crops. Residual moisture for crop/fodder production and drinking water for livestock and humans.
River basin	The area drained by a river and its tributaries.
Runoff	Water that flows over the land surface entering rivers, lakes or other reservoirs.
Saturation	Soil's water content when practically all pore spaces are filled with water. This is a temporary state for well-drained soils, as the excess water quickly drains out of the larger pores under the influence of gravity, to be replaced by air.
Seasonal Grassland	Land covered the natural growth of graminea and herbaceous vegetation or a land sown with introduced grass and leguminous for the grazing of livestock. Generally open and continuous flat areas dominated by grass.
Secondary users	People living outside the delineated area but moving through and utilizing the resource temporarily. There might be a traditional resource use agreement with the primary users.
Sediment	Particles, derived from rocks or biological materials, which are suspended or settled in water, having been transported by a fluid or other natural process.

Shrubland	is land with shrubs/bushes/combined canopy cover ≤ 10%. Shrubs and bushes are woody perennial plants with <2m in height at maturity in situ. Scrubs are low bushes and stunted trees, mostly spiny either deciduous or evergreen. On scrubland, more than half of the surface of the ground is bare of vegetation.
Slope	The side of a hill or mountain, the inclined face of a cutting, canal or embankment, or other inclination from the horizontal. The steepness of a slope can be expressed as a percentage, the term 'gradient' also being used.
Soil Erosion	The wearing away of the land surface by physical forces such as rainfall, flowing water, wind, ice, temperature change, gravity or other natural or anthropogenic agents that abrade, detach and / or remove soil or geological material from one point on the earth's surface to another. Soil erosion is normally a natural process occurring slowly over extensive geological timescales, but wherever the natural rate has been accelerated by anthropogenic activity, soil erosion becomes a process of rapid degradation and an immediate and identifiable threat to soil.

Transect	Also known as a 'transect walk'. This is a method used to explore the spatial dimensions of people's realities by factoring social aspects of a community into the layout of its natural and other resources. A transect is normally conducted following resource mapping the village in order to facilitate triangulation of the data generated on a resource map. The transect depicts a cross-section of agro-ecological zones and provides a comparative assessment of these zones in terms of topography, land type, land use, ownership, access, soil 104 type, soil fertility, vegetation, crops, problems, opportunities, solutions and other parameters.
Upstream	Opposite direction from the direction in which a stream or river flows.
Vegetative strips	planting of grasses and bushes in line along WSW or DSMs structures. Example: Elephant grass strip is highly suitable for WSW. Sisal and Sansevieria are also suitable for DSM by integrating additional physical structure like trench.
Water Spreading Weir (WSW)	Masonry structures constructed in a dry valley which spans the entire width of a dry river to spread floodwater over the adjacent land area. Water encounters the weirs and spreads off its side wings onto a larger surrounding area, overflow is channelled through a spillway and can be caught by the next weir. WSWs are constructed in cascades to increase the flood spreading effect and to reinforce each other against unseasonable floods etc.

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