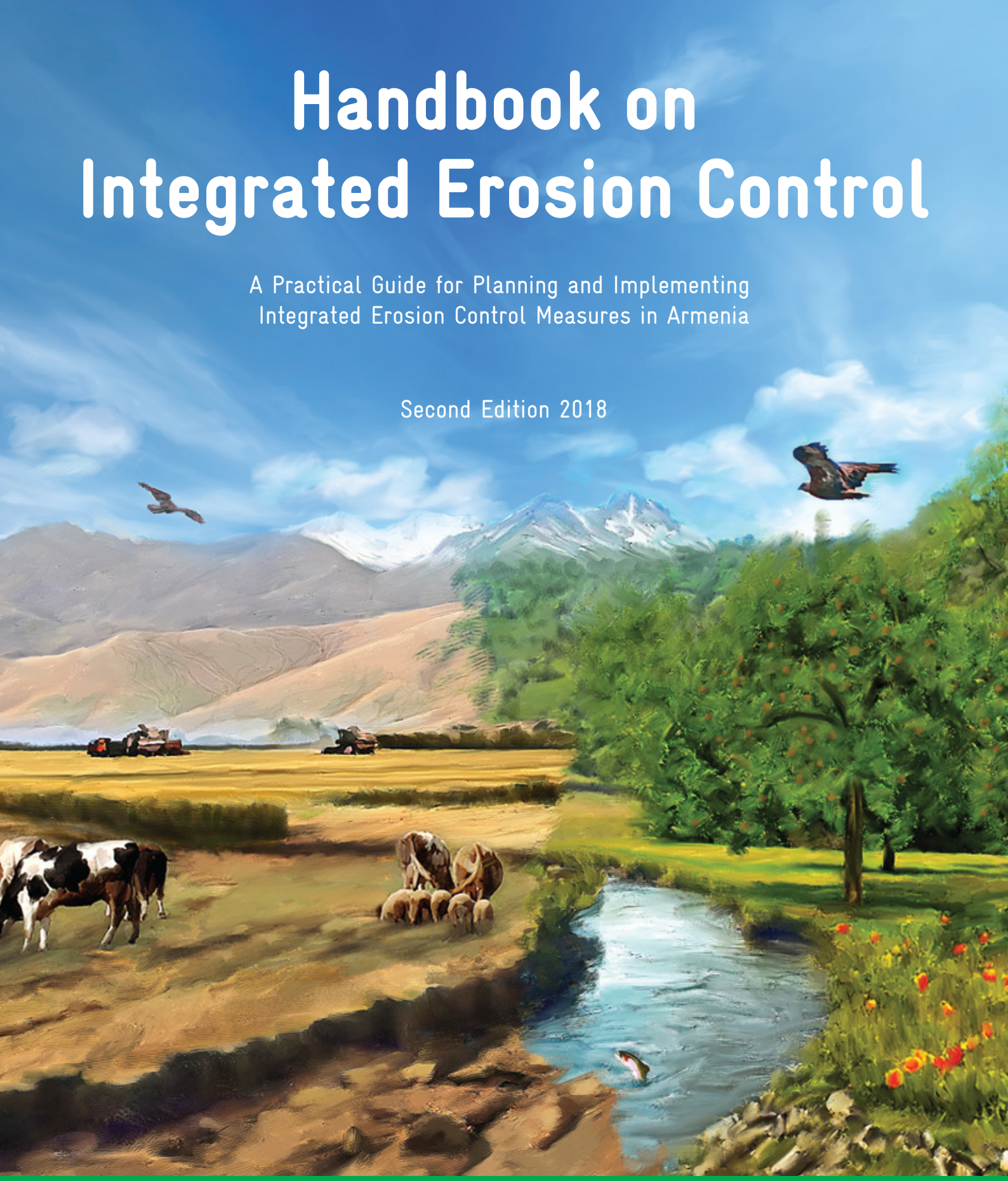
Handbook on Integrated Erosion Control

A Practical Guide for Planning and Implementing Integrated Erosion Control Measures in Armenia

Second Edition 2018



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A Practical Guide for Planning and Implementing Integrated Erosion Control Measures in Armenia

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This handbook was developed in the frame of the "Integrated Erosion Control (IEC)" project of GIZ IBIS programme in Armenia, based on the experiences from the pilot projects on erosion control between 2014 and 2017. It includes showcases from the pilot region, covering 10 communities in Aragatsotn and Shirak marzes in north-western Armenia.

The handbook reflects on the planning and implementation process of erosion control measures. It is not a general guide, but rather focuses on the specific situation in Armenia and the South Caucasus.

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Module 1: Introduction

1. Background and objective of this Handbook

This Handbook was developed in the frame of the "Integrated Erosion Control (IEC) Project"[1] in Armenia, based on the experiences from the pilot projects on erosion control between 2014 and 2017. It includes showcases from the pilot region, covering 10 communities in Aragatsotn and Shirak marzes in north-western Armenia.

The handbook reflects on the planning and implementation processes of erosion control measures. It is not a general guide, but rather focuses on the specific situation in Armenia and the South Caucasus.

The Handbook is designed as a training manual for multipliers, such as:

- training institutions;
- local, national, regional NGOs;
- government agencies a mandate for erosion control measures (e.g., Agricultural Extension Services).

The different **modules** of the handbook intend to give guidance on designing suitable training courses related to awareness on erosion and implementation of erosion control measures. **Showcases** from the pilot communities of the project describe concrete activities, results and experiences. The **Factsheets** contain summarized step-by-step instructions for practitioners in the field.

WHY THIS HANDBOOK?

- It promotes awareness raising on soil erosion processes in Armenia and ways to mitigate their negative effects.
- It supports capacity building – training institutions or NGOs who work with land users get technical background information and didactical explanations.
- It supports planning, implementation and upscaling of pilot activities.
- It provides Factsheets for farmers and land owners to foster practical implementation in the field.

[1] Officially titled "Communal Integrated Erosion Risk Management Project in Armenia", the IEC Project was part of the regional programme "Integrated Erosion Control in Mountainous Areas, South Caucasus".

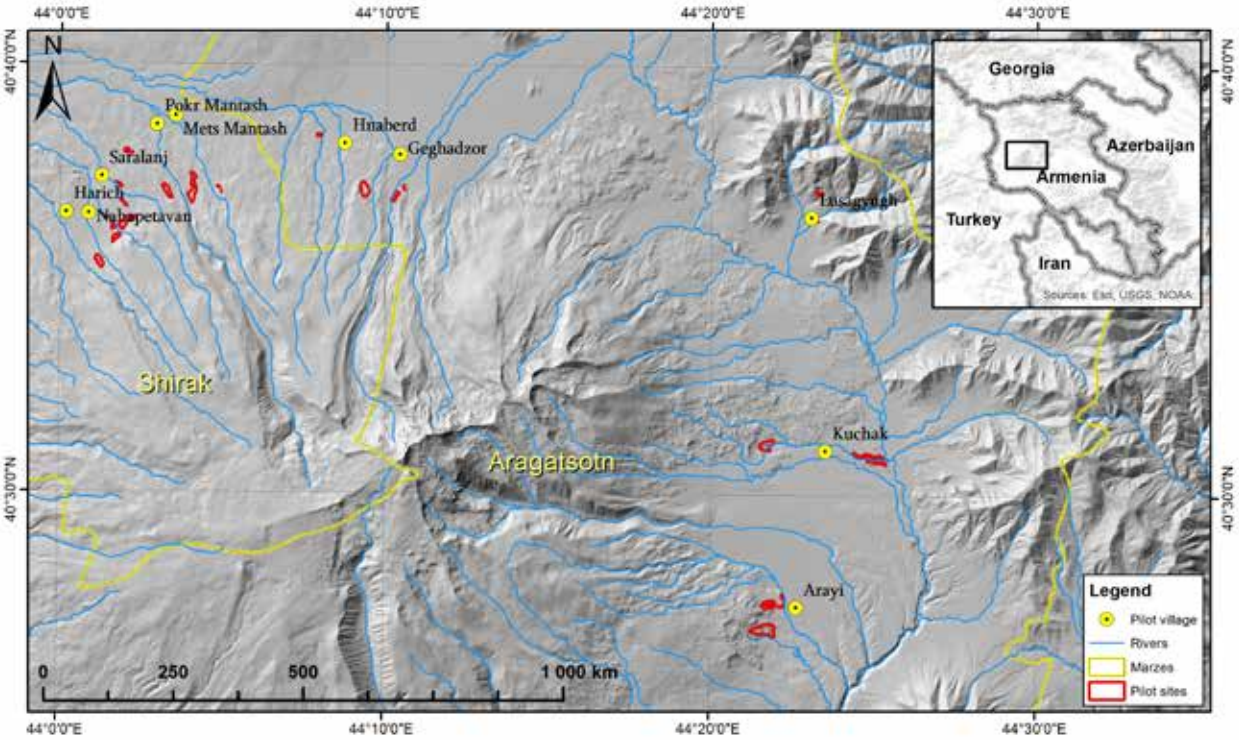


Fig. 1: Pilot region of IEC Project, Armenia

2. Brief project description

"Integrated Management of Biodiversity in the South Caucasus (IBiS)" programme

Within the framework of the Caucasus Initiative of the German government, the "Integrated Management of Biodiversity in the South Caucasus (IBiS)" programme cooperates primarily with the environment ministries of the three countries – Georgia, Armenia and Azerbaijan. In Armenia, the political partners are the Ministry of Territorial Administration and Development (MoTAD), the Ministry of Agriculture (MoA) and the Ministry of Nature Protection (MoNP).

The programme follows a multi-level approach. At national level, it promotes the development or revision of biodiversity strategies and regulations, particularly in forest and pasture management, and in erosion control. The experience gained from the pilot measures at district, municipal and local levels are incorporated into this process. As part of these pilot measures, relevant actors are provided with the skills needed to implement integrated approaches for sustainable management of biodiversity and ecosystem services.

The module objective of the programme is to promote better coordination of biodiversity and ecosystem services management across sectors on the basis of solid data. The programme comprises four areas of intervention with the following objectives:

A. Instruments and coordination processes for the sustainable management of biodiversity and ecosystem services at local level are tested.
B. The implementation capacity of line ministries, their subordinate bodies and of training institutions regarding the management of biodiversity and ecosystem services is improved.
C. The perception of the general public towards the importance of biodiversity and ecosystem services is more positive.
D. The regional exchange on sustainable management of biodiversity and ecosystem services is improved.

The IBiS programme, implemented by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH on behalf of the German Federal Ministry of Economic Cooperation and Development (BMZ) with co-funding in Armenia and Georgia from the Austrian Developement Cooperation (ADC), is planned for a period of four years (from December 2015 to November 2019).

Integrated Erosion Control (IEC) Project

From 2014-2017 the IEC Project in Armenia was implemented with co-funding from the Austrian Development Cooperation (ADC). Apart from the political partners at national level, the community administrations and the local self-government bodies in the pilot regions of Aragatsotn and Shirak have been important stakeholders. Different Armenian NGOs (ESAC, ATP, Shen, Global Armenian Response) have been involved in the process of implementation.
Until December 2016 the implementation of the project was outsourced by GIZ to a consortium consisting of 3 international consulting companies: ECO Consult, E.C.O. and AHT. Starting from January 2017 GIZ has been directly implementing the IEC component within IBiS Armenia.
The expected outputs of the project were:

- Local maps on erosion risks for the 10 pilot communities
- Increased forest cover: 200 ha of eroded territories afforested in small units
- 5 bioengineering measures for rehabilitation of eroded land
- Enhanced awareness on natural resource management at the local level
- Capacity building and regional exchange on integrated erosion control measures.

3. Main principles and approaches

The IBiS programme aims at an improved management of natural resources in the country, according to certain principles:

- Ensure a **participatory approach** in working with communities
- Promote the **Ecosystem Services (ESS) approach** in order to underline how humans benefit from nature.

By integrating stakeholders from different levels (local, regional, national) as well as from different sectors (forestry, agriculture, nature protection), IBiS intends to mainstream biodiversity and natural resource management in a sustainable and holistic way.
The IEC Project followed a participatory approach (fig. 2) starting from level 1 (e.g. initial community information meetings) up to level 3 (e.g. deciding together on delineation of afforestation plots) and even level 4 (e.g. joint efforts for irrigation and caretaking of plantations). Level 5 has not yet been reached, but is highly desired in relation to future upscaling activities.
Important aspects of stakeholder participation during the IEC Project are summarized in fig. 3.

5. Supporting independent community initiatives
You help others do what they want - perhaps within a framework of grants, advice and support provided by the resource holder.

4. Acting together
Different stakeholders not only decide together which is the best option, but they form a partnership to carry it out.

3. Deciding together
You encourage others to provide some additional ideas and options, and join in deciding the best way forward.

2. Consultation
You offer a number of options and listen to the feedback you get.

1. Information
The least you can do is tell people what is planned.

Fig.2: Levels of participation (source: https://www.slideshare.net/ocasiconference/c7d11-community-participation-and-empowermentrabindra-nath-sabat)

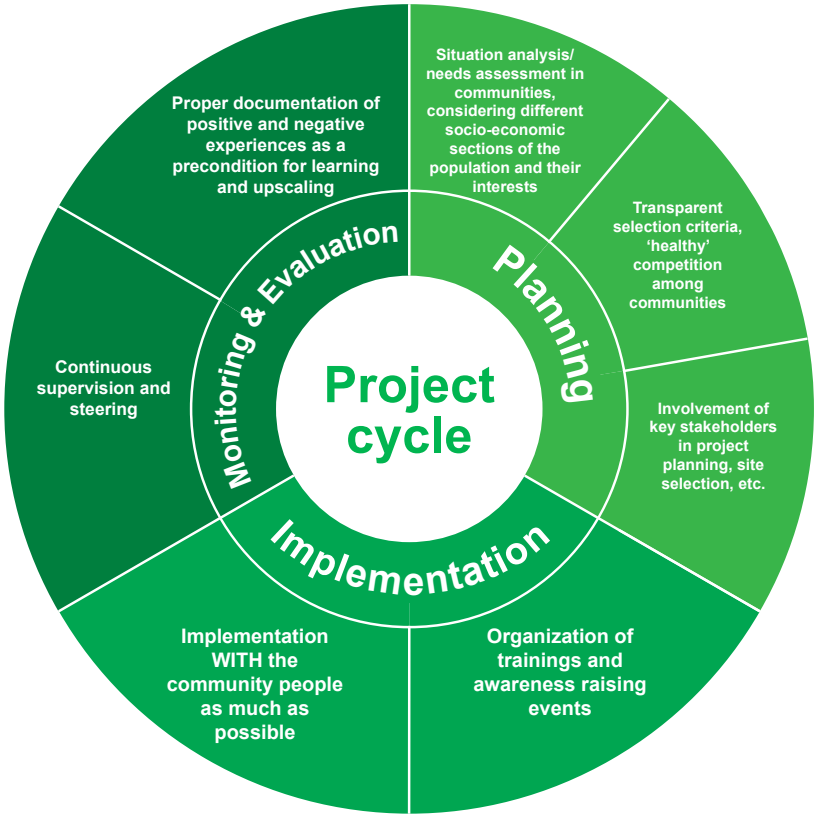


Fig. 3: Participation of stakeholders in different phases of the project cycle

Ecosystem Services or How Humans Benefit from Nature

An ecosystem is a community of all living organisms in a given area (habitat). These coexisting organisms are large and small animals, trees and smaller plants, insects, mushrooms and fungi, insects, and bacteria. Humans are also part of the ecosystem. Each type of organism (species) depends on the activity of others for its continued well-being and reproduction. Members of the ecosystem directly or indirectly interact with each other and provide each other with food and nutrients, or help maintain acceptable living conditions for each other.

Definition "Ecosystem Services"

(Smith et al., 2013)

"Ecosystem services are the diverse benefits that we derive from the natural environment."

Fig. 4: Natural ecosystem

Natural ecosystems have reached balance over many centuries, and this balance may seem stable and permanent (fig. 4).

While human activity in pre-industrial era could be seen as part of the natural processes within the ecosystem, the ever-increasing use of powerful machines, technologies, and commercial exploitation of natural resources have begun to disturb the natural balance of many ecosystems. As a result of increased human activity, as well as some natural factors, ecosystems are in decline around the globe. In sub-alpine regions of Armenia (e.g., in Aragatsotn and Shirak marzes) over-grazing and trampling of grassland ecosystems (pastures) by livestock leads to degradation of the vegetation cover, which keeps the soil in place. The consequence is soil erosion, which is intensified by wind and run-off water from rainfall, streams and intensive snow melting. This leads to nutrient depletion, reducing the quality of the pasture and its ability to sustain future livestock production (fig. 5).

Fig. 5: Degraded ecosystem as a result of destructive management practices and natural factors

Human intervention is not per se destructive. There are also sustainable land management practices, which enable humans to obtain benefits from nature without damaging it (fig. 6). For example, in most regions of Armenia sustainable land management practices would include: protection of existing forests, establishment of diverse agro-forestry systems, controlled grazing of livestock on appropriate pastures, protection of water resources, etc.

Fig. 6: Balanced ecosystem as a result of sustainable management practices

Different ecosystem services provide different kinds of benefits for human well-being. Forests, for example, provide a wide range of valuable ecosystem services – as a habitat for a diverse set of species, a source of timber and non-timber products (many of them serving as alternative sources of food), a place for recreation, etc. Less obvious but extremely important is the role of the forests in maintaining air and water quality for the surrounding communities.

Types of Ecosystem Services (adapted from MEA 2005 and TEEB 2010)

The more diverse the ecosystems, the more protection they provide to the community from environmental changes and natural hazards. Degradation of one component of the ecosystem may lead to a detrimental chain of events, often leading to irreversible consequences. For instance, over-grazing in forests by domestic animals can quickly lead to loss of some plant species and affect natural forest regeneration, eventually resulting in the loss of woodland on which community livelihood is dependent.

Thus, degradation of ecosystem services directly affects the communities who depend upon the degraded area for their livelihoods, and indirectly on the communities beyond, through such effects as water quality decline, food scarcity and insecurity, and increased food prices. The adverse effects of irresponsible agricultural practices, as well as other excessive human activity within the ecosystems, are reversible only partially and only for a limited time. There are many examples of irreversible changes caused by excessive, careless use of ecosystem resources in Armenia. These self-destructive practices are often justified by economic hardship. Thinking of our future generations, there is no choice but to adjust priorities and to start protecting and healing the damaged ecosystems.

This Handbook provides examples of how ecosystems and related services may be protected (e.g. erosion prevention through communal afforestation) or restored (e.g. rehabilitation of degraded land through bioengineering measures).

Local engagement

The presented erosion control measures emphasize on the use of locally available resources and local workforce in order to increase opportunities for replication. Some measures, in particular afforestation at larger, scale may require additional funding. However, the first step is the interest and the initiative of the communities. More options to start erosion prevention or rehabilitation measures are given in the box below.

What can community members do to initiate erosion control activities in their village?

- Identify suitable areas - community or private land. Check legal status and seek community agreement.
- Start small-scale with locally available resources.
- Lobby for support at local government agencies/marzpetaran.
- Contact an NGO that is competent and interested in providing technical support (e.g. ESAC, ATP, Shen).
- Contact private entities interested in sponsoring.
- Organize exchange visits among villages.

Module 2: What is Erosion?

General introduction

The global challenge of land degradation

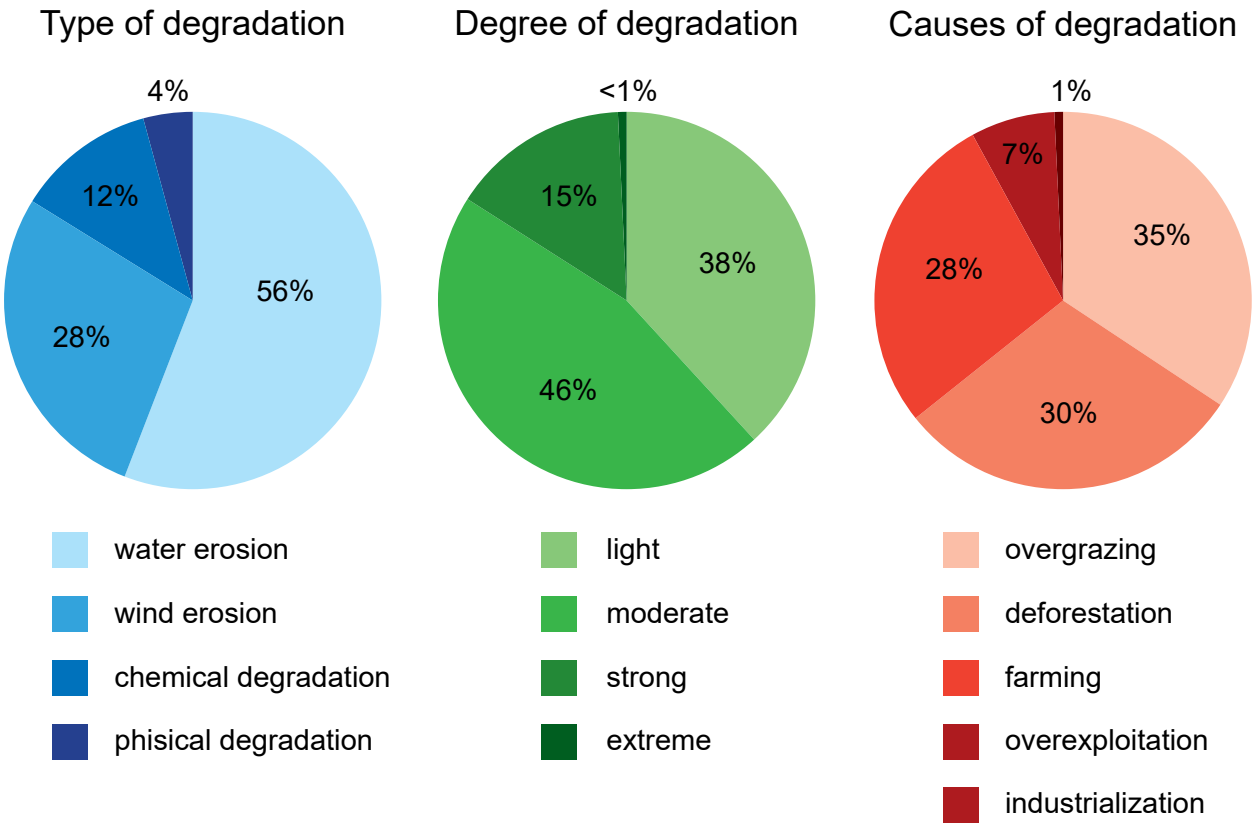


Fig. 1: Types, Degree and causes of global land degradation (Gruver, 2013)

Healthy soils are the basis of our food production. They supply plants with essential nutrients, oxygen, water and root support that they need to grow and flourish. Besides sustaining biological productivity, soils promote the quality of air and water, contribute to mitigating climate change by maintaining or increasing its carbon content and host a quarter of the total planet's biodiversity (FAO online source).

The continuous global degradation of soils and land threatens our food security, livelihoods and the functioning of ecosystem services. The main causes of degradation are linked with unsustainable land use practices, such as overgrazing, deforestation and unsustainable agriculture. The result are soils without a protective vegetation cover that are highly susceptible to wind and water erosion.

Recognizing its tremendous effects on food security and livelihoods, the reduction and reversal of land degradation is a global vision today. The so called "Land Degradation Neutrality" concept is part of the Sustainable Development Goals (15.3) and one of the strategic objectives of the United Nations Convention to Combat Desertification (UNCCD). It is a global "commitment to avoid degradation, to move towards sustainable land management and at the same time to massively scale up the rehabilitation of degraded land and soil" (UNCCD, 2016).

Why awareness is important

Land degradation is a global issue, which requires local solutions. Since land degradation and erosion are commonly caused or increased by inappropriate land use practices, it is the individual farmers and the specific pieces of land where improvements are most essential. However, favorable legal and political framework conditions and presence of incentives for a change towards more sustainable practices are key. Raising awareness of local stakeholders is the first step. Knowledge on the multiple functions and values of the soil, on the causes and influencing factors may already result in changes in behavior. Unfolding concrete practical solutions for preventing or reversing soil degradation may encourage communities to jointly address erosion challenges on their land.

The following sections aim at providing insights into different aspects of soil erosion, specifically highlighting the situation in Armenia and describing feasible approaches to deal with erosion. A strong message is sent out to encourage the implementation of erosion control measures in order to increase productivity and other socio-economic benefits before it is too late, and a complete change of land use is needed.

Soil erosion

Definition and relevance

Soil erosion is the most visible effect of land degradation, referring to absolute soil losses in terms of topsoil and nutrients (FAO soils portal). On a global scale, soil is currently lost 13 to 18 times faster than it is being formed (CBD factsheet). As its development is a very slow process, soil is an almost non-renewable resource. In the Caucasus region, for example, it took several thousand years after the last ice age to develop soil layers of 50-100 cm depth.

For farmers, the protection of the upper soil layer is of highest interest, as it contains the most organic and nutrient-rich materials, and thus, is a crucial agricultural production factor. Loss of the upper soil means loss of land productivity. To maintain the productivity of land for agriculture, pastoralism and forestry, sustainable land management practices need to be established.

Definition: Soil Erosion *(Schachtschabel et al., 1998)*

"Soil erosion is a process of mobilising and transportation of soil particles. Depending on the medium of transportation different sub-types of erosion are classified. The most important types of soil erosion are water erosion and wind erosion. When the amount of soil loss is larger than the natural soil regeneration, the process leads to soil degradation by erosion".

Causes & influencing factors

Erosion is a natural process in mountainous areas, but is often accelarated by poor management practices. Those inappropriate land use practices in the South Caucasus refer mainly to overgrazing, illegal deforestation and unsustainable agricultural practices. They cause vegetation loss, resulting in a lower level of protection against the erosive powers of wind or water.

In the mountainous regions of the Caucasus, water has the highest potential to cause erosion. Wind erosion occurs as well, but it mainly affects arable lands in the lowland-areas. Fig. 2 depicts the main factors that influence soil erosion through superficial water flows.

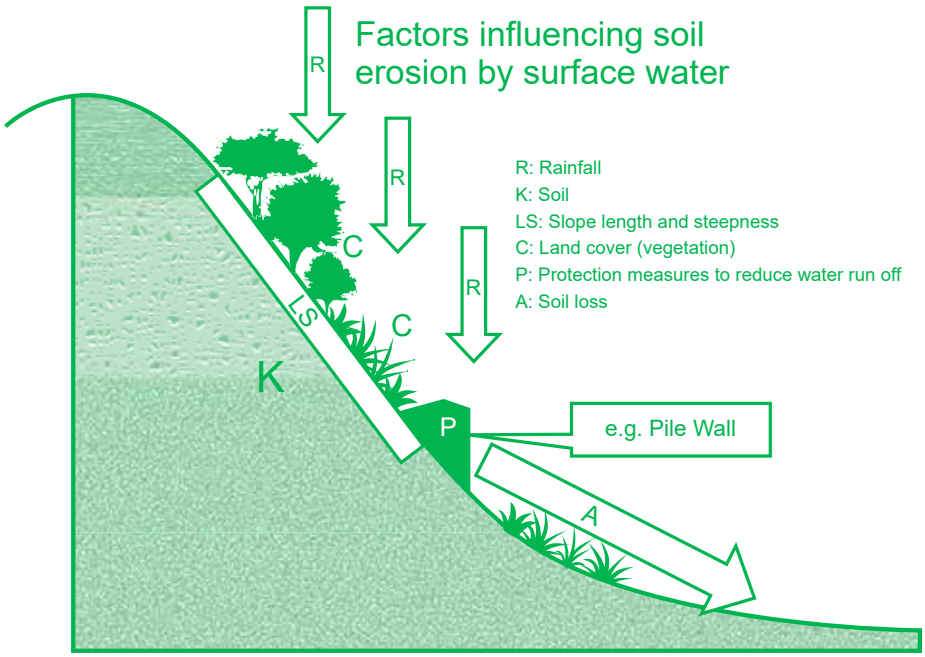


Fig. 2: Schematic figure of factors influencing soil erosion caused by rain and surface run off

Rainfall

Rainfall is the first influencing factor: the raindrops loosens the material and cause small fragments to detach. If the rainfall continues, water collects on the ground and causes superficial water flows, also called surface water run-off. The down streaming water carries the detached soil materials away and deposits them elsewhere. Thus, a high intensity of rainfall and strong winds accelerate erosion processes.

Geological erodibility

The severity of the impact of the water run-off depends, among others, on the erodibility of the soil and the geological subsoil. A high proportion of fine sands and silt in the soil, a low level of organic matter in the upper layer and a reduced soil permeability (e.g. due to impermeable soil layers or compaction) increase the susceptibility of a site to erosion.

Topography

The longer and the steeper a slope, the higher are the erosion risks.

Vegetation cover

If vegetation is scarce or not existent, there is no protective cover reducing the erosive power of heavy rainfalls, nor a root system giving stability to the soil. A soil cover composed of vegetation (e.g., intact grassland, bushes) or mulch reduce the erosion potential.

Protection measures

The water run-off along a slope, and thus also soil erosion, can be reduced by different measures such as rehabilitation of vegetation, or horizontal constructions that retain down streaming water and soil particles (e.g. pile walls, check dams).

Types of erosion

In order to identify appropriate and effective erosion control measures, the different types of erosion (fig. 3) that may occur need to be understood and recognized in the field.

Fig. 3: Types of erosion (source: www.cep.unep.org)

In the mountainous areas of the South Caucasus, three different types of erosion can be observed which are caused by the impacts of water:

1) **Surface/sheet erosion**
   Occurs more or less evenly over an area and is caused by a superficial water run-off when soils are saturated after heavy rainfalls. Areas with impermeable or compacted soil layers as well as bare soils have a reduced capacity to uptake or retain water and are, therefore, very much susceptible to sheet erosion. Soil particles are loosened by the erosive power of the raindrops and carried away by the down streaming water.

2) **Rill erosion**
   Rainfall, that is not up-taken by the soil, it accumulates on the surface and flows downhill, sometimes forming and thus may form small channels. Those rills may dry out after the rainfall, but will still be visible.

3) **Gully erosion**
   If the formation of rills is not addressed by erosion control measures, they may deepen and grow into larger gullies. This process will accelerate erosion, as more and more surface area will be prone to disturbance.

Sheet erosion is hardly visible on a larger area, as the upper soil layer is slowly carried away. Accumulating soil on the lower parts of a slope or in depressions are signs of sheet erosion. Rill erosion can be recognized much easier by the formation of permanent rills on the surface. Real problems are caused by gullies that become continuously larger and disturb farming activities, threaten settlements and infrastructure.

Soil erosion in Armenia

Data and information availability

In the South Caucasus, land degradation refers especially to the following phenomena:

- Loss of natural vegetation and soil quality caused by overgrazing;
- Loss of agricultural productivity and soil due to inappropriate farming techniques;
- Reduction of areas and the quality of forests because of illegal extraction and inappropriate forest management;
- Loss of productive land because of urbanization and conversion into non-agricultural areas.

In general, there is a large lack of accurate data on erosion phenomena, their scope and effects for land users and a large contradiction in existing data. No solid research on erosion has taken place in Armenia since its independence in 1991. Nevertheless, the existing sources document that since independence around half of the used land in Armenia has been exposed to erosion, especially as a result of intensive and irrational agricultural practices. Only a quarter of arable land has been on level ground, whereas another quarter under cultivation was in steep terrain. More than a quarter of Armenia's agricultural land was lost to erosion, with damages particularly evident on highland pastures (Josephson, 2013).

Political and legal framework

Although soil is acknowledged as a precondition for livelihoods, and soil erosion threatens agricultural production, infrastructure and livelihoods, there is yet a low level of awareness on this issue among the population. At the same time, erosion control is not a matter of priority for the Armenian government.

The following two strategic documents address the issue of soil erosion on an abstract level and lack practical guidance or a concrete regulation.

- **The Soil Code of the Republic of Armenia (2001)** defines in Chapter 11, Art. 36 that "soil should be protected from water and wind erosion". However, concrete measures to achieve this objective are not mentioned.
- **The Sustainable Agricultural Development Strategy 2010-2020** aims at the promotion of agricultural production and competitiveness, the increase of food and nutrition security in the country as well as protection of the environment and natural resources. Again, concrete measures for erosion control are not considered.

Need for action & priority of measures

Providing incentives

Land users must receive direct benefits from preventing or mitigating land degradation. Studies show that land users are more motivated to prevent or mitigate land degradation when they directly benefit from the necessary investments, and when those benefits are larger than the benefits of continuing current practices that degrade the land.

Local communities are, in general, also more likely to comply with regulations when they are enacted by local councils than if imposed by higher authorities. So national policies should support local levels and institutions in managing their own natural resources (IFPRI & ZEF, 2011).

As estimated by the Millennium Ecosystem Assessment (2005), about 60 percent of the earth's ecosystem services are degraded, largely because of human impact. The costs of this degradation could amount to US $66 billion per year (IFPRI & ZEF, 2011).

To encourage countries to undertake action, a calculation of costs-of-action versus costs-of-inaction would be interesting. Like for other environmental phenomena, it is generally much easier and cheaper to prevent erosion than to repair the damages once they have occurred. For a correct calculation, information about all the costs related to the prevention or mitigation of land degradation (action) and continued degradation (inaction) need to be used, considering also the immediate and underlying causes of degradation (IFPRI & ZEF, 2011).

Concrete numbers would be a great incentive for decision makers to start dealing more intensively with the challenge of erosion. Avoidance should always be prioritized over reducing land degradation, and the latter should be prioritized over reversing degradation (fig. 4).

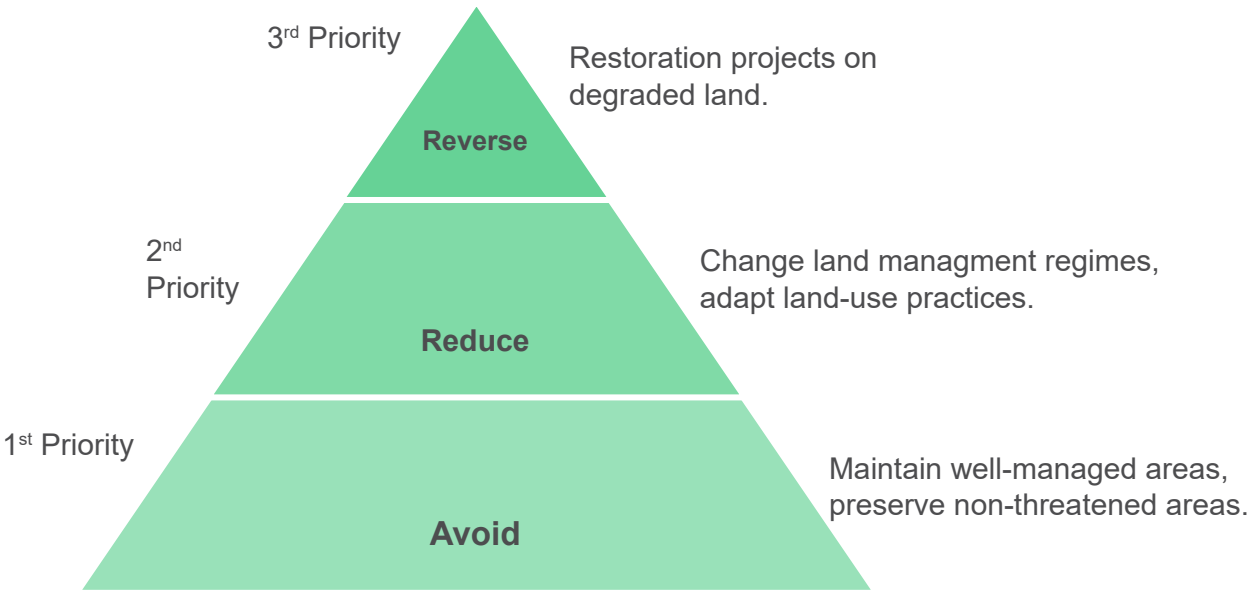


Fig. 4: Priority of measures against land degradation and soil erosion

1st Priority: Avoid

Maintain well-managed areas and preserve non-affected areas.

2nd Priority: Reduce

Change land management regimes and adapt land use practices in a way that they reduce negative impact on ecosystems.

3rd Priority: Reverse

Restore degraded land and ecosystems through sustainable land management practices: agroforestry systems, improved pasture management or conservation agriculture. Measures need to be designed according to the given causes of degradation, the development targets, the needs and initiatives of the local communities.

What can be done against erosion

While measures addressing land degradation can be categorized as *avoidance, reduction* and *reversal* of degradation, the term *erosion control* combines two aspects: preventing and controlling/reducing erosion.
The immediate causes of soil erosion include biophysical causes and unsustainable land management practices. Biophysical causes refer mainly to topography (e.g., inclination, aspect, geology) and climatic conditions (e.g., rainfall, wind, temperature) – both not manageable by humans. Unsustainable land management practices, on the other hand, (e.g., overgrazing, deforestation, reduction of soil quality and stability through inappropriate cultivation practices), are under the control of land users and, thus, can be adjusted to avoid or control/reduce erosion.

Prevention

Sites which are not affected yet by erosion or just show few signs of erosion (e.g., accumulation of material on lower parts of a slope) should be subject to preventive measures. An erosion risk assessment will give information on how likely erosion is on that specific site (see Module 3). Depending on the type of the land use, preventive measures can comprise – sustainable pasture management measures (e.g., limiting livestock numbers, introducing a rotational system), or establishment of sustainable agricultural systems (e.g., planting windbreaks, diversifying crop rotation, etc.).

Rehabilitation

When erosion is already visible (e.g., scarce vegetation or bare soil, rills or gullies), the measures to reduce erosion or rehabilitate the degraded area will be more complex and cost intensive. By fencing an area, the problem of degradation from overgrazing can be tackled. On steep slopes, pile walls will reduce erosion and support the rehabilitation of vegetation. A complete change of the land use type is by far the most sustainable solution: an overgrazed pasture may be turned into a forest or could be used for hay production.

Table 1: Erosion prevention versus rehabilitation of eroded land

	Erosion prevention	Rehabilitation of eroded land
Assessment	erosion risk assessment	assessment of the type and degree of erosion
Type of measures	protective measures, prevent damages – often include treatment of the root causes of erosion	treatment of occurred damage – mostly focuses on the treatment of symptoms
Examples	sustainable pasture management, rotational grazing, establishment of wind breaks, diversified land use systems (e.g., agroforestry)	enclosure from grazing (fencing), gully plugging, check dams, river bank stabilization with gabions
Costs	usually low (compared to the costs of repair or rehabilitation)	can be high especially when it comes to engineering works
Importance	not easily visible, therefore, not prioritized	prioritized, if a threat to humans

Gully erosion needs to be addressed with the construction of check dams. Those bioengineering activities will most probably only be implemented, if the effects of erosion cause a threat to human settlement or infrastructure.

Table 1 shows main differences between *erosion prevention* and *rehabilitation of eroded land.* It is a rough orientation with many gradients in between. In any case, it is always advisable to analyze the root causes of erosion in order to prevent or treat them. For example, if a severely eroded cattle track is rehabilitated through bioengineering measures, but the overall livestock and pasture management (as a root cause of the problem) is not tackled, the erosion will simply take place on the adjacent piece of land.

Brief description of applied measures in Armenia

Afforestation on community land

Afforestation measures can both be applied for erosion prevention and for rehabilitation purposes. In case of the pilot sites in Armenia, plots of 1-30ha were fenced and afforested, mainly as an erosion prevention measure. Detailed descriptions of the planting schemes and species, as well as examples of 2 pilot afforestation sites are given in Module 4 and 7.

Soil Bioengineering

The bioengineering measures applied in Armenia refer to the rehabilitation of vegetation cover on degraded cattle tracks as well as to gully rehabilitation. The selected sites are small (0,2–1ha) and protected from grazing animals by an electric fence. Detailed descriptions and examples are given in Module 5 and 7.

Any planned erosion prevention measure must consider the specific site conditions. In the pilot regions in Armenia, the high altitudes as well as the frequent strong winds are important limiting factors for afforestation as well as bioengineering measures.

Working with local communities

Based on IEC project's 4 years of experience, it is recommended to consider the issues below when working with the local communities of Armenia.

WHO should be involved?

- ☑ Always involve the marz representatives in community meetings as well as in the technical delineation of plots (for afforestation and for bioengineering).
- ☑ Emphasize the importance of women's participation in community meetings.
- ☑ Involve the young generation (schoolchildren and students) in meetings, in awareness raising campaigns and in implementation measures.
- ☑ Involve NGOs of young students for PR activities and participation.
- ☒ Not only involve the mayor but also other people with clear responsibilities (an "initiative group").

HOW to start?

- ☑ Be concrete and specific in presenting your ideas to the community stakeholders.
- ☑ If feasible, organize separate meetings for men and women. Encourage women to express their opinion.
- ☑ Select motivated community individuals with a clear initiative for implementation and for dissemination of information.
- ☑ Start with small-scale trust-building measures in parallel with awareness raising activities.
- ☒ Don't dictate project ideas. Be flexible in adapting the project ideas to the needs of the people.
- ☒ Don't underestimate the capacities of the communities.
- ☒ Don't just give input into the project for free, but also trigger the communities to contribute as well.

WHAT else to be considered?

- ☑ Involve the reliable community stakeholders in supervision and steering.
- ☑ Consider the opinion of the conflicting stakeholders (pasture users vs. forest users) and facilitate their negotiations, following a "do-no-harm-approach".
- ☑ Consider the opinion of the mayor's opponents when planning the activities.
- ☑ Respect the limited availability of the community people in busy seasons.
- ☑ Organize inter-community meetings to share information and knowledge.
- ☒ Don't consider yourself (the project or the project staff) superior to the community people.
- ☒ Don't send too many people (evaluators, monitors, students, guests, etc.) to the communities with the same type of questions.

Module 3: Erosion Assessment

General introduction

This chapter is meant to give orientation for assessing the erosion risk or the gravity of occurring soil erosion for a particular site and to give guidance in elaborating appropriate preventive or rehabilitative measures. Different assessment methods are presented, including remote sensing approaches for assessments on a larger scale and field assessments used on local level. Further, for each erosion type and erosion gravity, recommendations on addressing the specific situation are provided, including links to the subsequent handbook chapters and factsheets.

Why to assess erosion

As soil cannot be restored easily once it is lost, it is of utmost importance to avoid soil loss by erosion whenever possible. The earlier the problem is observed, the easier are the protection measures to be applied. In many mountainous regions of the Caucasus, grazing is an important land use type. Overgrazing, trampling and driving vehicles are the most common human influences causing soil erosion in those areas (fig. 1).

Fig. 1: Damage of the vegetation cover by trampling livestock (left); damage of vegetation cover and compaction of soil by heavy vehicles (middle); comparison of biomass on overgrazed site and fenced site (right)

Remote sensing tools should be used on a 2-5 years basis to monitor the change in vegetation cover as an important indicator for soil erosion. This can help to identify the regions with emerging erosion problems and to focus activities in these regions.

Overview on different methods and their application

For selecting the appropriate assessment method, the spatial scale and the purpose of the assessment have to be considered. For policy making and spatial planning, data and information might be needed on municipality level. For example, it could be important to know the distribution of areas with a high risk of landslides for natural hazard planning. Assessing the whole area with field assessment methods would be time and resource consuming and probably not necessary in that accuracy.

For generating information for an area of several square kilometers or even a whole country, remote sensing tools can be used. As a rough benchmark, sites > 100 km² are assessed by remote sensing yielding spatial data on an approximate scale of 1:25,000.

On the local level, erosion type and gravity or the risk of erosion can be directly assessed in the field. Thus, precise information can be collected on a scale of 1:10.000 up to 1:1.000, which is useful for planning concrete erosion control or prevention measures, for example, on the community level.

Field assessment

In the field, the stage of erosion can be assessed by estimating the vegetation cover or by other visible signs of erosion, as the occurrence and gravity of rills and gullies. The field assessment method described in this chapter is based on the observation of erosion signs and potential causes. It aims at understanding the influencing factors for planning appropriate erosion control measures.

As explained in module 2, there are three main types of erosion occurring in the mountainous areas of the South Caucasus:

1) Sheet erosion
2) Rill erosion
3) Gully erosion

These three erosion types usually occur one after another and are caused by superficial water-flows on slopes with a degraded vegetation cover. It normally starts with sheet erosion (detached particles are carried away from the topsoil), followed by the development of small rills and channels on the ground. If this process is not stopped by erosion control measures, the power of the water will wash out the rills and turn them to larger gullies.

1) Sheet erosion

Sheet erosion can be assessed by looking at the vegetation cover. The vegetation cover in % is the relative amount of the surface covered by vegetation (or fixed stones that cannot be easily relocated).

We distinguish among three levels of sheet erosion:

Table 1: Different levels of vegetation cover and resulting sheet erosion

> 90% vegetation cover = no erosion, the vegetation protects the upper soil layer	30% - 90% vegetation cover = clear signs of erosion, soil particles are detached and moved	< 30% vegetation cover = severe erosion, upper soil layer is exposed to the erosive power of wind and water

In the case of > 90% vegetation cover, the erosive energy of raindrops is slowed down by the vegetation. When water collects on the surface, the speed of run-off is reduced by the resistance of the vegetation. The root system of the grass, shrubs or herbs fixes the upper soil layer and prevents the soil particles from being washed away. Dead leaves and stems form a litter layer, which protects the soil as well and contributes to the development of a humus layer and the generation of new soil.

When the vegetation cover is damaged and reduced to 30-90% - for example, by overgrazing, trampling or driving off road-, this protective function of the vegetation is reduced. In combination with a steep and long slope, the process of washout of fine, fertile soil particles will start. This can be observed from the grey or brownish surface water after heavy rainfalls and from the apparent "accumulation" of stones at the site.

The more severe the erosion process is, the larger are the loose stones on the surface. While the fine material is washed away, the loose stones are left on the soil surface between the vegetation patches. Fig. 2 gives an example of a site with accumulated stones and a vegetation cover of < 30%.

2) Rill erosion

General rule:
The steeper and longer the slope, the stronger the erosive energy of the down streaming surface water.

If the process of sheet erosion and continuous vegetation damage is not stopped, the erosion process will self-accelerate (fig. 3): The wash out of soil particles reduces the amount of fertile soil available for the root system of the vegetation. This again leads to reduced growth rate and thus to a reduced vegetation cover. The lower the vegetation cover, the less stable the soil, the lower the retention of water leading to higher speeds of superficial water flows. This results in more erosion phenomena such as small channels and rills of 10-30cm depth (fig. 2).

Fig. 2: Rill erosion caused by overgrazing

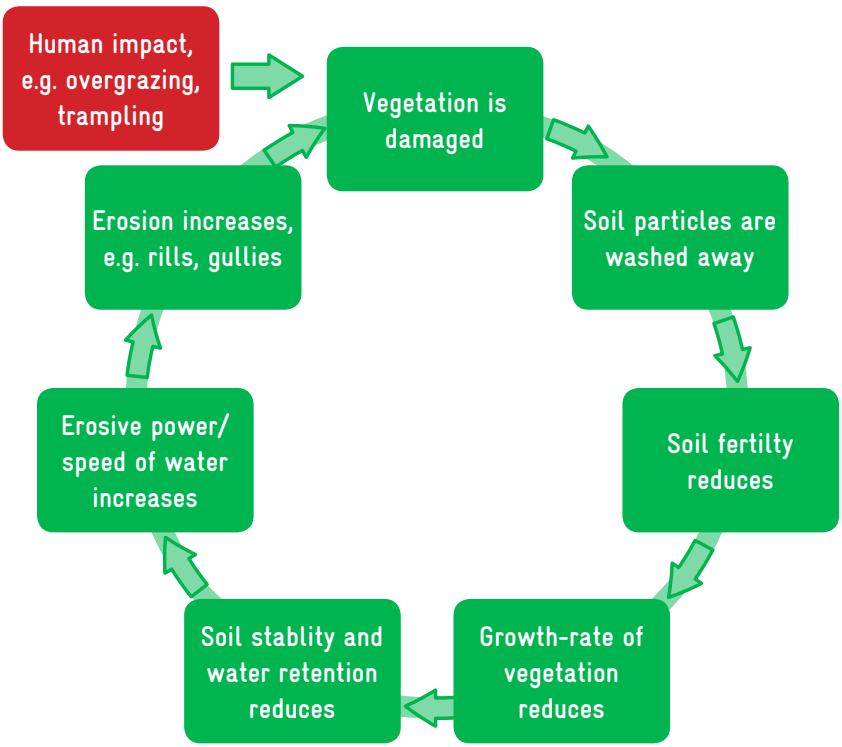


Fig. 3: The self-accelerating process of erosion

3) Gully erosion

The small rills and channels collect the surface water and are usually oriented in the direction of the slope. Sometimes, the development of rills is enhanced by the trampling of cattle, which may lead to rills with other orientations. The concentration of surface water in the rills accelerates the erosive power of the water. If no active measure is taken to stop the accumulated flow of surface water, the rills will grow to larger gullies (fig. 4).

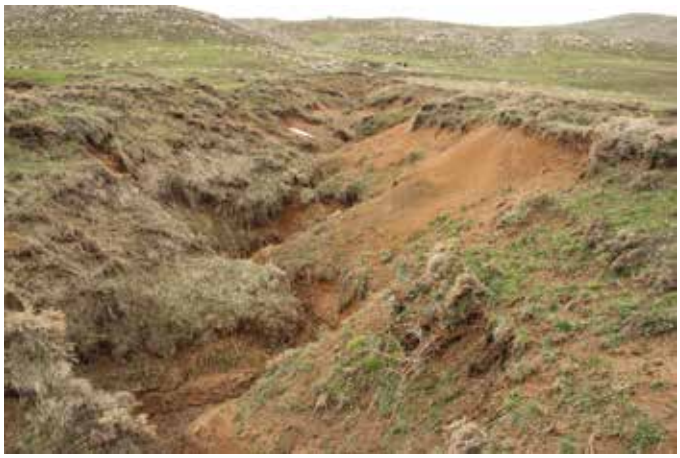


Fig. 4: Gully erosion

Identifying appropriate erosion control measures

Measures in case of sheet erosion

Case 1: Early sheet erosion (vegetation cover 80-90%)

It is important to act as soon as the vegetation cover is reduced by 10-20% on a larger area. At this stage, the self-rehabilitation potential of the vegetation is still high and can be promoted by eliminating the causes of the vegetation damage (if human induced). The damage of vegetation is often caused by certain land use practices, e.g. overgrazing, trampling, cutting of shrubs or other horizontal structures. Stopping further degradation of land and the self-accelerating process of erosion can be achieved at this stage, for example, by a temporary fencing of the area until the vegetation has recovered or by reducing the grazing intensity.

Fig. 5: Pile walls and mulching are applied to combat advanced sheet erosion on a slope

Fig. 6: Pile walls to combat rill erosion

Fig. 7: Check dams to slow down water movement in gully

Case 2: Medium/strong sheet erosion (vegetation cover < 70%)

In the case of loss of more than 30% of vegetation, the rehabilitation of vegetation should be supported additionally by measures like mulching and sowing of grass seeds. The area needs to be excluded from grazing until vegetation has recovered. For very steep slopes, the construction of horizontal pile walls is recommended.

Measures in case of rill erosion

Case 3: Rill erosion

In order to prevent the formation of gullies, rill erosion needs to be treated. Effective measures are the construction of pile walls, the control of grazing (temporary fencing or less grazing pressure) and the support of the rehabilitation of vegetation through mulching, application of grass seeds or organic fertilizer.

Measures in case of gully erosion

Case 4: Gully erosion

If rill erosion is not stopped, most probably it will grow to a gully from 0,3 to several meters depth. Appropriate measures to stop the dynamic of gully erosion relate to the construction of horizontal barriers to slow down the water flow in the gully. Depending on the size of the gully, there are different types of such barriers (pile walls, palisades, check dams). The treatment of large gullies is very complex and cost intensive. Generally, those areas are lost for pasture use and the costs-of-action (erosion control measure, e.g. check dam construction) are exceeding the cost-of-inaction (loss of pasture area).

If, however, settlements or infrastructure are endangered by the growing gully and the strong water flows and soil movement, the implementation of protective measures needs to be considered. In this case, the cost-of-inaction (damage of houses, infrastructure) exceeds the cost-of-action (erosion control measure).

Table 2: Overview on preventive and rehabilitative measures to control erosion

Type of erosion	Potential measures	Link to handbook chapters
Early sheet erosion	• Temporary fencing (1-2 years) • Reduce grazing pressure ✓ less animals ✓ shorter grazing periods -> pasture rotation	• Module 5 • Factsheet 5
Medium/strong sheet erosion	• Temporary fencing (1-2 years) • Mulching • Seeding • Fertilizing • Horizontal pile walls	• Module 5 • Factsheet 5 • Showcase 3 • Factsheet 3
Rill erosion	• Pile wall construction • Control of grazing ✓ temporary fencing ✓ less grazing pressure • Support the rehabilitation of vegetation ✓ mulching ✓ application of seeds or fertilizer	• Module 5 • Factsheet 5 • Showcase 3 • Factsheet 3
Gully erosion	• Temporary fencing (1-2 years) • Pile wall construction • Check dam construction	• Module 5 • Factsheet 5 • Showcase 3 • Showcase 4 • Factsheet 3 • Factsheet 4

Remote sensing methods

Relevance & preconditions

Remote sensing methods provide data for large geographic units and are therefore extremely useful for planning systematic interventions at the national scale. Making appropriate use of remote sensing methods requires certain preconditions, such as:

- a supportive legal framework
- an organizational infrastructure
- human capacities (at local administrations, municipalities, extension services etc.)
- financial resources.

Technological approach & use

Remote sensing can help to assess the current erosion level and erosion risk (fig. 8). The methodology of remote sensing is proposed to prepare maps indicating which areas are affected by erosion. This information will help to develop strategies to adapt land use to control erosion and to monitor erosion process es over time. The time series could be used to monitor changes in erosion. On the one hand, the success of erosion control measures can be monitored on a national level. On the other hand, new sites or increase of spatial cover of erosion can help to prioritize activities.

The objective is to develop and implement a remote sensing technology to produce maps of erosion risks in order to give a spatial information on erosion risks (the potential of soil loss)

and to provide techniques and methods, which are reproducible and can be used for monitoring changes in erosion risks.

Satellite images provide actual information on vegetation cover by analyzing different spectral bands of the images (red, near infrared). Climatic data and maps on precipitation give the amount of rainfall for specific regions and digital elevation models can provide information on the degree of inclination and the length of slopes. Based on these input data, the can be calculated using computer models, and maps of the sites that are sensitive to erosion can be produced.

The so called "Sensitivity Model" developed by experts from the Caucasus region with the support of GIZ is a tool to produce erosion risk maps (Mikeladze & Nikolaeva, 2016).

The incentives are manifold: it is a relatively cheap and rapid method of acquiring up-to-date information over a large geographical area in a homogeneous way; it is the only practical way to obtain data from inaccessible regions; and resulting data can be processed using a PC and then combined with other geographic layers in a GIS. However, they are not direct samples of the phenomenon, so they must be calibrated against reality through some sort of ground-truthing; distinct phenomena can be confused if they look the same to the sensor, leading to classification errors; phenomena which were not meant to be measured can interfere with the image and must be accounted for; and the resolution of satellite imagery is too coarse for detailed mapping.

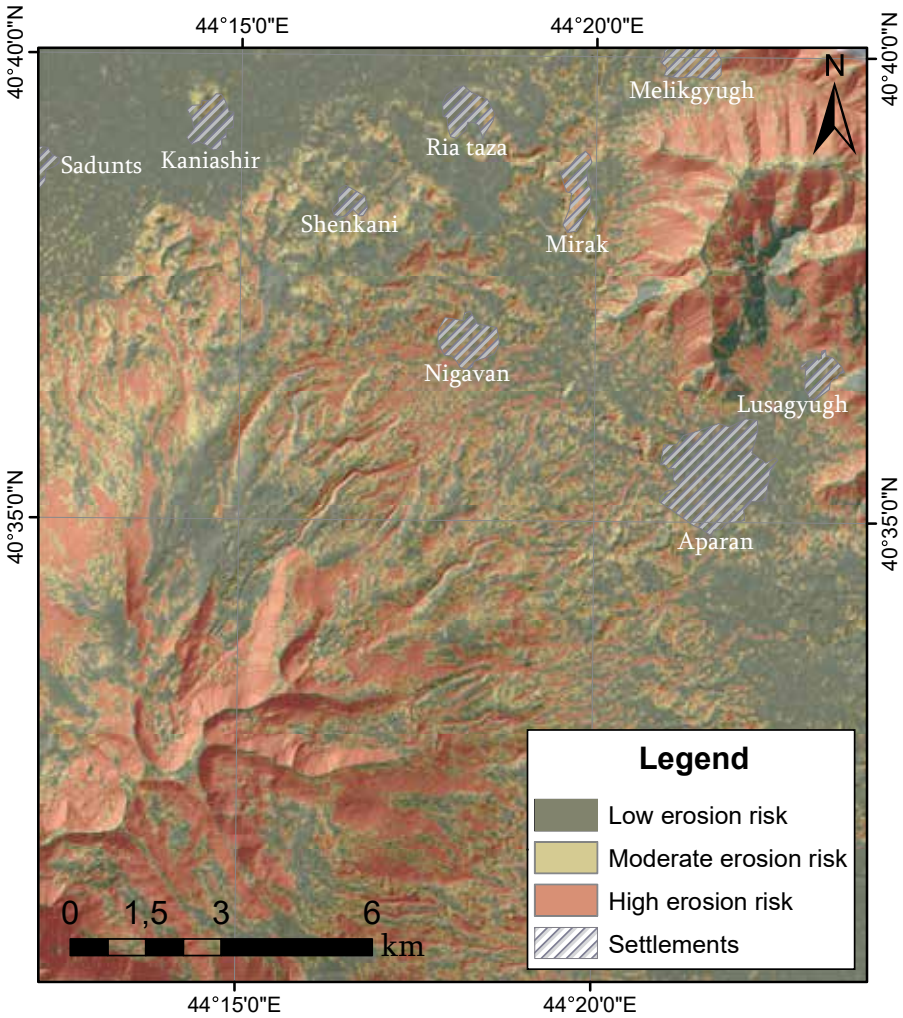


Fig. 8: Erosion risk map of the pilot region derived from satellite imagery

Module 4: Afforestation on Community Land

General introduction

Forests are - in terms of biomass accumulation and stability - the most successful ecosystems in the world. This is true for all sites where climate and soil conditions allow the growth of trees. Only where the climate is too cold (arctic and subarctic zones), water availability is too low (deserts, semi-deserts, savanna and steppe ecosystems) or soil conditions are not suitable (bogs, less nutrients), forests face their ecological limits.

In the South Caucasus, two natural limits restrict forest expansion: at 2.300-2.600m a.s.l. the upper tree line is visible, whereas steppe and semi-desert ecosystems form the lower tree line. The map of natural vegetation of Europe (fig. 1) depicts the possible natural vegetation cover in Armenia without human intervention. In the middle of the 6th millennium BC (Hamon, 2009), human intervention started to change and reshape the natural forest cover. Forests were cleared for gaining arable land and pastures, and open landscapes expanded, especially after a huge forest clearance at the end of the 20th century.

Definition: Forests *(Forest Code of the Republic of Armenia, 2005)*

"The interconnected and interacting integrity of biological diversity dominated by tree-bush vegetation and of components of natural environment on forest lands or other lands allocated for afforestation with the minimal area of 0,1 ha, minimal width of 10 m and with tree crowns covering at least 30% of the area, as well as non-forested areas of previously forested forest lands."

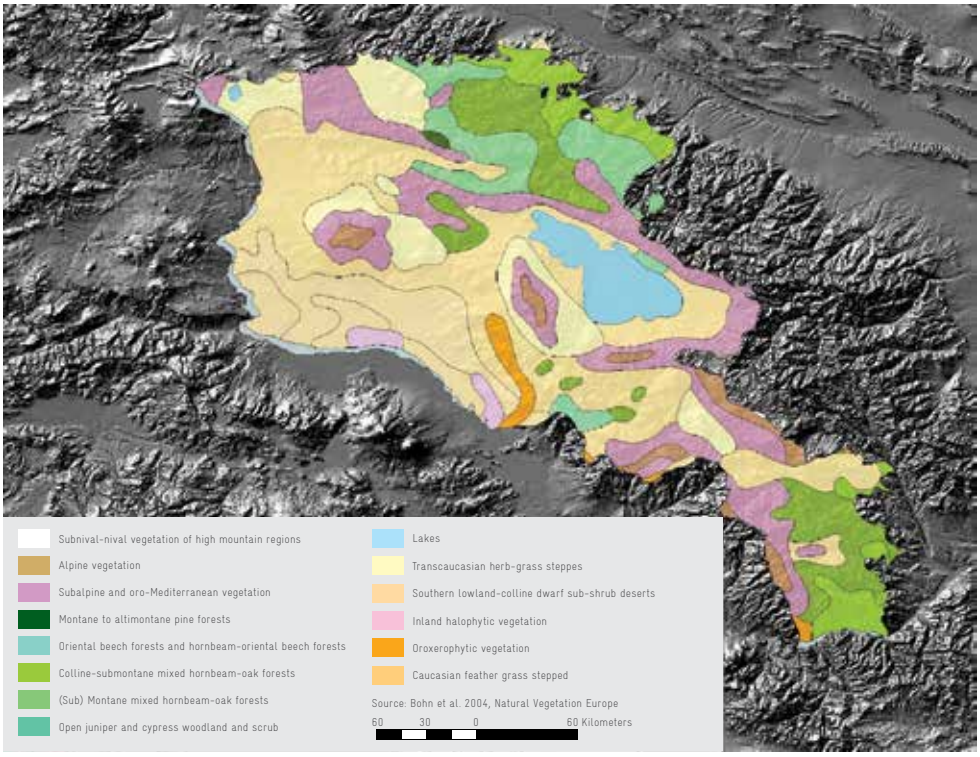


Fig. 1: Potential natural vegetation of Armenia (Bohn et al., 2003)

Important functions of forests

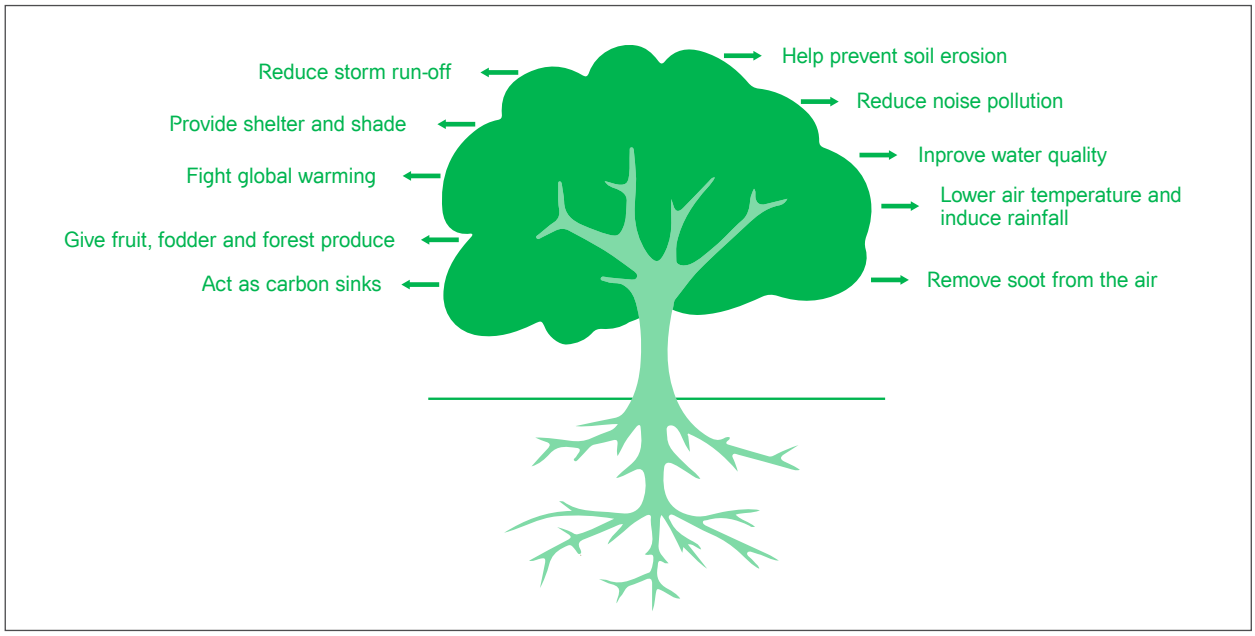


Fig. 2: Multiple ecosystem services of forests (source: www.grow-trees.com)

Forests form stable ecosystems, which regenerate naturally, persist for long time periods and are resilient to most disturbances. Natural forest ecosystems offer multiple ecosystem services, such as timber and fuel wood provision, water purification, carbon sequestration, recreation, etc. (fig. 2). In mountainous landscapes, forests have an additional protective function against erosion and natural hazards (e.g., avalanches, landslides, debris flows or rock falls).

Open landscapes with damaged vegetation cover – e.g., through clear-cuts or overgrazing – are very much susceptible to erosion by rain and surface water runoff. The closed crown cover of a forest reduces the erosive power of heavy rainfalls by detaining some of the water in the crowns (interception). The deep root system provides stability to the soil and, hereby, reduces the risk of landslides and debris flows. Forests effectively protect villages and human infrastructure from damages caused by rockfalls or avalanches, thus, also reducing the costs of investment into technical means to protect settlements and infrastructure.

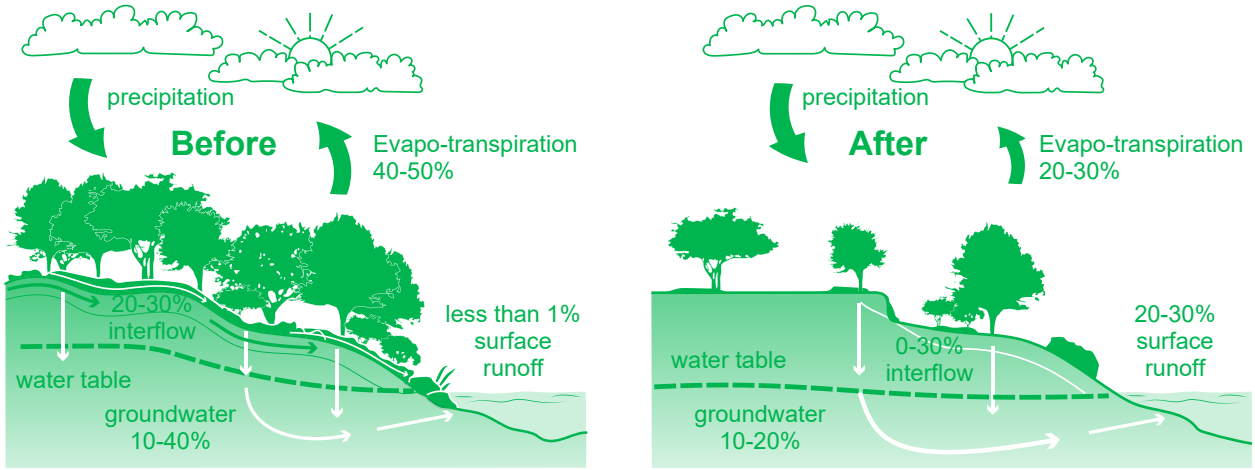


Fig. 3: In natural conditions, almost all rainfall is taken up by plants, evaporates or infiltrates through the ground. After human intervention (construction, deforestation), surface runoff increases significantly while evaporation and infiltration into the ground decrease (source: http://www.ecy.wa.gov/programs/wq/stormwater/images/runoff_illustration.jpg)

Planning & preparing an afforestation project

Definition: Afforestation *(Forest Code of the Republic of Armenia, 2005)*
"The establishment and growing of artificial forest cultures through planting and seeding on non-forested lands as well as lands having other special-purpose significance."

In the mountainous areas of the South Caucasus, sites that suffer from erosion and overgrazing can be rehabilitated through fencing (protection from livestock) and planting of tree seedlings. The advantages of such intervention are multifold, as grown up trees not only stabilize the soil but also contribute to the improvement of rural livelihoods.

Afforestation activities can be divided into 3 main phases:

A general rule of any afforestation measure: imitate the natural vegetation in terms of species, composition and structure.

Afforestation: Selection of planting scheme and species, fencing and planting of seedlings (time: from several weeks to several months)

Maintenance: Irrigation, cutting, mowing, etc. (time: to be continuous after the planting of seedlings, 3-10 years)

Management: Silvicultural measures like thinning, harvesting or regeneration of forests (time: to be continuous after he maintenance phase ongoing).

To achieve good results in terms of the survival rate of the seedlings, cost efficiency and erosion control effectiveness, the afforestation measures should be carefully planned. While this handbook mainly focuses on the planning and implementation of afforestation activities, it is important to think of the maintenance and management from the very beginning: Who are the landowners and the beneficiaries of the afforestation site? Who will be responsible for maintenance and harvesting? Is a legal framework in place, that allows the local community to benefit from afforestation sites?

Checking general framework conditions & availability of resources

As a first step, the general framework of the afforestation activity has to be clarified:

- **Availability of financial resources** (determine the plot size, the afforestation scheme and maintenance practices);
- **Availability of human resources & in-kind contributions** (local workers from the communities, forest experts, local materials such as seeds, seedlings, mulching material)
- **Time frame** (afforestation is a long-lasting process, taking 10-30 years until the first timber can be harvested)
- **Long-term rights, beneficiaries and responsibilities** (setting up binding agreements with local communities and/or authorities for assuring long-term maintenance and management)

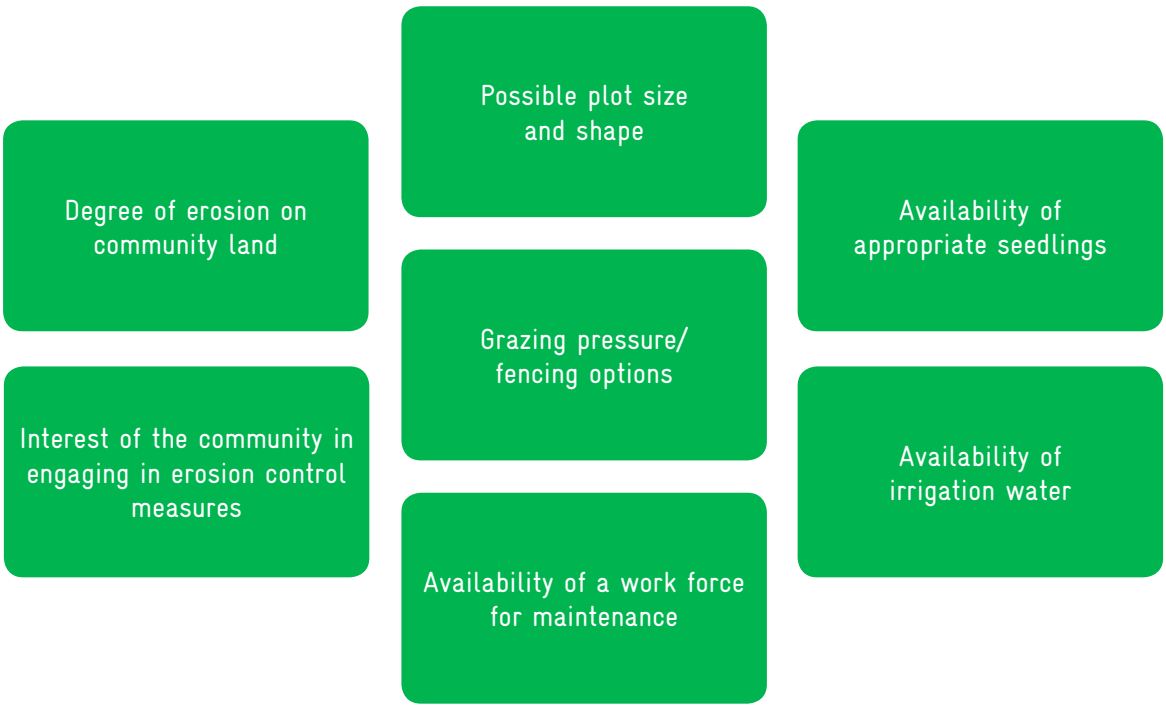


Fig. 4: Main factors to be considered when planning afforestation

Site selection

A proper site selection is of utmost importance when starting an afforestation activity the results of which should last over many decades or even centuries. While in case of many agricultural activities the location might be changed after a couple of years, afforestation activities are bound to the place of the seedling plantation for a long time. Usually the selection of sites has (at least) two dimensions: a technical/ecological dimension and a social/economic dimension. Both are closely interlinked.

Technical/ecological site selection criteria:

- Which sites can be afforested (climatic limits, minimum soil requirements)?
- Which desired ecosystem services are prioritized by community people (e.g., erosion control, recreational values, natural hazard protection, timber production, drinking water protection, etc.)?
- Are sites accessible and do they have an appropriate size and shape?

Socio-economic site selection criteria:

- Does the community / land owner support the afforestation on the selected piece of land?
- Is there any conflict with other land use types (e.g., loss of pasture land or hay meadows, blocking of cattle tracks)?
- Do the expected positive effects of the new forest ecosystem exceed the benefits of the current land use? Is the investment in afforestation justified?
- Are legal requirements in place, which allow a land category change from non-forest to forest?

More questions and criteria might be added. Some questions, especially in the socio-economic field can only be answered in a qualitative manner and should be based on intensive discussion with all the stakeholders.

Considering the shape and the size of the site

The total afforestation costs per hectare are closely interlinked with the absolute size of the site: with an increase of the total afforestation area, the costs per hectare decrease. This is mainly because of the costs for fencing which account for a larger part of the total afforestation costs. When increasing the afforested areas (in case of square-shaped areas), the relative fence length per hectare decreases. Experiences from pilot sites in Armenia show that the total afforestation costs per hectare (work and materials for fencing and planting, but without seedling costs) for sites < 5 ha are three times higher than for the sites >10 ha (2.400.000 AMD/ha versus 716.000 AMD/ha).
For afforestation sites with a longish or irregular shape this might not be true, as the relative fence length per hectare does not necessarily decrease with an increase of the total area. For very scattered or small afforestation sites protection of individual trees with a mesh wire should be considered.

Identifying the appropriate planting season

The climate in the South Caucasus region shows in many parts low precipitation rates in the summer period. As seedlings have a small root system, young we trees are more sensitive to droughts than the grown up trees. Planting in autumn has the advantage that deciduous trees have already lost their leaves and, therefore, show lower transpiration rates (loss of water by leaves). During autumn, winter and spring, more moisture is available that helps the seedlings to develop deeper root systems to survive during summer droughts. Also planting in early spring allows to profit from winter moisture before the summer drought begins.

Fencing

In many cases, afforestation sites are located on pasture land. To protect the planted seedlings from browsing by livestock or wild game, it is recommended to fence the afforestation site before starting the plantation of the seedlings. The costs and advantages of different fencing types are given in Table 1.

Table 1: Advantages and disadvantages of different fence types

Fence type	Type of fencing posts	Costs of material	Labour costs of construction	Advantages / disadvantages
Mesh wire fence	Metal or wooden (or combination of both)	High (2.200-4.500 AMD/m)	High (especially when using cement for fixing the posts, 2.500-4.500 AMD/m)	Advantage: long durability, effective for small and big animals. Disadvantage: hard to be removed and re-used after afforested seedlings are grown up.
Barb wire fence	Concrete	Low (approx. 1.000 AMD/m)	Low (300-400 AMD/m)	Disadvantages: not easy to construct an effective barb wire fence against small livestock (goat, sheep). If barb wires are not removed after the fence is not needed, it could lead to severe injuries to humans or animals.
Electric fence	Plastic	Medium - low (approx. 1.500 AMD/m)	Low (50-100 AMD/m)	Advantage: can be easily removed and re-used. Disadvantage: daily maintenance is needed.

Tree species & seedling quality

Tree species selection

It is recommended to use different local tree species for any afforestation activity, as they can cope best with the given environmental conditions and, therefore, are more resilient towards pests and climatic variations.

For selecting suitable species, screening of the wider project area is essential in order to prepare a list of species, which would naturally grow under the given ecological conditions. The assessed natural forest should be similar to the afforestation site in terms of elevation, exposition, inclination, soil type, hydrology. To simulate natural succession after disturbances (e.g., windthrow, land slide, fire), include pioneer trees (e.g., Popular tremula, Betula litwinowii) and shrub species (e.g., raspberry, rosehip, spirea) in the set of selected afforestation species. Quercus macranthera, Acer trautvvetteri and Betula litwinowii are suitable to be the main species (see below).

During the Soviet period, large pine plantations (Pinus sylvestris) were afforested. P. sylvestris is not a native tree species to the alti-montane forest belt in the Southern Caucasus. Nevertheless, being a pioneer tree having broad ecological amplitude, its plantations can grow up to an elevation of 2.300m a.s.l.

Checklist: Tree species selection

- Local species well adapted to environmental conditions
- Assess natural forests in the surrounding
- Include pioneer and shrub species
- Consider local needs: timber, fruit or nut trees, berries, etc.

Recommended tree and shrub species for afforestation in Armenia

Main species

Persian Oak, *Quercus macranthera*

The Persian oak comes from southwest Asia (Turkey/Iran), is a deciduous tree and grows up to 30m high. It prefers sun to half-shade and porous, nutrient-rich soils.

Caucasian Maple, *Acer trautvvetteri*

The Caucasian Maple, which is endemic to the Caucasus and the pontic coast of minor Asia, grows with a large crone up to 16m high. It is adapted to the climatic conditions of the subalpine level (1.800-2.500m a.s.l.), not very tolerant to droughts, but resistant to frosts.

Scots Pine, *Pinus sylvestris (var. hamata)*

The Scots Pine grows naturally in a variety of habitats, and is the most widespread of all pines, occupying many millions of hectares across Eurasia. It grows well on soils with nutrients deficiencies. In the Caucasus it ascends to 2.600m a.s.l.

Pioneer, fruit and shrub species

Birch, *Betula litwinowii (Synonym: B. pubescens)*

This birch species is distributed in northeastern and eastern Turkey to the Caucasus. It is a tall tree found in sub-alpine woods and on mountains above the tree line.

Mountain Ash, *Sorbus aucuparia*

The Mountain Ash is a deciduous tree or shrub from the rose family. It develops red pomes as fruit, that are eaten by many bird species. It is a pioneer species and very undemanding regarding growing conditions.

Oriental wild apple, *Malus orientalis*

Malus orientalis grows up to 10m and is mostly found in mountain forests, on forest edges, in glades and along riverbanks. It occurs at elevations up to 2.000m a.s.l. and is native to the Caucasus, Iran and Turkey.

Other species

- Wayfaring tree, *Viburnum lantana*
- Iberian spirea, *Spiraea hyhypericifolia*
- Rose, *Rosa sp.*
- Siberian pea shrub, *Caragana arborescens*

(sources for photos and species information: wikipedia and iucnredlist.org)

Seedling selection - bare rooted versus containerized seedlings

Tree seedlings provided by tree nurseries come either as bare rooted seedlings or as containerized seedlings. **Bare rooted seedlings** are usually grown in tree nurseries on the fields. The infrastructure costs for tree nurseries to produce bare rooted seedlings in comparison to containerized seedlings are lower. For transportation from the tree nursery to the final place of afforestation, seedlings are removed from the ground without soil. Bare rooted seedlings need to be packed carefully into plastic bags, and the time until they are planted should not exceed 1-2 days. During this time neither the root systems nor the transport bags should be exposed to

the sun. Exposure to open air leads to fast damage of fine roots and limits the uptake of water and nutrients after plantation. Seedlings with damaged root systems often after 1-2 weeks after the plantation.

Fig. 5: Containerized oak seedlings, one year old (left) versus 2.5 year-old bare rooted oak seedling (right)

Containerised seedlings are usually produced in nurseries equipped with green houses and irrigation systems. The deciduous trees (oak, ash, birch, maple) are usually grown in containers with 4x7 units and a depth of 18cm, while pine (Pinus sylvestris) is grown in containers with 5x8 units and a depth of 14cm. The seedlings are grown in the container for 1-2 years until they are transported in the container. They can be put into the ground with the root ball and the soil from the container. This is an advantage especially in dry areas, as the root ball has a soil compartment that can keep moisture better than the bare root systems. The disadvantage of containerized seedlings is the possibility of root deformations, if the container is too small and the saplings are kept in the container for too long. Root deformations might lead to decreased vitality and growth rate and even to death after some years when the root system cannot develop properly. For containerized seedlings, special tools can be used for making plant holes according to the size of the root-soil aggregate formed by the container.

Table 2: Comparison of bare rooted versus containerized seedlings

Seedling type	Advantages	Disadvantages
Bare rooted	• Usually cheaper • Produced in tree nurseries without high infrastructure investments • Root system usually well developed	• Very sensitive to improper handling during transport and planting • Might have long roots (>20cm) that need deep plant holes and proper planting procedure
Containerized	• More robust for transport and storing over several days (need watering!) • Roots are protected and get less damaged during planting • Roots stay in their soil environment after plantation, trees show less stress symptoms • Plantation costs can be significantly reduced by using special planting tools	• Production of containerized seedlings needs more investments and leads to higher seedling costs • Root deformations might occur, if seedlings are kept too long in the container

Planting schemes & techniques

The **planting scheme** describes the number of seedlings per hectare and their spatial distribution. The **planting technique** describes how the seedling is planted.

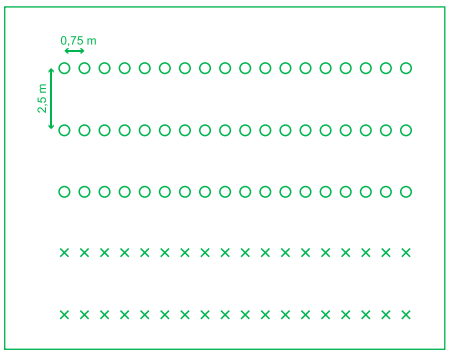
Schemes – lines versus groups

The traditional scheme is a **plantation in lines,** ideally parallel to the contour lines. The planting scheme for this approach would describe the spacing between lines and between the trees within a line (see fig. 6A). If different tree species are included the order of the tree species is given as well. Usually, each line consists of one species but alternation of species is possible, too. The more complex a planting scheme is, the more difficult its implementation in the field and the monitoring of survival rates.

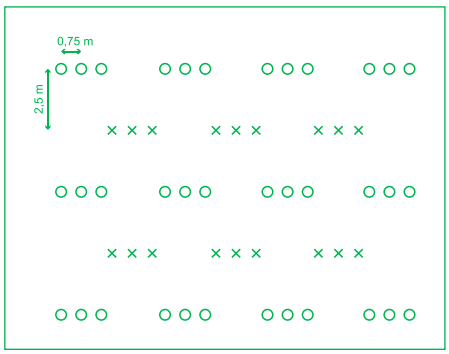
The line approach is usually linked to a high planting density (6.000-9.000 seedlings per ha), as a short spacing between seedlings is needed for creating favorable micro climate (e.g., reduction of wind speed). A modification of plantation in lines is the **chess pattern planting design** (fig. 6B). The number of seedlings is reduced, while the alternating design ensures that run-off water will infiltrate in the next trench downhill.

Modern afforestation approaches favor **group plantation** (fig. 6C, 6D) more and more over line plantation. Most group plantations are designed in a raster of 10x10m to 15x15m, resulting in 100 to 45 raster nodes per hectare. At each node, a group of seedlings is planted in close spacing to each other. The groups might be designed in rings or squares with spacings of 0,4m-1m between the trees. With 9 to 12 seedlings per group and 10–15m between the centres of the groups, each hectare displays 45-100 groups and a total number of 500–1.200 seedlings.

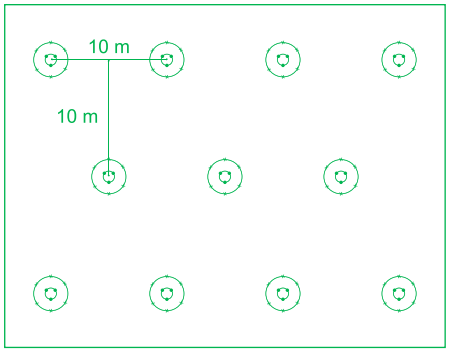
As a drop out of planted seedlings with overall survival rates of about 60-80% is expected, the actual forest will be formed just by a few trees from those that have initially been planted.



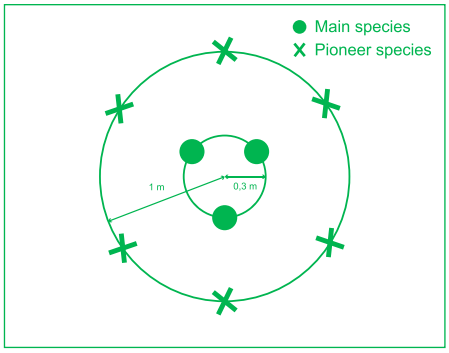
A. Line planting scheme



B. Chess pattern planting scheme



C. Overview of group plantation scheme



D. Example of planted group with different main and pioneer species

Fig. 6: Comparison of different planting schemes

Table 3: Comparison of advantages and disadvantages of different planting schemes

	Advantages	Disadvantages
Line planting	• Easily understandable and widely used • Success is easy to monitor, as long as the same tree species are in one line • Mechanical soil preparation (by tractor) is possible • High planting density ensures a dense stand, even when a high level of die-back is expected	• High costs caused by a large number of seedlings • High costs of planting and maintenance • Large amount of irrigation water per hectare needed • A mechanized mowing of grass between the lines is difficult without damaging the seedlings
Chess pattern planting	• Fewer seedlings and thus less work for planting activities • Effective control of surface water run-off • A good option for erosion control plantings for larger areas	• Mechanical soil preparation is difficult (staggered trenches) • Irrigation is more labour-intensive
Group planting	• Smaller number of seedlings reduces the afforestation costs • Easier maintenance: fewer seedlings to be mulched and irrigated • The micro-climate function is important. • Even with a high level of die-back rates (60%), at least 3-5 trees/shrubs per group survive, which leads to a minimum of 200-500 trees/ha • Easy hay cutting between the groups	• More difficult to irrigate compared to trenches • Group planting is not known in Armenia, and people are skeptical about this method • It might take longer for the area to be covered with with protective trees/shrubs

Technique-Trenches versus holes

During the Soviet period and up to now, a common afforestation technique is by digging trenches parallel to the contour lines (30cm wide, 35cm deep) with a spacing between trenches of 2–3m, depending on the inclination (the steeper, the shorter the spacing). In these trenches, seedlings are planted planted at 30-50cm intervals, resulting in 6.000-9.000 tree seedlings per hectare (fig. 7A). With this high planting density, one would aim at a quick closure of the crown layer of the young trees to avoid the growth of other plants.

An alternative to trenches are plant holes with a diameter of 20-40cm and a depth of 30-40cm (fig. 7B). Plant holes can be used for the plantation as well as for group plantation. Deep holes make irrigation easier, provide wind protection but increase the risk of being overgrown by surrounding vegetation.

Dig trenches and plant holes directly before planting of seedlings in order to keep the moisture and have favorable soil conditions!

Fig. 7A: Oak seedlings in a trench plantation

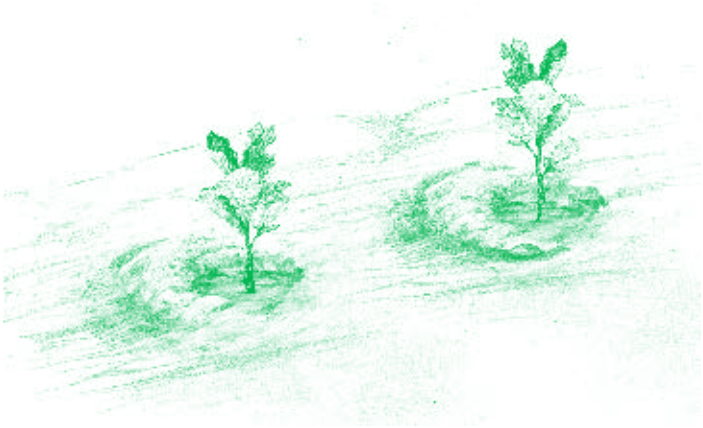


Fig. 7B: Oaks planted in plant holes

Table 4: Comparison of different planting techniques

Planting technique	Advantages	Disadvantages
Trenches	• Trenches can be dug by a tractor - this is time and resource efficient. • Trenches capture run-off water and conserve moisture. • It is easy to plant and irrigate along the trenches. • Trenches are appropriate for high planting density.	• If trenches are not dug along the contour line of the slope this leads to increased erosion in case of heavy rainfalls. • It is difficult to dig on a stony ground. • Seedlings planted close to each other compete for sunlight water and nutrients. Thinning is necessary after some years.
Plant holes	• There is high flexibility in terms of identifying the location of the seedlings, especially in stony terrain and on steep slopes. • Deep planting holes preserve moisture and provide protection against the wind. • Plant holes allow flexibility in spatial design (lines or groups). • The speed of digging can be increased by using a motor-soil drilling machine.	• Labour-intensive in terms of planting and maintenance (irrigation, grass cutting). • Preparation of holes with proper depth and shape (incl. half-moon at the lower side) needs supervision.

Maintenance

Irrigation

Irrigation may support the root development of the seedlings in the first 1-3 years and increase the survival rate. If no permanent irrigation system is established, each tree seedling should be supplied with at least 5-10 litres of water right on the day of planting, unless it is raining or the soil is saturated with water from the previous rain. Irrigation 1-4 times during the summer drought with 10 litres/tree will support growth and survival rate. Drip irrigation systems are most efficient, but very costly. Irrigation by hand with buckets or rubber tubes seems more realistic, as irrigation should be limited to the first 1-2 years (in case of low growth rates up to 3 years). It can be meaningful to install mobile water tanks of 1,5-3m³ for gathering water from sources with lower water output to speed up the irrigation process.

Mulching & weed control

When soils are fertile, the growth rate of herbs and grasses might be higher than those of the seedlings and might shade out the seedlings. Depending on the growth conditions, weed-control (cut back of grass and herbs) might be needed 1-3 times a year. Sites on higher altitudes (> 1.800m a.s.l.) and low precipitation might only need one intervention per year. The frequency of hay cutting in nearby meadows can be used as an indicator of how often weed control might be necessary. The cut hay can be used for mulching (covering the ground around the seedlings). By reducing water evaporation from the soil, mulching reduces irrigation requirements and also counteracts weed growth (fig. 8).

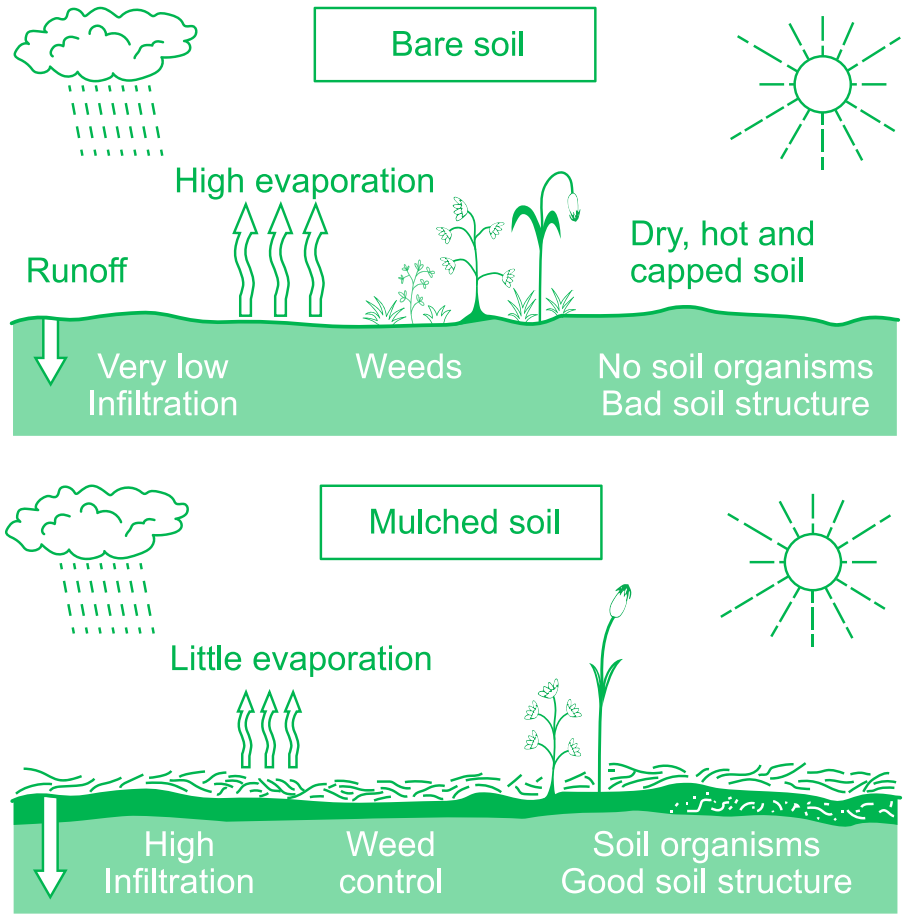


Fig. 8: The effects of mulching (source: Vukasin et al, 1995)

Module 5: Soil Bioeningeering

General introduction

Definition: Soil Bioengineering *(Polster, 2002)*
"Soil bioengineering is the use of living plant materials to construct structures that perform some engineering function. These "living engineering systems" make use of locally available materials, and are often used to increase surface stability and to combat erosion problems".

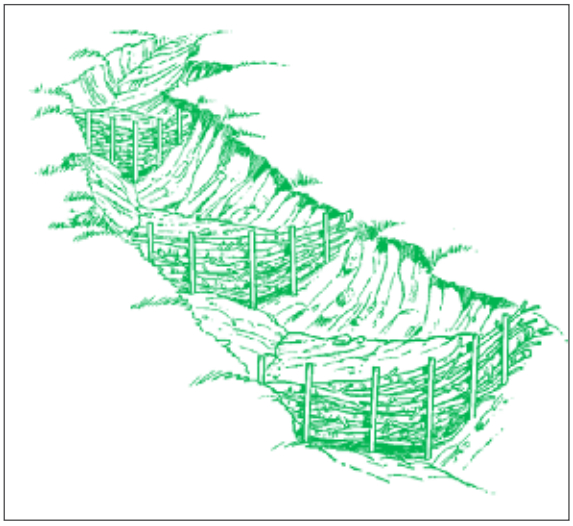


Fig. 1: Gully breaks (source: Polster, 2003)

Soil bioengineering refers to measures that combine principles of ecology, hydrology, geology, physics and engineering to construct vegetative protective structures. They are used to reduce or control erosion, to protect soils, and to stabilize slopes. As living systems, soil bioengineering structures need almost no maintenance and provide an effective, long-term protection against soil erosion, as they even grow stronger over the years (Polster, 2003).

Bioengineering uses materials, which are found in nature and combines them with technical building materials. Examples are small retaining pile walls on slopes to stop stones and soil from moving down, or gully breaks to slow down the velocity of water movement (fig. 1).

In contrast to pure physical engineering, bioengineering structures based on living vegetation need time to reach their maximum strength and protective effectiveness. A combination of technical and vegetative construction materials therefore, enables to achieve immediate results in terms of soil protection and erosion control while fostering a long-term, "nature-based" solution.

Soil bioengineering is an appropriate approach to deal with erosion problems and shallow seated landslides (Lammeranner et al., 2005), especially in situations with limited financial resources. The technique can be implemented in a very cost-effective way, if locally available materials and labour is used. Usually, the low technological requirements with regards to machinery, equipment and knowledge allow to involve the local population in establishing and maintaining the bioengineering structures.

Another benefit of the bioengineering approach is the support of ecosystem functions and the strengthening of biological diversity through, for example, the protection of vegetation cover or the establishment of natural landscape structures. Adequate bioengineering techniques dense vegetation result in effective and long-term control of erosion phenomena.

Benefits of bioengineering measures

- Cost-effective
- Low requirements in terms of machinery, materials, and knowledge
- Allow participation of local population
- Contribute to ecosystem functioning and biological diversity
- Improve soil quality & land productivity
- Ensure effective, long-term erosion control

Table 1: Technical and ecological functions of bioengineering structures (Zeh, 2007):

Technical Functions

- Protection of the soil surface from erosion by wind, precipitation, frost or flowing water
- Protection from rockfall
- Drainage
- Protection from wind
- Reduction of destructive forces of water (rivers, gullies)

Ecological functions

- Improvement of water regime by soil interception and storage capacity
- Soil drainage
- Protection from wind
- Mechanical soil amelioration by plant roots
- Balancing of temperature conditions in ground level air and soil layers
- Shading
- Improvement of the nutrient content of the soil
- Productivity improvement of adjacent pasture and crop lands

Fields of application & natural limits

Bioengineering methods can be applied wherever the plants, which are used as living building material, are able to grow. Natural limits may be imposed for example by too high altitudes in alpine (mountainous) regions. The observation of the surrounding will help to recognize potential limitations in growth of trees or shrubs.

Bioengineering can provide solutions for the following erosion phenomena frequently occurring in the mountainous areas of the Southern Caucasus: degraded slopes, cattle tracks, and small gullies.

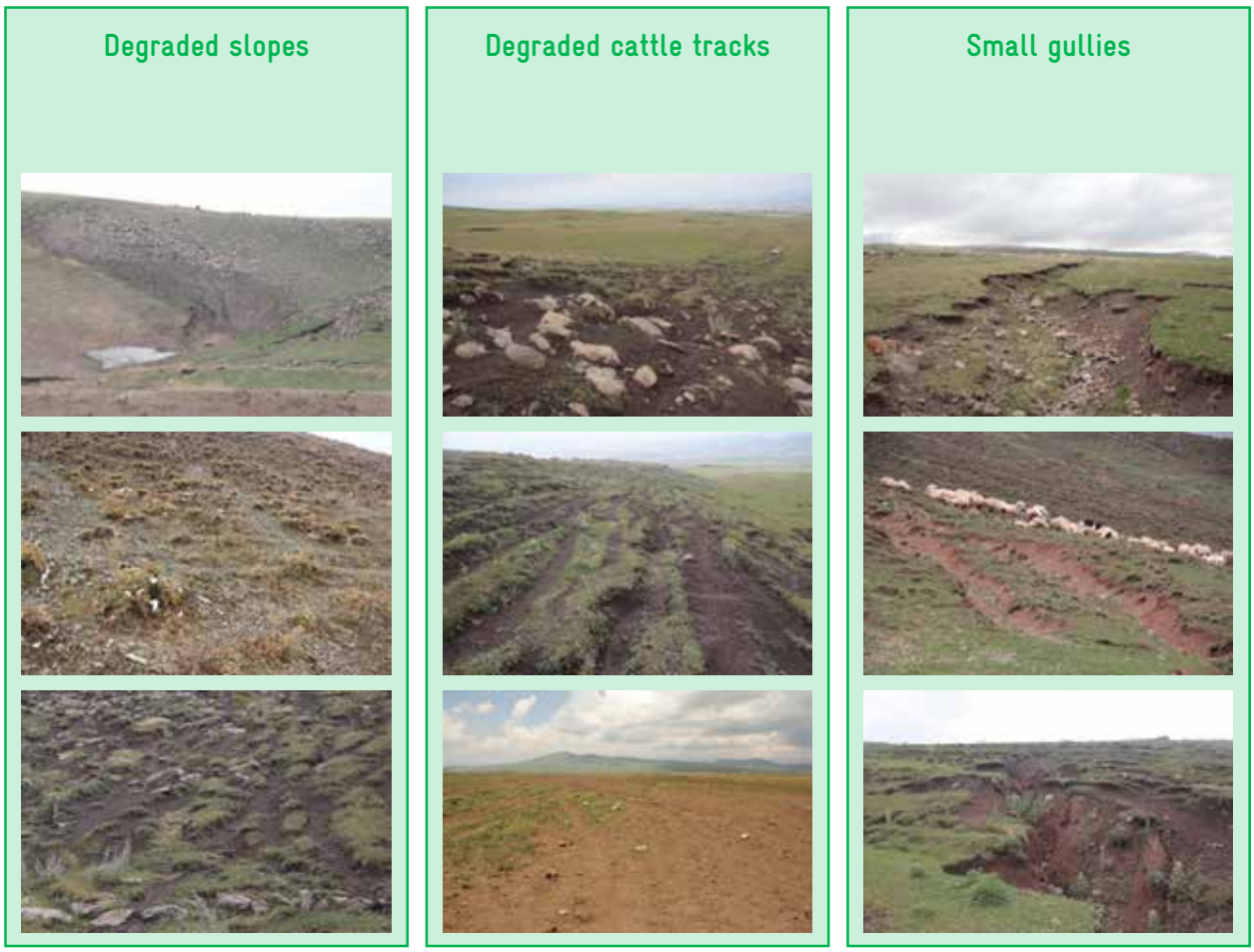


Fig. 2: Frequent soil degradation and erosion phenomena in the South Caucasus that can be addressed with bioengineering

Selection of bioengineering sites and appropriate measures

Bioengineering measures support the rehabilitation of degraded or eroded areas. Thus, there are two main criteria for site selection:

- **Occurrence of erosion: what kind of erosion phenomena are present?**

Erosion frequently occurs on steep or over-used sites. Consequently, the most common areas where bioengineering is appropriate, are cattle tracks (particularly around villages), ravines, trenches, gullies with temporary or permanent water flow, overgrazed areas with a visible share of open soil, slopes along roads and trails, river banks that constantly extend.

- **Importance of erosion: does it threaten lives, infrastructure or livelihoods?**

The implementation of bioengineering measures – even though cost-effective – requires effort and resources (workpower, materials). Therefore, sites should be selected based on the following criteria:

- ✓ Erosion, mud flows, rockfall threatening human life or infrastructures (roads, houses, dams)
- ✓ Erosion resulting in an adverse economic impact (e.g., loss of soil/pasture productivity, threatening of livestock, blocking of cattle tracks)
- ✓ The site has a realistic chance to regenerate. Sites with only 10-20% of vegetation cover left, intense use and high inclination require more effort. Such sites should be discarded unless professional companies work on it
- ✓ Erosion threatens other ecosystem services or long-term perspectives (gradual degradation of pastures)

- ✓ At least temporary fencing needs to be ensured. Bioengineering works with living plants and seeds, which need to be protected from grazing animals.
- ✓ Once the areas to be treated are identified, appropriate measures need to be selected. This process is determined by:
  - ➢ the erosion type,
  - ➢ natural conditions (inclination, precipitation, natural vegetation, temperatures, water availability, wind, elevation),
  - ➢ availability of materials for construction (rocks, logs, branches, etc.) and rehabilitation of vegetation (seeds, hay, grass, cuttings, seedlings, etc.).

For specific erosion phenomena and natural conditions, different measures may be appropriate or could even be combined (Table 2).

Table 2: Bioengineering options for different erosion processes and natural conditions

Type of erosion process & natural conditions	Bioengineering options
Degraded cattle tracks	Temporary fencing, pile walls, hay/grass mulch, seeding
Overgrazed slopes	Temporary fencing, hay/grass mulch
Rocky, low productive slopes inclined to rockfalls	Temporary fencing, palisades/ check dams, flattening of steep edges, hay/ grass mulch, planting of shrubs
Small gullies	Temporary fencing, pile walls, hay/grass mulch, planting of shrubs

The availability of materials will influence the final selection of measures. An overview of the most commonly used materials is given in Table 3. To match existing resources with the envisaged measures and results, creativity and improvisation may be required. For instance, logs used for pile walls can be replaced by bundles (fascines) made of smaller living branches from poplar or willow (fig. 3).

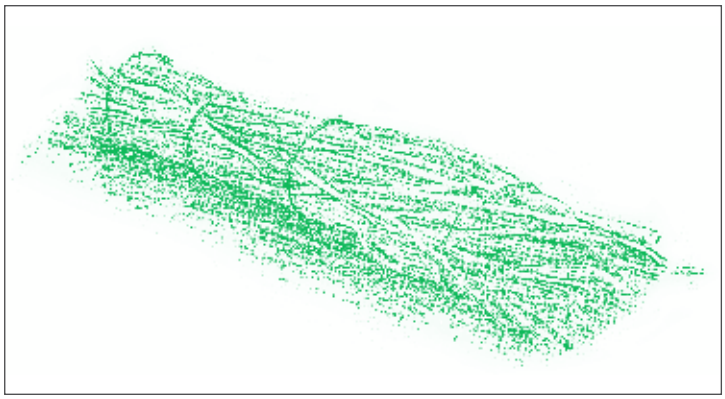


Fig. 3: Bundles of branches (fascines) as alternative to wooden logs

A general rule of any bioengineering: **Have a look around and make use of the materials you have**!

Table 3: Characteristics of the most commonly used materials for bioengineering.

Type of material	Description	Use	Limitations	Availability around Aragats	Availability in Armenia
Wooden logs	Diameter: 10–20cm, Length:< 4m	All types of construction, e.g. pile walls, crib walls, check dams	None	Limited	Available in certain parts
Branches of woody species	Living or dry, 1-3cm diameter	Cuttings for planting, long branches for fascines	Availability of locally adapted species (for arid or cold conditions)	Limited; only willow, rosehip, poplar suitable	Available
Hay or cut grass	Dried or fresh grass (cut after seed development!)	Re-establishment of vegetation on bare soil	None	Available	Available
Straw	Remnants of crop harvest	Mulching	May need coverage in case of strong winds	Available	Available
Manure	1-2 year old manure from cows or sheep	Fertilizing of degraded soils	Fresh manure is not suitable	Available	Available
Seedlings of selected species	Seedlings of poplar (Populus sp.), willow (Salix sp.), rosehip (Rosa sp.), wild apple (Malus sp.), small shrubs	Rehabilitation of vegetation and stabilization of steep areas	Not above the tree line; minimum requirements for moisture and soil; protection against grazing	Limited; only willow, rosehip and poplar suitable	Available
Seeds of locally adapted species	Collected/ commercial seeds (or from grass)	Re-establishment of vegetation on bare soil	Availability of adapted species	Extremely limited, alpine species required	Limited
rocks	In mountain areas	For all type of constructions and barriers	None	Abundant	Abundant

Detailed description of three selected bioengineering measures

1) Hay or grass mulch application

Field of application

For rehabilitation of extreme locations (e.g., high altitudes, steep slopes, dry sites), the application of hay or grass mulch is an appropriate method. Covering the open soil provides mechanic protection against erosion. Additionally, the mulch provides seeds and organic (decomposable) material and conserves the moisture on dry sites. It is a proven method for rehabilitation of sites where there is still some vegetation and soil left.

Technical description

Long hay, grass or straw (300-500g/m²) is distributed on the open soil providing a cover layer up to 5cm thick. Depending on the site, it can be additionally mixed with locally adapted seeds (10-30g/m²) or manure (Florineth, 2004). Particularly, when it is unclear how many seeds the hay contains, the use of additional seeds is recommended. The advantage of using local hay provides a guarantee to have an autochthonous seed mixture, but its disadvantage is that the amount of seeds is variable.

Before application, it is recommended to prepare the soil - removal of stones and cutting of steep edges along gully erosion - to support vegetation establishment. The best time for mulch application is early spring or late autumn. Due to hot and windy summers in Armenia, application between June/July and September should be avoided, unless additional fixing, e.g., with decomposable nets or small rocks is done (Huber, 2016). Fig. 4 provides examples of decomposable coconut-nets (left) that can be used for protecting hay mulch from being blown away, and of a manure-mulch mixture from composted manure as well as barley straw including seeds (right). If grain seeds are foreseen to germinate and grow to serve as green manure, the seed-containing mulch should be applied in early spring, so that enough moisture is available for growth before the dry summer season starts.

Fig. 4: Decomposable nets to cover hay mulch (left), manure-mulch mixture (right)

If communities reserve certain hay meadows for grass mulch, the ideal moment for harvesting has to be selected (between late June and late July). In general, the earlier the cut, the more grass seeds you gain, the later the cut, the more seeds of herbs are ripe. However, further research needs to be conducted in order to determine the ideal moment for harvesting suitable grass and herb varieties.

2) Vegetated or non-vegetated pile walls

Field of application

(Vegetated) pile walls support the establishment of vegetation on steep slopes. Furthermore, they slow down superficial water run-off and allow for accumulation of organic material and soil. They are supposed to stop rocks and stones moved by grazing cattle or erosion processes and to slow down vertical water flows. Thus, this technique can also be used at a very small scale for consolidating small paths (hiking trails, cattle paths), for example when crossing rock fields or ditches with starting erosion or starting gullies. It can be used in combination with any other bioengineering measure and is usually supported by measures to re-establish vegetation (e.g., cuttings, seeds, hay mulch).

Technical description

To establish one pile wall, one log of about 4m length and 20-25 cm diameter as well as two iron poles of approximately 1m are required (Florineth, 2004). A team of two workers can establish up to 4 pile walls per hour. The average distance between the logs varies depending on terrain conditions. Due to their durability, it is recommended to use either pine or acacia wood. Nevertheless, any type of available wood (e.g., poplar) can be used that guarantees proper functioning for several years.

Fig. 5: Examples of pile walls on different pilot sites. Offset establishment of pile walls (left) and below each other in water run-off grooves (right)

The distribution scheme and amount of pile walls is based on the degree of inclination and the character of the terrain. To reduce the water velocity, the pile walls should be established offset to each other (fig. 5 left and fig. 6 left). In case of uneven slopes, the construction should rather be made in the depressions where the main water-flow occurs (fig. 5 right).
Depending on the available material, the wooden logs can be replaced by bundles of branches (fascines, fig. 3). Wherever possible, vegetated pile walls should be given priority as roots provide additional stability to the ground. The establishment of pile walls should always be accompanied by some terracing to "optimize" the slope and provide good starting conditions for vegetation establishment.

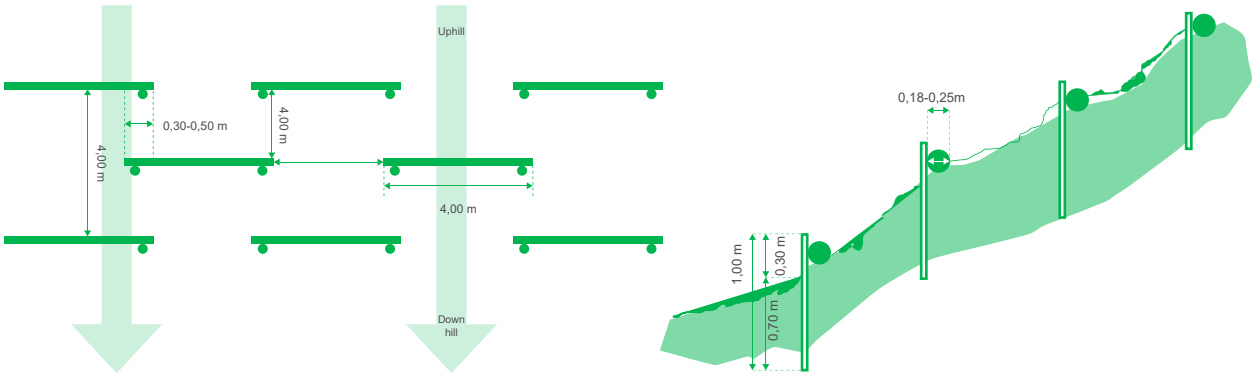


Fig. 6: Scheme of pile wall distribution across the slope. View from above (left) and vertical scheme (right)

3) Gully plugging with check dams

Field of application

For rehabilitation of small gullies – less than 1,50 m deep and 5 m wide – simple measures such as palisades and planting of shrubs can immediately stop erosion processes. Gully plugs, also called check dams, are simple engineering constructions to prevent erosion and to settle sediments. Furthermore, they help to keep soil moisture through an increased water infiltration. Depending on the topography, the amount of precipitation, available materials and financial resources, there are several methods to construct a gully plug out of wood, branches, rocks or a combination of different materials (fig. 7).

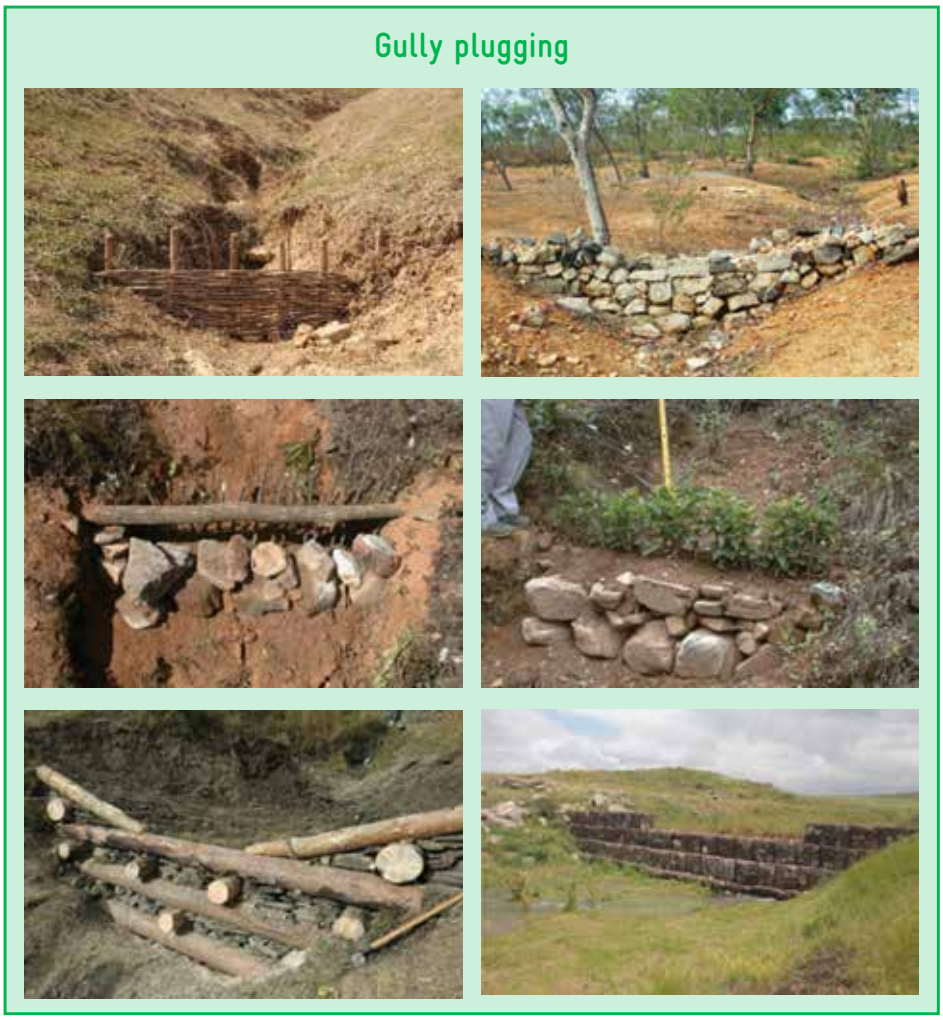


Fig. 7: Gully plugs constructed with different materials

Technical description

Vegetated check dams are used as a transverse structure for bed consolidation in steep gullies and for slope stabilization. Double-walled cribwalls are built of round timber. The constructed layers are filled with drainable material, living branches or rooted woody plants are inserted in the sidewalls, not blocking the discharge section (fig. 8).

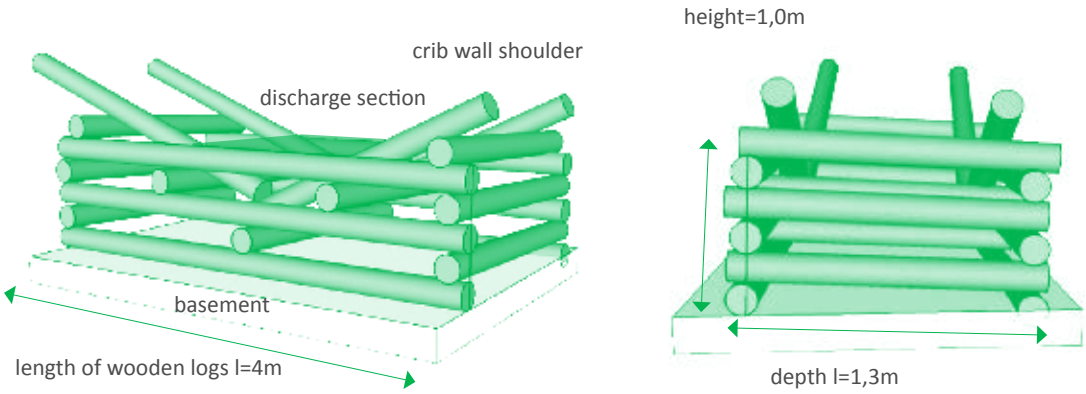


Fig. 8: 3D views of the wooden structure of the vegetated crib wall (Rauch et al., 2016)

Following the same principle, the check dam can also be constructed with gabions (filled rock boxes) or for smaller sections with palisades (vertical wooden branches or logs). The larger the gully, the larger and more complex the required check dam structure.
The construction of check dams is usually accompanied by supporting measures, such as cutting the steep edges of the gully, re-establishment of vegetation on the gully slopes, filling of the gully bottom with rocks or branches or planting of shrubs. The selected combination of measures is defined by the dimension of the gully and whether there is permanent or periodic flow of water.

Further reading

There are many other bioengineering options, depending on the specific situation and available resources. For further reading please check the following links:

Polster, 2002: Soil bioengineering techniques for riparian restoration. Online available at: https://www.researchgate.net/publication/237468581

Training handout on bioengineering and survey, design and estimation of soil conservation and watershed management, 2005. Nepal. Dep. of Soil Conservation and Watershed Management, Kathmandu:

- Chapter 4: Bioengineering measures: http://lib.icimod.org/record/27708/files/Chapter%204%20Bioengineering.pdf
- Chapter 5: Physical Methods for Slope Stabilization and Erosion Control, from: http://lib.icimod.org/record/27709/files/Chapter%205%20Physical%20Methods.pdf

Module 6: Upscaling of Pilot Measures

"Small is beautiful but big is necessary" (GIZ South Africa, 2016)

Definition: Upscaling *(WHO, 2016)*
"Scaling up means to expand or replicate innovative pilot or small-scale projects to reach more people and/ or broaden the effectiveness of an intervention".

This chapter provides an overview of upscaling strategies and ideas for their practical implementation. Upscaling is of particular importance for managers and technical staff (implementing agencies, governmental bodies, NGOs) who are in charge of planning and implementing pilot projects. The aim of any pilot project or measure is that the experiences obtained will be used for replication and upscaling. In particular for pilot measures related to natural resources management (NRM), a tangible impact can only be achieved when certain measures or improved practices are applied at a larger scale. There are different types of upscaling strategies:

1) **Horizontal scaling up ("replication", "scaling-out")** refers to applying experiences in similar or comparable contexts.

Horizontal scaling up "asks": what changes in comparable "local systems" will be based on the particular experience?

2) **Vertical scaling up** looks at influencing the policy environment (developing and changing policies, laws and regulations).

Vertical scaling-up "asks": what changes in the larger (political-administrative) system will be based on the "local" experience?

3) **Functional scaling up** refers to the transfer of successful approaches to another context or service. This can include horizontal as well as vertical upscaling approaches.

Functional scaling up "asks": what changes that proved to be successful under specific conditions can be adapted to the conditions in another country or in another sector?

GIZ projects follow a multi-level approach worldwide, which relates to horizontal as well as vertical upscaling (fig. 1). In case of the IBiS project, horizontal upscaling would include the extension of erosion control measures to the same pilot communities as well as to other communities with similar conditions. Vertical upscaling is envisaged through constant policy dialogue with political partners at the marz and at the national level. In this context, the goal is to have successful pilot projects being taken up by the Armenian government, incorporated into policy guidelines or regulations and then being applied at a larger scale.
Functional upscaling is also observed in the frame of the IBiS programme. Since IBiS is a regional programme working in the three South Caucasian countries, successful measures and approaches are shared and adapted to specific circumstances, e.g. application of bioengineering measures in Georgia and Armenia.

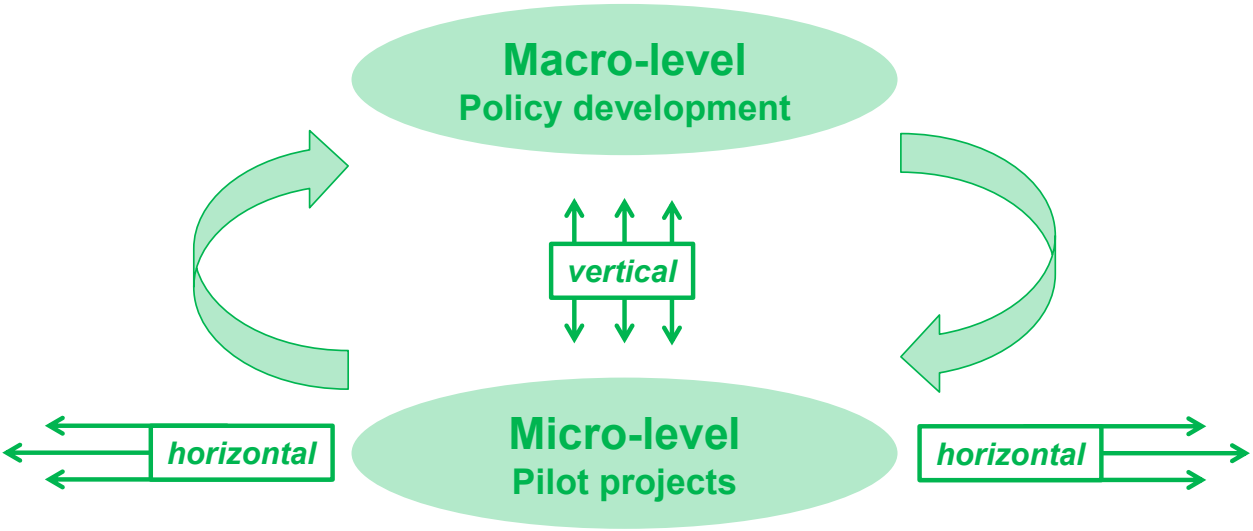


Fig. 1: horizontal and vertical upscaling

Tool for assessing the upscaling potential of a pilot measure

The following tool, which combines a checklist and a spider diagram, helps to identify the strong and the weak points of a particular pilot measure in terms of its upscaling potential. In the given context, it refers primarily to horizontal upscaling, but may be adjusted for vertical and functional upscaling processes as well.

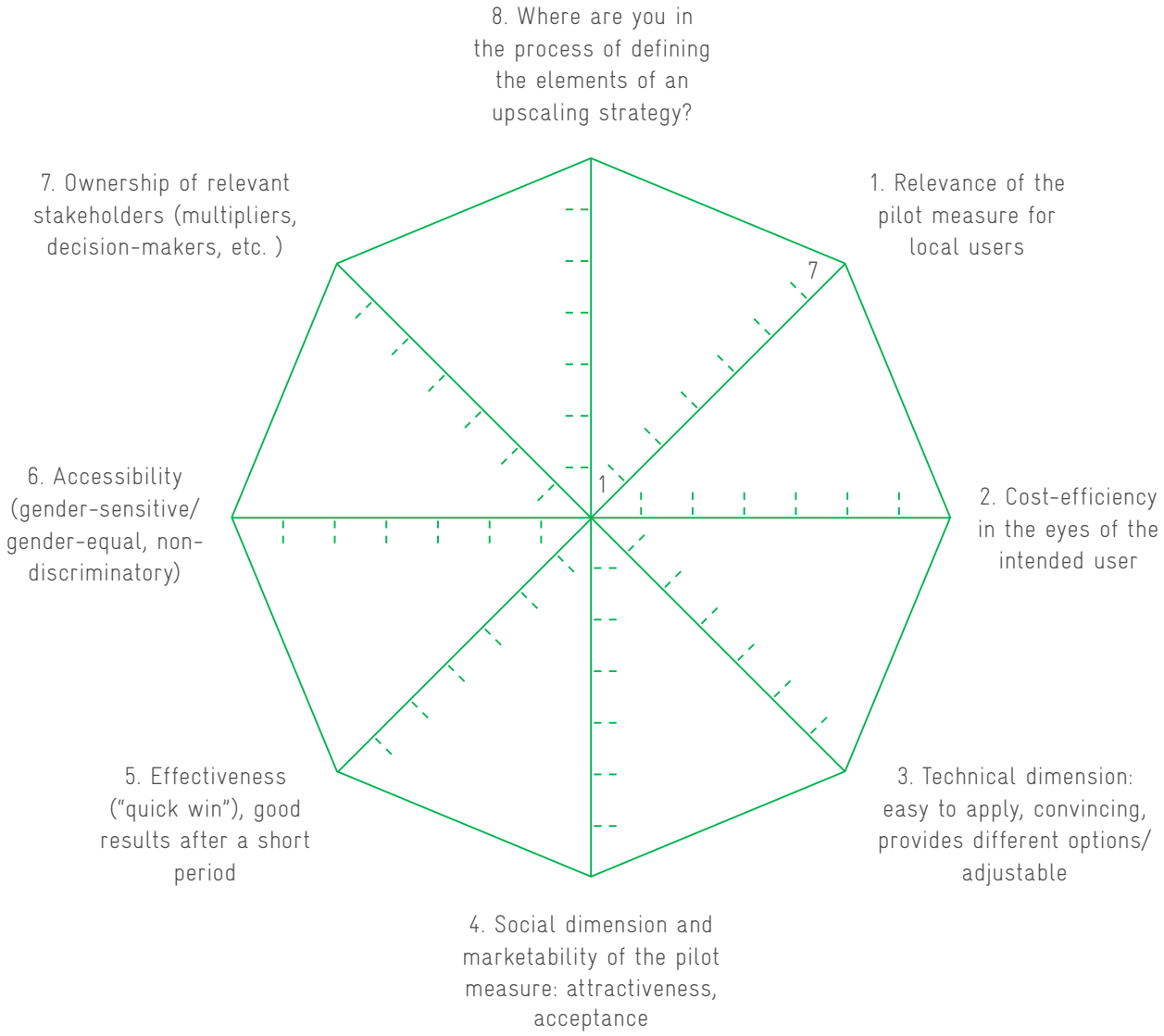
1. Assessment grid: upscaling potential of a pilot measure

Assess the following criteria on a scale from 1-7 (1=low/little developed; 7= high/very advanced):

No.	Criteria	Score (1-7)
1	How relevant is the pilot measure for local users?	
2	Following a simple cost-benefit analysis of the pilot measure: are there financial benefits for the local user?	
3	Check carefully the technical dimension of the pilot measure: is the measure easy, persuasive, convincing, adjustable? Does it provide different options?	
4	Check carefully the social dimensions of the pilot measures Is the pilot measure affordable for its intended users? Does it have a market potential?	
5	Check the effectiveness of the pilot measure: does it give good results in a short time?	
6	Check, if equal access (e.g., gender sensitivity and gender equality) is assured, and if pilot measures are not discriminatory e.g., against minorities.	
7	Check, if the pilot measure ensures ownership by its intended users, as well by relevant stakeholders such as multipliers and decision makers.	
8	Invest time, efforts and strategic thinking in defining an upscaling strategy, or, at least the elements of it. It is necessary to update the elements and steps of your upscaling strategy on a regular basis. Where are you in this process?	

2. Spider diagram

The spider diagram helps to visualize the upscaling potential of a particular pilot measure as well as to identify the weak points, which need improvement.



Module 7: Showcases

Showcase 1: Afforestation of Eroded Pasture Land, Saralanj Community

Description

The community of Saralanj is located in Shirak Marz in North western Armenia. Main income sources of about 600 households of Saralanj are livestock keeping – mainly cattle and sheep - and the cultivation of potatoes and cereals. Annual precipitation is about 500mm, mainly coming in the cold season between autumn and spring, while the summer periods tend to be hot and dry. Most sites around the village experience soil erosion, mainly caused by trampling and grazing of livestock.

For demonstrating different measures against soil erosion, one degraded site of about 16 ha and another plot of 2,5 ha next to the community Saralanj were afforested with the support of GIZ. The pilot sites are located on a slope (lower 7,5°) about 2km southeast of the village on an altitude of 2.100–2.134m a.s.l.

WHAT – Implemented pilot measures

- 2.900m permanent mesh wire fence established
- 48.000 seedlings on 18,5 ha using different planting schemes (2.500–4.500 seedlings/ha) planted

WHY – Erosion phenomena & causes

- High grazing pressure on pasture area
- Loss of upper soil layer because of water erosion (initial stage)
- Low pasture quality because of low biomass and lots of stones

WHO – Main stakeholders involved

- Local population of the community
- Local experts from Global Armenian Response NGO (irrigation system)
- Local experts from ESAC NGO (fencing and afforestation)
- GIZ IEC/IBiS program staff & international experts

Fig. 1: Pilot sites (light green) next to the village Saralanj

Fig. 2: Pilot site – degraded pasture with scarce vegetation and lots of stones (August 2014)

WHERE

- Saralanj in Shirak Marz, Armenia
- Pilot sites: 16 ha and 2,5 ha on degraded slopes
- Village pasture on the community owned land

Methodology

Site selection & preparation

In 2014, a socio-economic assessment was conducted covering 14 villages within the pre-selected pilot provinces of Aragatson and Shirak. In Shirak province, Saralanj was identified as one of the pilot communities for implementing afforestation measures against soil erosion. The willingness and interest of community representatives served as the main selection criteria.
In a joint process involving community members, marzpetaran representatives, national and international experts, potential sites for afforestation were assessed based on the following criteria:

- Erosion is a current problem.
- Site is accessible.
- Water for irrigation is available.
- Pilot activities do not significantly affect daily business (e.g., fencing should not hamper cattle movement).

The selected site in the southeast of Saralanj community is heavily affected by the daily migration of livestock from the village to the higher mountain pastures. Trampling and grazing caused erosion and degradation of the land, exacerbated by natural conditions – low precipitation and exposition on the northern slope.
The preparation of an afforestation concept was the next planning step. The concept, developed by a team of national and international experts, captures selected tree species, the foreseen planting scheme, the needed resources and expected costs.

Implementation

The afforestation activities in the community Saralanj started in autumn 2015, about one year after the start of the preparative work (socio-economic assessment, selection of pilot village and pilot sites).
The two sites (6 ha and 2,5 ha) were fenced and afforested in autumn 2015, another 10 ha (extension of the 6 ha plot) were fenced in 2016. Containerized seedlings, mainly birch, oak and pine (table 1) were obtained from Hrazdan nursery, belonging to "Hayantar" State Forest Agency.
On the 6 ha and 2,5 ha areas, the trench and hole plantation techniques were applied with an average of 4.500 seedlings/ha. In 2017, the number of planted seedlings/ha was reduced to 2.500. The seedlings were mainly planted in trenches. Mechanical ploughing of 30 cm deep trenches with a distance of 2,5m eased the process (fig. 4).

Fig.3: Transportation of seedlings to the afforestation site. Containerized seedlings were removed from containers and packed in plastic bags before transportation

Table 1: Tree species and number of seedlings planted in different years

Species	Latin name	No. of seedlings planted in 2015	No. of seedlings planted in 2016	No. of seedlings planted in 2017
Birch	*Betula litwinowii*	10.000	500	500
Pine	*Pinus sylvestris var. hamata*	10.000	4.500	5.500
Oak	*Quercus macranthera*	6.000	1.500	1.500
Mountain ash	*Sorbus aucuparia*		1.000	
Elm	*Ulmus pinnato-ramosa Dieck.*		500	500
Siberian pea shrub	*Caragana arborescens*		1.000	1.000
Seabuckthorn	*Hippophae rhamnoides*		1.500	1.500
Ash				1.000
Totals		26.000	10.500	11.500

In 2016 and 2017, additional seedlings were added to the afforestation sites, including some new species, such as mountain ash, elm, siberian pea shrub and seabuckthorn (table 1). Irrigation water was obtained from an irrigation channel above the afforestation plot. Plastic pipes and rubber tubes were supplied by the project and used for open furrow irrigation.

Fig.4: Pilot site with ploughed planting trenches (October 2015)

Fig. 5: Community members planting tree seedlings in the ploughed lines (October 2015)

Community members were paid for their engagement in fencing, planting and irrigation activities.

Needed resources

The table below gives an overview of the needed costs for purchasing equipment, constructing the fence and planting the seedlings:

Materials	Amount (AMD)	Labour	Amount (AMD)
Fencing material	10.900.000	Fencing	8.300.000
Seedlings	4.300.000	Planting	10.300.000
Irrigation pipeline	2.600.000		
Total material costs	17.800.000	Total labour costs	18.600.000

The total cost is 36.400.000 AMD for afforestation of 18,5 ha, which means approx. 2.000.000 AMD/ha.

Evaluation & lessons learnt

- *Planning & implementation:* the prepared afforestation concept was a useful guideline throughout the preparation and implementation process. When it came to the practical implementation, some arrangements and adjustments were undertaken. For example, the distance between planting rows was reduced to 2m. The distance between seedlings was often much shorter than the foreseen 0,75-1m. The final tree species selection and composition was influenced by the availability of seedlings.
- *High planting density:* with up to 4.500 seedlings/ha, planting planting was labour intensive and required lots of materials. Thinning will be needed after some years.
- *Importance of joint vision and leadership:* Saralanj has been one of the most active pilot communities before, during and after the implementation of afforestation activities. The community has a clear vision to establish a community forest after 10-15 years. They have a young, motivated and dynamic leader who has the ability to mobilize the community.
- *Maintenance:* the community has taken over the responsibility for care taking activities. The mayor has recruited 2 employees who are responsible for mulching and irrigation of the afforestation plots. The community has also contributed to installation of irrigation pipeline.
- *Effectiveness:* a documentation of survival rates of seedlings in 2017 gave the following picture for the three main tree species:

Species	Latin name	Survival rate (%)
Birch	*Betula litwinowii*	55
Pine	*Pinus sylvestris var. hamata*	90
Oak	*Quercus macranthera*	53

- *Costs:* costs for the fence material summed up to 4.500 AMD/m, the labour costs for establishing the fence accounted for 3.200 AMD/m. This can be considered a "luxury" fencing option.
- *Documentation:* the deviations from the foreseen concept throughout the practical implementation emphasize how valuable a continuous documentation is for evaluating the pilot activities and for deriving lessons learnt. Careful documentation should comprise: description of the implementation process (timeline, involved stakeholders, disturbances, reasons for deviating from the concept), final planting scheme, planted species, costs, labour, survival rates, maintenance, etc.

Perspective

- The high level of ownership provides a good basis for continued care-taking and possible extension of afforestation activities in Saralaj community.
- Pioneer in changing land category: on his own initiative, the mayor of Saralanj community obtained a legal basis for establishing a community forest. The process of changing the land category (from pasture to forest land) is usually very long and complicated. It is important to share this experience with other communities.
- The territorial reform process is perceived as a risk factor in the community: in spring 2018 Saralanj is supposed to become part of Artik consolidated community. Certainly, there will be changes in responsibilities, but possibly there will also be new opportunities. GIZ IBiS will actively seek cooperation with the new leaders of the consolidated communities and lobby for continuation of erosion control activities.

Showcase 2: Afforestation of Eroded Pasture Land, Nahapetavan Community

Description

The community of Nahapetavan with about 1.250 households is located in Shirak marz in Northwestern of Armenia. As it is the neighbouring village of Saralanj (showcase 1), the general characteristics are quite similar.

Nahapetavan was selected as pilot community of GIZ IBiS in 2017, and measures were implemented in the same year. As a result of participatory discussions, three separate sites with a total area of 9,7 ha in close distance to Nahapetavan community were selected for afforestation activities. The pilot sites are located on a slope (7,5°-15°) about 0,7-1,5km southeast of the village in an altitude of 2.035–2.150m a.s.l.

WHAT –Implemented pilot measures

- Around 2.800m permanent barb wire fence established
- Planting of 24.250 seedlings on 9,7 ha (approx. 2.500 seedlings/ha) planted

WHY – Erosion phenomena & causes

- Moderate to high grazing pressure on pasture area
- Off-road driving across the pasture land
- Low pasture quality because of low biomass and lots of stones

WHO – Main stakeholders involved

- Community mayor and village council
- Local population of the community
- Local experts from "Armenia Tree Project" (ATP)
- GIZ IEC/IBiS program staff & international experts

Fig.1: Pilot sites (light green) next to the village Nahapetavan

WHERE

- Nahapetavan in Shirak marz, Armenia
- Pilot sites: 9,7 ha on degraded slope
- Village pasture on community-owned land

Methodology

Site selection & preparation

Based on the recommendations of the marzpetaran (regional administration body) and the initiative of the village mayor, Nahapetavan was considered as an additional pilot community of the GIZ IBiS Project in 2017.

The selected site southeast of Nahapetavan community is heavily affected by the daily migration of livestock from the village to the higher mountain pastures. The community's interest was to plant a forest around the monument, close to the village. However, it was not possible to find a larger afforestation site, because of the wide-spread presence of private property and roads. As a compromise, three separate sites were identified.

As there is scarcity of irrigation water in the village, this issue had to be clarified before starting the implementation process.

Implementation

Preparatory works started in spring 2017 and implementation of measures was done in autumn of the same year. The following steps were implemented:

- Fencing: to test low-cost options, which promise higher replication potential, ordinary barb-wire fence was used in combination with concrete fencing posts (fig. 2).
- Preparation of planting sites according to different schemes (fig. 4-5):
  - ✓ upper plot: planting in lines. Trenches prepared by a tractor
  - ✓ middle and lower plot: group planting, using single plant holes
- Planting: bare-rooted seedlings (mainly from ATP nursery in Margahovit) of pine, oak, ash and apple were used. The seedlings were already quite large (2-3 years old) and of good quality. Additionally, shrubs such as sea buckthorn, raspberry and caragana /yellow acacia were planted (table 1).

Fig.2: Installed barb wire fence at the upper plot in Nahapetavan

Piloting different afforestation approaches in Nahapetavan

Since it was a pilot project, different approaches with regard to fence type and planting schemes were tested. Important conclusions and recommendations for possible replication are expected after the initial years of implementation.

Table 1: Tree species and the number of planted seedlings

Species	Latin name	No. of seedlings planted in 2017
Pine	*Pinus sylvestris var. hamata*	7.700
Oak	*Quercus macranthera*	4.050
Raspberry	*Rubus idaeus L.*	2.500
Siberian pea shrub	*Caragana arborescens*	1.000
Seabuckthorn	*Hippophae rhamnoides*	1.000
Apple	*Malus orientalis*	4.000
Ash	*Fraxinus excelsior*	4.000
Total		**24.250**

Fig. 3: Piloting two different planting schemes and techniques: group planting scheme with individually dug holes (left) and line planting scheme with trenches prepared with a single-plough (right)

To ensure the irrigation of all the three afforestation sites, GIZ IBiS decided to support the community by purchasing irrigation equipment, such as a mobile water pump, rubber and plastic pipes. The irrigation channel, which passes through the second and third plot, serves as a source for irrigation water. The installation of pipes is implemented by the community when needed.

Fig. 4: Seedlings prepared for planting

Fig. 5: Community members get to know a new planting scheme: group plantation

The application of organic materials around the young seedlings is known to protect the seedlings from extreme temperatures, maintain soil humidity and thus, reduce irrigation requirements in a significant way. Based on a Memorandum of Understanding (MoU) signed between ATP and "Hayantar" State Forest Agency, ATP may use residues of sanitary cuttings

from selected forest enterprises to produce wood chips for mulching. GIZ has supported this initiative with the procurement of a mulching machine, handed over to ATP. In turn, ATP provides mulching material for different afforestation sites of the project. In Nahapetavan, mulching was implemented by the community people.

Fig. 6: Mulching machine preparing mulch from sanitary cutting residues

Fig. 7: Tree seedling with applied mulch

Needed resources

Materials	Costs (AMD)	Labour	Cost (AMD)
Barb wire fence, concrete posts	2.900.000	Fencing: 21 days/6 people	800.000
Tree seedlings (19.390 seedlings *120 AMD)	2.300.000	Planting: 12 days/28 people	2.500.000
Shrub seedlings (raspberry, sea backthorn, Caragana/yellow acacia)	800.000	Mulching: 8 days/6 people	400.000
Irrigation equipment	500.000		
Total materials	**6.500.000**	**Total labour**	**3.700.000**

In total, 10.200.000 AMD were spent for afforestation of 9,7 ha, which means approx. 1.000.000 AMD/ha.

Evaluation & lessons learnt

- *Plot size and costs:* small plots are more expensive for fencing, even when barb wire fence is used.
- *Barb wire fence:* it is difficult to stabilize concrete posts in stony ground. Barb wire (lowest line) needs to ensure that sheep/goats cannot enter the site.
- *Crossing the road through the site is a risk factor:* if the gates are left open, animals can easily enter.
- *Group afforestation design needs to be explained in detail:* people are used to plant in trenches and do not immediately see the sense of doing it in a different way.
- *Origin of mulching material is important:* ATP uses wood from sanitary cuttings to produce mulch. If it is produced from the infected trees of the same species (e.g., pine), it can spread diseases in the afforestation site.

- *Size of wood chips for mulching:* the procured mulching machine produces quite course wood chips. It needs to be adjusted to get optimal (smaller) mulching material for seedlings.
- *Quality of bare-rooted seedlings:* despite the fact that containerized seedlings have a number of advantages compared to bare-rooted seedlings, the quality of bare-rooted seedlings planted in Nahapetavan was high. Survival rates of the relatively larger seedlings need to be observed in the coming years.
- *Impact/effectiveness:* as the above mentioned measures have only been implemented recently, it is too early to have concluding results and measurements of impact.

Perspective

- Low-cost approach: the comparably cost-efficient fencing technique and the smaller number of seedlings/ha may be an interesting option for upscaling.
- Monitoring of seedling survival and growth rates as well as overall vegetation monitoring need to be followed up during the coming years.
- Decentralized nurseries/seedling stations should be established for re-planting. Local species can be grown from seeds or cuttings and would enrich the diversity of afforestation sites.

Showcase 3: Pile Wall Construction, Lusagyugh Community

Description

In the community of Lusagyugh in Aragatsotn Marz, livestock keeping is a major source of income. Large numbers of sheep and cattle are grazing on the surrounding pastures of the village, especially in spring and autumn when summer pastures are not used. The carrying capacity of pastures is regularly exceeded, and they are degraded more and more. Indicators of the degradation process are the high density of the thorny inedible Astragalus bush, the downward movement of loose stones on steep slopes as well as soil accumulation on the lower parts of the slope.

Since 2016, GIZ has supported the local community in identifying and piloting different measures to rehabilitate the degraded site. In order to stabilize the steep eroded slope, pile walls have been established. Accompanying measures have comprised temporary electric fencing and application of hay mulch. Major advantages of these measures are: they are not expensive since mostly locally available materials are used, and a positive effect can already be observed within one year.

WHAT –Implemented pilot measures

- Establishment of wooden logs as pile walls
- Terracing behind pile walls
- Application of hay mulch on terraces to support vegetation growth
- Temporary electric fencing of the site

WHY – Erosion phenomena & causes

- High grazing pressure on pasture area
- Loss of upper soil layer because of water erosion
- Low biomass production for grazing
- Spreading of inedible plant species

Fig. 1: Pilot site (in light green) next to the village Lusagyugh

Fig. 2: Cattle tracks, water erosion rills and scarce vegetation on the degraded pilot site (November 2016)

WHO – Main stakeholders involved

- Administration and council of Lusaguygh village
- Local shepherds using the area
- Local experts from ESAC NGO
- GIZ IEC/IBiS program staff & international experts

Where

- Lusagyugh village, Aragatsotn marz, Armenia
- Pilot site: 0,15 ha on a steep degraded slope
- Village pasture on community-owned land

Methodology

Planning & preparation

Main planning & preparation steps:

- Set-up collaboration with the community and discuss potential rehabilitation measures
- Assess the foreseen pilot area, occurring erosion phenomena and causes
- Choose & mark the exact pilot site
- Agree on implementation methods & community involvement
- Assess the locally available materials
- Purchase the needed materials

National experts from ESAC NGO, who were familiar with the local setting and the community, facilitated the planning process and the discussions with the local population. The exact location for the pilot measures was selected in such a way, that grazing activities were almost not impaired. For temporary exclusion of livestock, electric fencing was proposed. Within the fenced area, pile walls should be established in the washed-out rills along the slope to address the water erosion phenomena. Application of hay mulch for accelerating vegetation growth on small terraces above the pile walls should complete the rehabilitation measures in Lusagyugh. As the local population wanted to use the area as soon as possible again after the temporary exclusion, the planting of shrubs and trees was not desired.

Regarding the needed resources, the community agreed to provide local workers and hay bales. The electric fence and the wooden logs (pine) had to be purchased due to the limited local availability of timber. Planning and preparation of the measures was done in autumn (September and October 2016).

Implementation

The selected pilot site measures about 50m x 30m. The construction work was implemented together with community members in November 2016. The following working steps were done:

1. Preparation of electric fencing (putting wooden corner posts)
2. Construction of pile walls and terracing:
   - ✓ set the wooden logs on appropriate positions,
   - ✓ fix the logs horizontally with two iron posts,
   - ✓ fill the space behind the log with soil (forming small terraces).
3. Application of hay on terraces to cover bare soil
4. Establishment of electric fence to protect the site from grazing

Fig. 3: Putting logs in correct position across the slope (November 2016)

The wooden logs were cut in 1-2m length to fit into the irregular rills of the slope. After identifying the locations of individual pile walls, the team fixed the logs with iron poles of about 70-100cm length. The distance between the pile walls varied between 1-3m, depending on the topography: the steeper the slope, the closer the distance.

Fig. 4: Filling up the area behind the wooden log with soil and plant material (left) and covering open soil with hay (right). November 2016

The space behind the logs was filled with soil, plant material and rocks to stabilize the construction and to reduce the risk of water washing out the soil and passing below the logs. As a last step, the terraces were covered with hay to provide protection against precipitation and to accelerate re-growth of grass through the seeds contained in the hay residuals (fig. 4). The electric fence was established in May 2017.

Needed resources

The table below gives an overview of the needed resources – materials and labour – for implementing the mentioned working steps on 0,15 ha[1]:

[1]Required resources depend on the degree of degradation, the slope gradient, etc.

Materials	Amount
Hay (grass)	15 bales (260-325 kg)
Hay (crop)	5 bales (100-125 kg)
Iron poles (70-100cm length)	93
Pine logs (4m long, 20-25cm diameter)	38
Wooden fence posts	4
Wooden stiffener	12
Labour (measure 1-4 without fencing)	15 working days (2,5 working days x 6 workers)

Evaluation & lessons learnt

- ***Participatory site selection:*** areas requiring such type of erosion control measures are usually intensively used and are, thus, of high importance for the community. Even a temporary exclusion from use must be thoroughly discussed and agreed upon.
- ***Wind:*** Wind is is likely to be a major challenge, particularly for the use of hay cover. In general, hay from grass should be used as it is heavier than hay from crops. When bio-degradable nets are not available, other solutions need to be considered, e.g., covering the mulch with manure or soil.
- ***Importance of fencing:*** bioengineering measures use living materials (seedlings, cuttings, trees, shrubs), seeds or hay. In order to protect the sites from grazing animals and enable rehabilitation processes, fencing is necessary for at least 2-3 vegetation periods after implementation measures are completed.
- ***Availability of materials:*** two key resources for bioengineering (wood and seeds) are hardly available in the area.
  - ✓ Wood is a precious and scarce resource in general, which has the following implications:
    - ➢ Wood used for bioengineering measures could be removed by residents to be used for other purposes -> pine can be used for bioengineering, because it is not used as fuelwood.
    - ➢ Replication and continuous application of wood-based methods requires a reasonable supply with wood.
    - ➢ The use of fascines (bundles of branches) should be considered as alternative.
  - ✓ Availability of locally adapted seeds is also limited. Therefore, grass should be harvested at adjacent sites and immediately applied at the bioengineering sites. In general, for covering 1m² of open soil, 2m² should be harvested. In areas, which are more exposed to wind, hay should not be processed to mulch, but be applied with complete stalks to ensure stability.
- ***Time & labour:*** community members were surprised how easy and quick the pile walls could be established. A team of two workers established one pile wall within 30 min. The most time-consuming part was the preparation of the area and the identification of the exact location of the logs.

- ***Effectiveness & stability*** of pile walls can be increased by vegetative material. Further, it is important to ensure proper filling behind the logs in order to avoid underwashing.
- ***Short-term impact:*** results are already visible after one year.

Fig. 5: Vegetation development inside the fenced area after one vegetation period

Perspective

The measures proved to be effective in reducing soil erosion and were well feasible to implement. The pile walls are relatively easy to establish without any need of heavy machinery or specific knowledge and, therefore, allow the involvement of the local population. The combination of applied measures (fencing + pile walls + hay mulch) show good results in terms of erosion mitigation.

In general, it is important to enhance local awareness and inform the community about the purpose of the bioengineering measure, the necessary materials and their costs. Practical "on-the-job" training (participatory implementation) will enable the land users to replicate the measure on other eroded areas. Low-cost bioengineering measures are very appropriate for tackling the wide-spread erosion risks in the South Caucasus.

Showcase 4: Gully Rehabilitation, Mets Mantash Community

Description

Several kilometers behind the village of Mets Mantash in Shirak Marz, the main cattle track of the community ascents on steep slopes towards the grazing grounds of Mount Aragats. In this area, livestock keeping is an important source of income. Thus, the cattle track is of major importance for the community with its several thousands of animals. However, the intense use has negative effects on vegetation and soil; through the ongoing erosion, some parts have already become inaccesible.

Especially in the section where livestock moves vertically to the slope, the track has almost been washed away. A gully has formed by the power of down streaming water. The V-shaped 40m long gully has almost vertical sidewalls, with a depth of about 1,5m and 1,5-2m width (fig. 1). If no mitigation measures were undertaken, the cattle track might have been blocked within a few years.

Starting from 2017, GIZ has supported the local community in identifying and piloting bioengineering measures at two degraded sites: 1) cattle track rehabilitation and 2) gully treatment. As cattle track rehabilitation is similar to the measures described in Showcase 3, this Showcase focuses on the description of the gully rehabilitation measures.

WHAT – Implemented pilot measures

- 4 palisade check-dams with rocks and cuttings
- Flattening of steep gully shoulders
- Planting of cuttings and seedlings
- Electric fencing

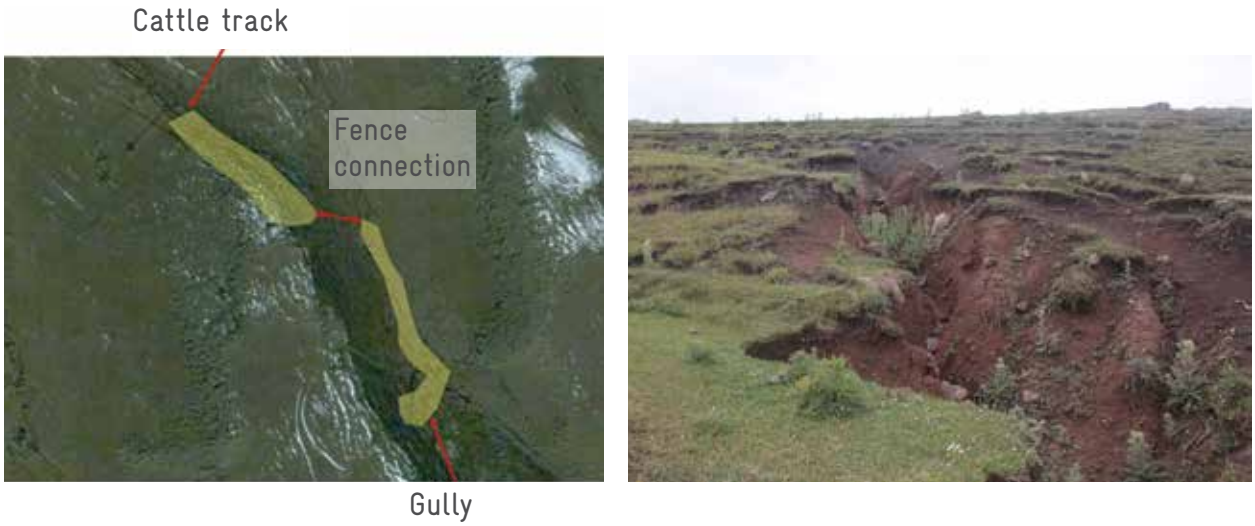


Fig. 1: Map and photo of the gully before treatment

WHY – Erosion phenomena & causes

- Heavy use by passing livestock
- Destruction of cattle track
- Advanced stage of gully erosion
- Loss of soil cover and adjacent pastures

WHO – Main stakeholders involved

- Administration and Council of Mets Mantash village
- Local shepherds using the cattle track
- Local experts from ESAC NGO
- GIZ IEC/IBiS program staff & international experts

WHERE

- Mets Mantash Village, Shirak Marz, Armenia
- Pilot sites: 0,6 ha cattle track + 0,06 ha gully area on community pasture land

Methodology

Planning & preparation

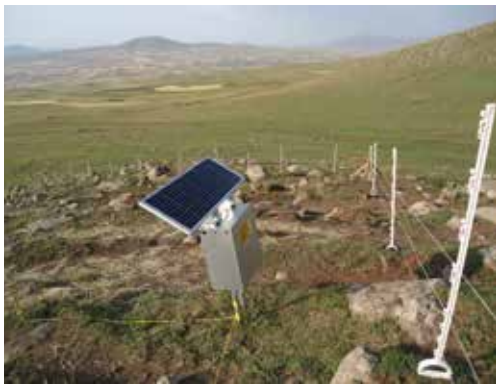


Fig. 2: Electric fence with solar panel (left) and above ground connection (right)

The selection of the gully site was done in June 2017, in combination with another nearby bioengineering site (eroded cattle track, treated with pile walls and mulch). An idea emerged to use one solar panel for the 2 sites (approx. 200m distance). A technical solution was found – to have an above-ground wire between the 2 sites (fig. 2).
In order to give the people of the involved community a basic understanding of the foreseen gully rehabilitation measure, a practical 'on-the-job-training' was initially organized. The main questions were clarified, such as why, how and when different working steps would need to be implemented.

Implementation

Electric fencing of both bioengineering sites of Mets Mantash community was done in July 2017. Other gully rehabilitation measures were postponed to October 2017, mainly to give the willow cuttings better chances for survival when the soil contained sufficient moisture.
First of all, gully edges were flattened, and stones from the gully site were collected (fig. 3). Then, the wooden logs were placed at the identified locations for the construction of palisades and fixed with iron poles. The palisades were constructed using stones at the lower part, and willow cuttings, filled up with soil, at the upper part (fig. 4-6).

Fig. 3: Flattening of gully shoulders

Fig. 4: Placing of tree cuttings behind the wooden log

Fig. 5: Forming terraces by filling the space behind the wooden log and the willow cuttings with soil

Fig. 6: Fortification of check dams with rocks and stones

Needed resources

Materials required for gully restoration	Amount
Wooden logs (length 2-3m, diameter 12-20cm)	6
Iron poles (60-90cm)	14
Willow cuttings (6x20, 50-100cm for palisades)	150
Rosehip cuttings/seedlings (to be planted in spring 2018)	40

Labour requirements

Description of activities	Working hours
Transportation of wooden logs and Iron poles from the community to the gully site	1 hour/3 workers
Fastening of wooden logs	1 hour/2 workers
Collection of stones from the gully site	0,5 hour/3 workers
Wall/barrier preparation with stones	1 hour/3 workers
Planting of willow cuttings	0,5 hour/1 worker
Soil works (covering palisades, flattening of edges)	1 hour/2 workers
TOTAL	**12 hours**

Evaluation & lessons learnt

- Use one electric fencing kit for the 2 sites as a creative solution
- Plant willow cuttings also at the edges of the gully to prevent washing out
- Always start working on the upper section and work your way down to the bottom
- Choose the correct planting and cutting season for the wooden parts
- In areas above 2.000m a.s.l. the use of wooden species is limited. In areas with higher altitudes only seeds/herbaceous species can be used.

Perspective

- Additionally, it is planned to plant rosehip and/or wild apple seedlings in spring 2018.
- The new vegetation cover should be protected from grazing livestock and, thus, be fenced for at least two vegetation periods;
- If applied at smaller gullies (less than 1,5m deep and 5m wide), gully plugging can be considered a low-cost technique: locally available materials are mainly used, and labour requirements are moderate. After initial technical introduction and guidance, trained community workers can replicate the measure at similar sites.
- Many gullies started to develop recently, and the degradation process advances quickly. As this is the first experience of gully rehabilitation efforts in this area, it is important to monitor and document the obtained results and spread them among communities.

Module 8: Factsheets

Factsheet 1: Erosion assessment

General information

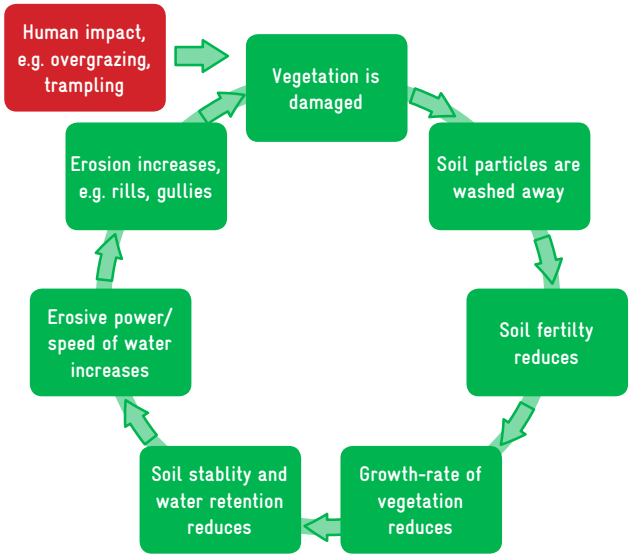


Fig. 1: The self-accelerating process of erosion underlines the importance of early intervention

Healthy soils are the basis for our food production. The upper soil layer contains organic and nutrient-rich materials, which are crucial production factors for agriculture and pastoralism.

As soil cannot be restored once it got lost, it is of uppermost importance to avoid soil loss by erosion whenever possible. The earlier the problem is observed, the easier measures to prevent or control erosion can be applied. In case of inaction, erosion processes will accelerate (fig. 1).

Assessing the occurrence and gravity of erosion through easy field methods (see back page) supports decision-making between different land use options and allows the identification of appropriate erosion control measures.

Factors that influence soil erosion

Natural factors

- Rainfall
- Characteristics of soil & geology
- Slope length & steepness

Effects of human activities

Disturbance of vegetation cover & soil stability through, e.g.

- Trampling of livestock
- Overgrazing
- Heavy vehicles

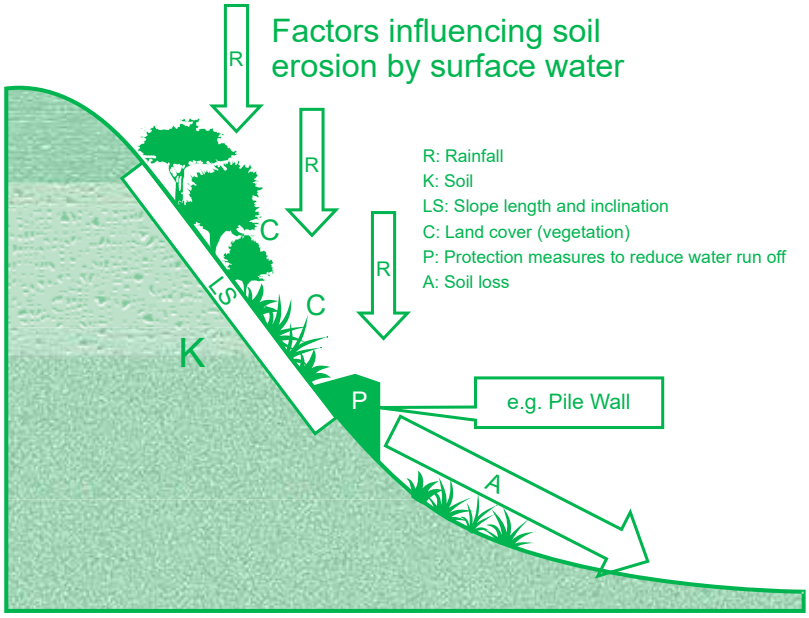


Fig. 2: Factors influencing soil erosion caused by rain and surface run off

Erosion assessment in the field

Erosion phenomena	Visual assessment	Appropriate measures
No erosion › 90% vegetation cover		• No immediate action required • Regular observation, if site has a natural high risk of erosion (e.g. steep slope, heavy rainfalls)
Beginning sheet erosion 70-90% vegetation cover		• Temporary fencing (1-2 years) → vegetation will recover • Reduce grazing intensity → pasture rotation or lower livestock numbers
Medium/strong sheet erosion ‹ 70% vegetation cover		• Temporary fencing, mulching, sowing of grass, manure application • Slope › 10°: Horizontal pile walls • Slope › 30°: Change of land use: hay meadow, forest, no use
Rill erosion: rills up to 0,3m deep		• Reduce grazing pressure: Temporary fencing, pasture rotation or reduced livestock numbers • Horizontal pile walls • Mulching, sowing of grass, manure application
Gully erosion: rills deeper than 0,3m		• Temporary fencing, mulching, sowing of grass, manure application • Horizontal pile walls • Check dams (if settlements or infrastructure are endangered)

Factsheet 2: Tree Planting

General information

Tree planting can be an effective measure to reduce soil erosion caused by wind, water or unsustainable land use practices (e.g., overgrazing). With their deep root systems, trees give stability to the soil, and their crown cover and foliage reduce the erosive power of heavy rainfalls and wind. Thereby, trees can contribute to the increase in productivity of agricultural lands and pastures and may protect villages or other human infrastructure from damages caused by rockfalls or landslides.

For erosion control purposes, trees can be planted on larger sites - either in rows or in groups as windbreaks along agricultural fields or on small constructed terraces for stabilizing steep slopes. Appropriate seasons for tree planting are spring and autumn.

Needed materials & resources

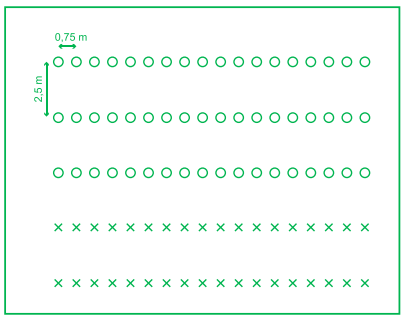
Needed resources for 1 ha afforestation:

- 2.000-5.000 seedlings
- 10-50 t water (for initial irrigation)
- 40 – 100 working days
- Shuffles or soil driller
- Means of transport

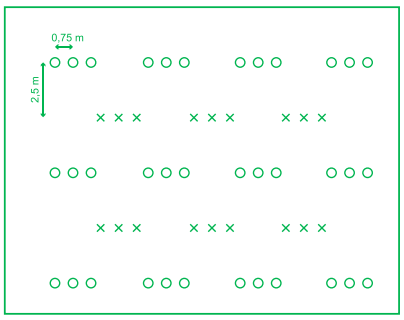
- Tree seedlings: preferably local species adapted to site conditions.
- Hole driller of spades: hole driller is recommended for larger afforestation activities as it substantially reduces working time.
- Means of transportation for seedlings and irrigation water.
- Water: 5-10 l per seedling.
- Labor: tree planting by hand takes about 8-10 minutes per seedling, with the drilling machine 2-4 minutes.

Planting scheme

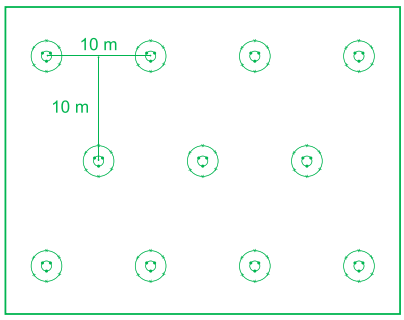
For afforestation of larger areas, select a planting scheme according to the specific site conditions:



A. Line planting scheme



B. Chess pattern planting scheme

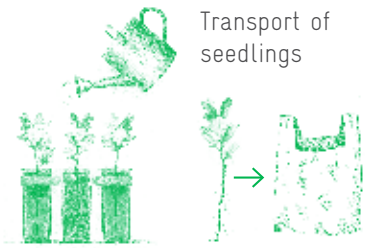
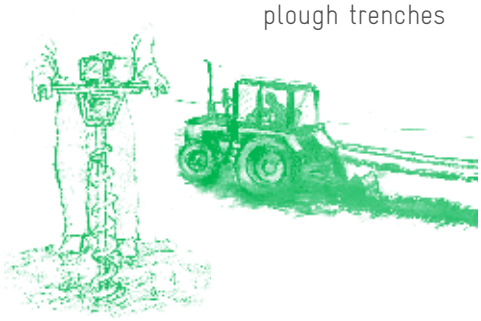


C. Group plantating scheme

Site preperation

Establish a fence (for larger afforestation sites) to protect young seedlings from grazing animals or procure individual tree protection shields.

Planting

Description	Working step
• Water the containerized seedlings 24 hours before transport. • Package the bare rooted seedlings in plastic bags. • Store the seedlings for max. 4 days at a cool protected place.	 Transport of seedlings
• Use a spade or a soil driller for excavating a hole for the seedling: 30-40cm deep, 25cm diameter, min. 1m spacing between holes. • If the site is not too stony or too steep, prepare trenches with a single-plough: 30cm deep, 2m spacing between the rows.	Excavate a hole or plough trenches 
• Place the seedling 5-10cm lower than the upper ground. • Keep some space between the roots and the ground. • Fill the hole up with soil and slightly press it down.	Planting
• Apply 5-10 l water to each seedling immediately after planting.	Watering
• Cover the ground around the seedlings with organic material to reduce the need for irrigation and weed control.	Mulching

Maintenance

- Irrigate young seedlings at least 2-4 times per year with 5-10 l each (during the first 2 years).
- Protect the area from wild fires, e.g. by preparing fire protection trenches around the site.
- Prevent overgrowth of vegetation, e.g. by mowing the grass 1-2 times per year.
- Renew the layer of mulch on an annual basis (after hay harvest in late summer).

Factsheet 3: Pile Wall Construction

General information

Pile walls are horizontal constructions along a slope, functioning as erosion control measures by retaining materials and supporting the rehabilitation of vegetation. A typical site for such construction would be a steep slope with scarce vegetation or bare soil, where the superficial water runoff and the grazing animals cause a high risk of rockfalls and landslides. Settlements or road infrastructure may be seriously endangered, if they are located below such an erosive site.

Pile walls slow down the superficial water runoff and support the accumulation of organic materials and soil. They stop rocks and stones that roll down due to grazing cattle or erosion processes. Forming small terraces behind the logs and planting tree cuttings can stabilize the slope even further.

Needed materials & resources

Pile walls are established by using a combination of technical and vegetative construction materials. The technical requirements and workload are relatively low. Materials with the following specification are needed:

Needed resources for 1 pile wall

- 2 iron piles + a hammer
- 1 wooden log (or a bundle of branches)
- 10-20 tree cuttings (for a 2-4m long pile wall)

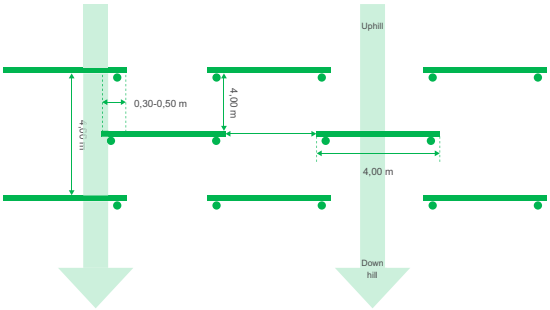
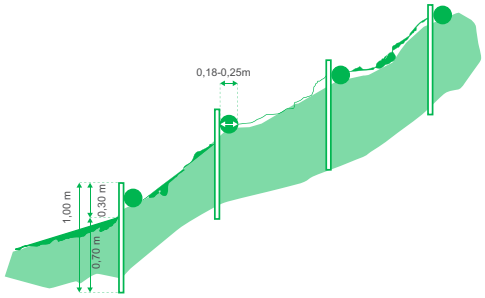
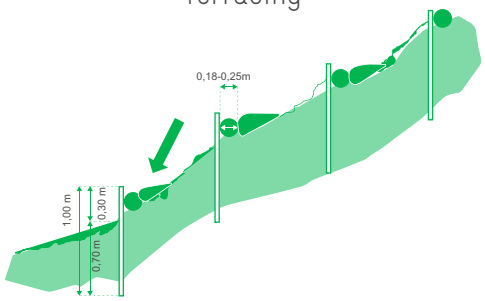
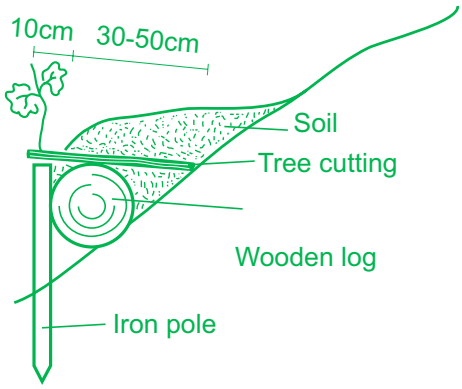
- Iron piles: 70-100cm length, approx. 2cm diameter
- Wooden logs: 2-4 m length, 20-25cm diameter
- Tree cuttings (5 pieces per meter, 40-50cm long and thumb-thick/2cm, from a narrow leaved willow or hazel)
- Labour (2 persons construct 4 pile walls/hour)
- Optional: tree seedlings, hay mulch fencing materials

Besides tree cuttings, tree seedlings can be planted on the small terraces formed by the pile walls. On highly degraded slope areas exposing open soil, hay mulch, cut grass or straw can also be applied. To prevent the hay mulch from being carried away by wind, decomposable nets may be spread on top.

Preparation of the site

The establishment of a fence is important in protecting the area from trampling and grazing and in enhancing the rehabilitation of the vegetation cover. The fence can be either a permanent (barbed or mesh-wire) or a temporary construction (electric fence). However, the fence should remain until sprouts from the tree cuttings grow up to 1,3 m high to withstand the pressure caused by grazing.

Construction

Description	Working step
• Distribute the piles along the slope in a scattered and offset manner. • On uneven ground, place them mostly in depressions with the main vertical water flow. • If needed, shorten the logs so that they fit in the depressions. • The steeper the slope, the shorter the vertical spacing (1-3m).	Identification of the appropriate position and the length of the pile walls 
• Drive 2 iron poles into the ground at both sides of the log (30cm from either end). • Secure the logs behind the 2 poles.	Securing the logs with iron poles 
• Use large stones to close the holes below the log: water should not pass underneath the wooden log! • Fill the space behind the log with soil and plant materials, forming small terraces.	Terracing 
• Place tree cuttings with a slightly upward tilt on the soil of the terrace. • The spacing between the cuttings should be 20cm. • Cover the cuttings with soil, so that only 10cm show out and the remaining 30-50cm are covered. • Make sure the cuttings are oriented in the right way -> check the growing direction!	Planting tree cuttings 

Optional measures

- Apply hay mulch on the terraces to cover the bare soil and to support vegetation growth (300-500g/m²).
- Plant tree seedlings on the terraces (see Factsheet 2).

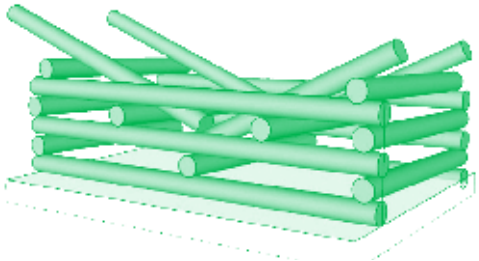
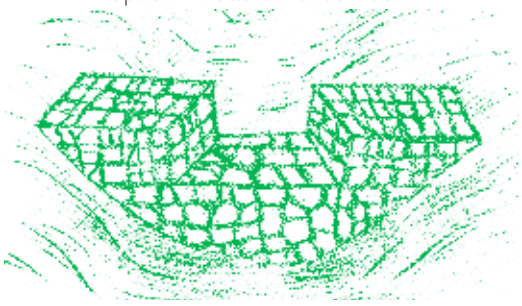
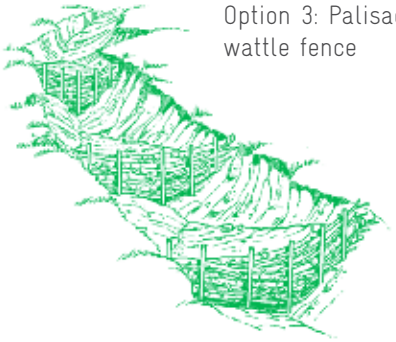
Factsheet 4: Gully Plugging

General information

Down streaming water has a strong erosive power and can form erosion gullies or channels. Especially steep slopes with scarce vegetation have a weak water retention capacity and are very susceptible to that kind of erosion phenomena.
Check dams are structures built across a gully or channel to prevent it from deepening further. In case of small gullies (less than 1,50m deep and 5m wide) the water velocity can be reduced significantly with relatively little efforts. Depending on the available materials, the dam for plugging the gully can be constructed either from wooden logs, branches or rocks or from a combination of different materials. Combined with the planting of tree and shrub cuttings or seedlings, such dams show immediate effects: they slow down the vertical water movement, increase water infiltration, and enhance the settlement of sediments.

Different construction types & needed materials

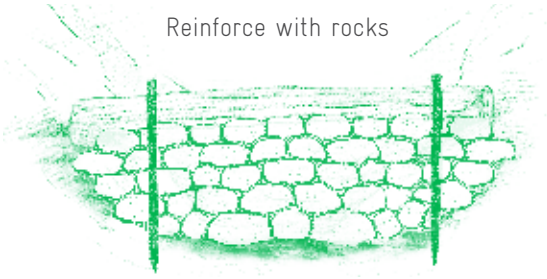
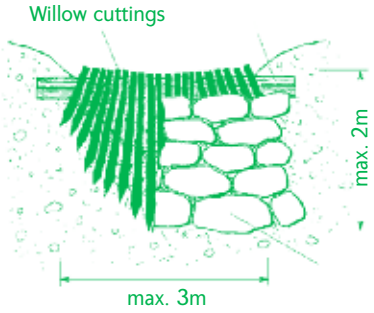
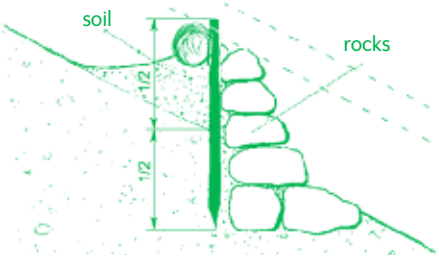
Depending on the topography of the eroded site (e.g., the depth and the width of gully) and the available materials, check dams can be constructed in different ways. Three examples are presented below. Keep in mind that each situation may require its own improvised approach!

Used materials	Type of construction
• Wooden logs • Living branches • Stones & soil	Option 1: Wooden check dam 
• Large stones • Mesh wire fence • Thin iron poles	Option 2: Gabion check dam 
• Cuttings of living branches (e.g., willow branches) • Stakes (100cm long, 4-6cm diameter), sharpened at the bottom • Cuttings of long and flexible material (> 60cm long, 2-3cm diameter)	Option 3: Palisade/ wattle fence 

Construction of a palisade check dam

Materials for 1 unit:

- 2 iron poles a hammer
- 1 wooden log
- 15-25 living branches (> 60cm length, 2-3cm diameter), e.g. willow cuttings
- Stones & rocks

Description	Working step
• Ensure appropriate position of the log: transverse to the gully, blocking the complete gully width, about 20-50cm above the gully bottom. • Secure the wooden log in place with 2 iron poles (60-90cm long). • The wooden log should be burrowed into the side walls of the gully.	Secure the wooden log
• Pile up large rocks and stones on the front (downhill) section of the structure.	Reinforce with rocks 
• Place tree cuttings side-by-side behind the wooden log driven slightly into the soil (uphill-side). • There should be approx. 5cm spacing between the cuttings.	Establish palisade with living branches 
• Fill up the space behind the wooden log with soil (min. 50cm high). • Cuttings should show out for max. 10cm.	Cover branches with soil 

Optional measures

- Flatten the adjacent gully shoulders to support revegetation.
- Plant cuttings/seedlings on the gully shoulders and cover with grass.

Factsheet 5: Electric Fencing

General information

Electric fence systems are useful tools for excluding livestock for a limited period of time (a few days/weeks up to 1-2 years) from a certain area. In the context of erosion control measures, electric fencing is normally used in combination with other activities such as small-scale afforestation, mulching or bioengineering. Electric fencing – as an alternative to permanent fencing – is preferred, if temporary or flexible fencing of an area is needed, for example, for protecting young seedlings, rehabilitation of eroded grassland through exclusion of livestock, mulching or sowing, or for flexible pasture rotation systems.

Needed materials

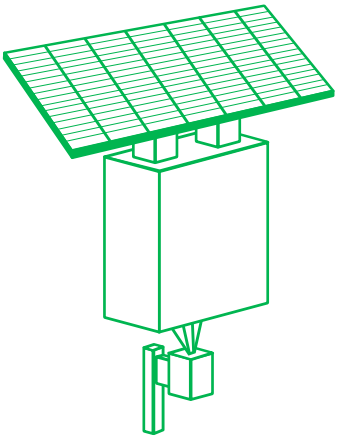


Fig. 1: Solar panel and box containing energizer and battery

- Metal box including the energizer and 1-3 earth stakes
- Solar Panel (40 W, 25W, 15W) and rechargeable battery (12 V)
- Metal wire (2-4 times of the total fence length)
- Wooden posts (4 for each corner + 2 for the gate)
- Fiber or plastic posts (amount: fence length divided by 5)
- Gate(s)
- Insulation rings for wooden posts
- Fence tester (Volt measure)

Selection of the appropriate system

Energizers and solar panels for electric fence systems exist in different power levels, the selection of which depends on the planned fence length and the intensity of vegetation.

Number and height of fence wires for different livestock:

Sheep:

- 4 wires, heights: 20, 40, 65, 90cm above the ground.

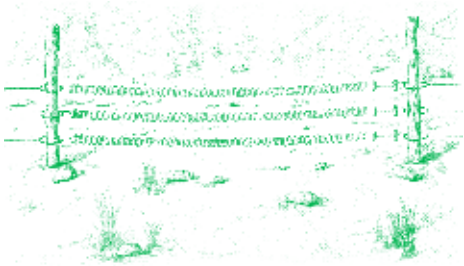
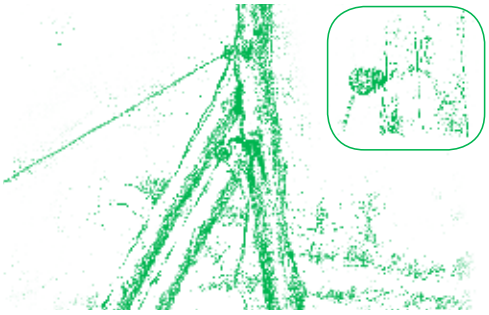
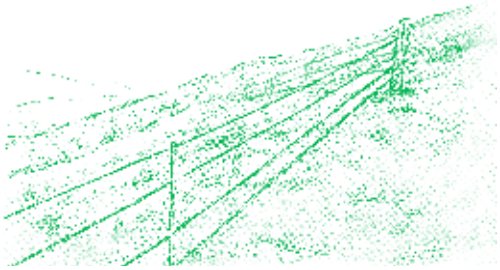
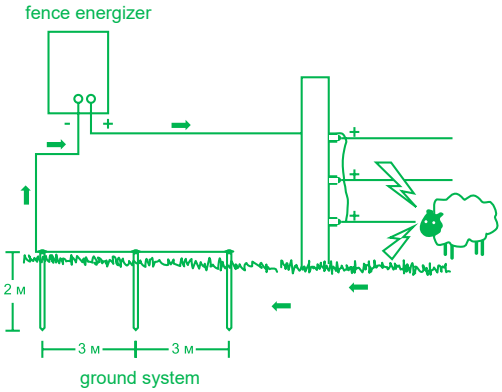
Cattle:

- 3 wires, heights: 30, 60, 90cm.
- Or: 2 wires, heights: 45, 90cm.

Sheep and cattle:

- 3 wires, heights: 25, 55, 90cm.

Set-up of an electric fence

Description	Working step
Installation of wooden posts • Set up 4 wooden posts in the corners of the preselected area. • Identify the location of the gate (3-5m width). • Install the 2 wooden posts for the gate.	
Install the upper wire • Attach 2-4 electrically insulated rings on each post at correct heights. • Install the upper wire 90cm above the ground.	
Set up fiber/plastic posts • Set up fiber or plastic posts along the straight line of the upper wire. • There should be 5m spacing between them. • Install the remaining lines of the wire.	
Establish the electric system • Connect the energizer to 1-3 earth stakes (green cable). • Connect the battery and the solar panel -> + to + (red to red) and – to – (black to black). • Connect the energizer to the fence (red cable) and activate the energizer by closing the box.	

Final Check

- Measure the voltage in different parts of the fence (> 4,000 Volt).
- Wire: straight with slight tension, no knots or disturbances.
- Energizer: connected to the ground (green cable) and to the fence (red cable).
- Battery: connected correctly to the solar panel and the energizer.

Maintenance

- Weekly: check the wire, the energizer, and the battery and make sure that they are connected correctly.
- Prevent overgrowth of vegetation that touches the wires.
- Winter season: dismount the system completely and store it in a frost-free, dry place.

Annexes

Annex 1: Glossary of terms

No.	English	Armenian	Explanation
1	Afforestation	Անտառապատում	Afforestation is the establishment of forest cultures through planting or seeding on a previously non forested forest land and also on other purpose lands.
2	Deforestation	Անտառահատում/ անտառազրկում	Deforestation, also known as clearance or clearing, is the removal of a forest or stand of trees where the land is thereafter converted to a non-forest use.
3	Desertification	Անապատացում	Desertification is land degradation in dryland areas and/or the irreversible change of the land to such a state it can no longer be recovered for its original use.
4	Die-back	Կենսունակության կորուստ	Die-back is a condition in a plant in which the branches or shoots die from the tip inward, caused by any of several bacteria, fungi, or viruses or by certain environmental conditions (e.g. drought).
5	Ecosystem	Կենսունակության կորուստ	An ecosystem is a community of all living organisms in a given area (habitat).
6	Ecosystem services	Կենսահամակարգային/ էկոհամակարգային ծառայություններ	Ecosystem services are the diverse benefits that are derived from the natural environment.
7	Forest	Անտառ	Land with tree crown cover (or equivalent stocking level) of more than 10% and area of more than 0,5 ha. The trees should be able to reach a minimum height of 5 m at maturity in situ (FAO).
8	Grazing capacity	Արոտավայրի հզորություն	Grazing capacity is the carrying capacity of a pasture or area of range usually expressed as the number of animals (cattle, sheep) that it will support for a specified length of time or indefinitely.
9	Gully	Ողողատ, հեղեղատ	A gully is a ravine formed by the action of water and through which water often runs after rains.
10	Land degradation	Հողածածկի քայքայում	Land degradation covers all negative changes in the capacity of the ecosystem to provide goods and services (including biological and water related as well as land-related social and economic goods and services).
11	Land rehabilitation	Հողածածկի վերականգնում	Rehabilitation is required when the land is already degraded to such an extent that the original use is no longer possible and the land has become practically unproductive. Here longer-term and often more costly investments are needed to show any impact.
12	Mulch/mulching	Մուլչ/մուլչապատում	A protective covering (e.g. sawdust, grass, straw) which is spread or left on the ground to reduce evaporation, maintain even soil temperature, prevent erosion, control weeds, enrich the soil, etc.
13	Natural succession	Բնական վերաճի օժանդակում	Natural succession or "ecological succession" is the observed process of change in the species structure of an ecological community over time.

14	Planting scheme	Տնկման սխեմա	The planting scheme describes the number of seedlings per ha and their spatial distribution, e.g. line planting, chess pattern or group planting schemes.
15	Planting technique	Տնկման ագրոտեխնիկա	The planting technique describes how the seedling is planted, e.g. in trenches or in plant holes.
16	Prevention	Կանխարգելում	Prevention implies the use of conservation measures that maintain natural resources and their environmental and productive functions.
17	Reforestation	Անտառվերականգնում	"Reforestation" is defined as the re-establishment of forest through planting and/or deliberate seeding on land classified as forest. Essentially, reforestation is used to bring back the environment to its former state following deforestation.
18	Remote Sensing	Հեռահար զոնդավորում	"Remote sensing" is the science of obtaining information about objects or areas from a distance, typically from aircraft or satellites by remote sensors, which collect data by detecting the energy that is reflected from Earth.
19	Seedling	Սերմնաբուսակ	A seedling is a young plant that grows from a seed. *Bare rooted seedlings* are grown in tree nurseries on fields. *Containerized seedlings* are produced in special growing containers, usually in nurseries equipped with green houses and irrigation systems.
20	Soil bioengineering	Հողային բիոինժեներիա/ կենսաճարտարագիտություն	Soil bioengineering is the use of living plant materials to construct structures that perform some engineering function. Those "living engineering systems" are making use of locally available materials, and are often used to increase surface stability and to combat erosion problems.
21	Soil erosion	Հողատարում	Soil erosion refers to soil losses in terms of topsoil and nutrients. It is a natural process in mountainous areas, but is often made much worse by poor management practices. Rainfall, and the surface runoff which may result from rainfall, produces four main types of soil erosion: *splash erosion*, *sheet erosion*, *rill erosion*, and *gully erosion*. Splash erosion is generally seen as the first and least severe stage in the soil erosion process, which is followed by sheet erosion, then rill erosion and finally gully erosion (the most severe of the four).
22	Upscaling/ scaling up	Տարածում/ընդլայնում	Scaling up means to expand or replicate innovative pilot or small-scale projects to reach more people and/or broaden the effectiveness of an intervention.

Annex 2: List of planted tree and shrub species

No.	Scientific name (latin)	English name	Armenian name
1	*Quercus macranthera*	Eastern Oak	Խոշորառէջ կաղնի
2	*Pinus sylvestris L.*	Pine	Սոճի սովորական
3	*Pinus pallasiana Lamb.*	Pine	Սոճի ղրիմյան
4	*Betula Litwinowii*	Birch	Կեչի Լիտվինովի
5	*Betula verrucosa*	Birch	Կեչի ելունդավոր
6	*Acer trautvetterii Medv.*	High mountainous maple	Թխկի բարձրլեռնային
7	*Fraxinus excelsior*	Ash	Հացենի սովորական
8	*Ulmus pinnato-ramosa Dieck.*	Elm	Թեղի փետրաճյուղավոր
9	*Sorbus aucuparia L.*	Rowan (mountainous ash)	Արոսենի սովորական
10	*Malus orientalis*	Wild apple	Խնձորենի արևելյան
11	*Pirus caucasica Fed.*	Wild Pear	Տանձենի կովկասյան
12	*Hippophae rhamnoides L.*	Sea buckthorn	Չիչխան դժնիկանման
13	*Caragana arborescens*	Yellow acacia	Դեղին ակացիա
14	*Rosa canina L.* (native varieties)	Rosehip	Մասրենի սովորական
15	*Rubus idaeus L.*	Raspberry	Ազնվամորի

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