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# Handbook on Integrated Erosion Control

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

First Edition 2017

Գերմանական համագործակցություն
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# Handbook on Integrated Erosion Control

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

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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 experiences from 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-west 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.

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

- Training institutions;
- Local, national, regional NGOs;
- Government agencies with 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

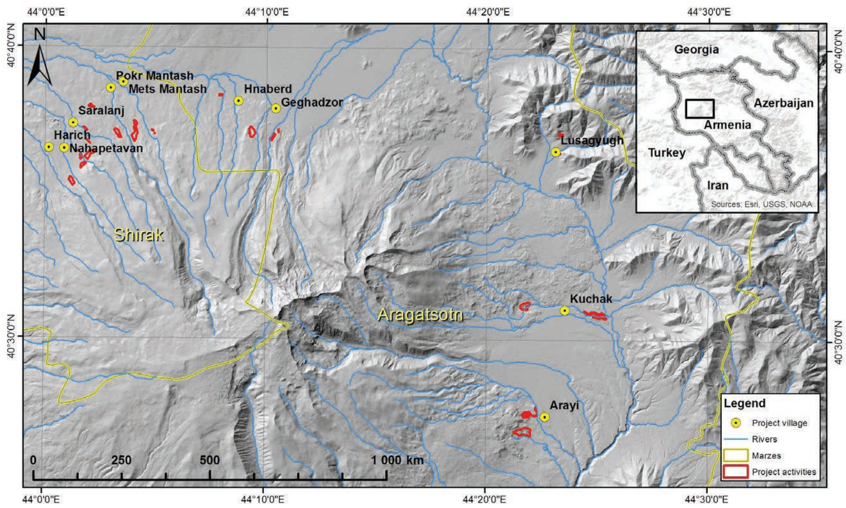



Fig. 1: Pilot region of IEC Project, Armenia

[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".

## 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 partner is the Ministry of Territorial Administration and Development (MoTAD), implementing partners are 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 to last four years (from December 2015 to November 2019).

### Integrated Erosion Control (IEC) Project

From 2014-2017 the IEC Project in Armenia has been realized 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 Aragatsotn and Shirak have been important stakeholders. Different Armenian NGOs (ESAC, ATP, Shen, Global Armenian Response) have been involved during 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 available
- Increased forest cover: 200 ha of eroded territories afforested or protected in small units
- 5 bioengineering measures for rehabilitation of eroded land
- Increased 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 realizing irrigation and caretaking of plantations). Level 5 has not yet been reached, but is highly desired in relation to future upscaling activities.

Important moments of stakeholder participation during the IEC Project are summarized in fig. 3.

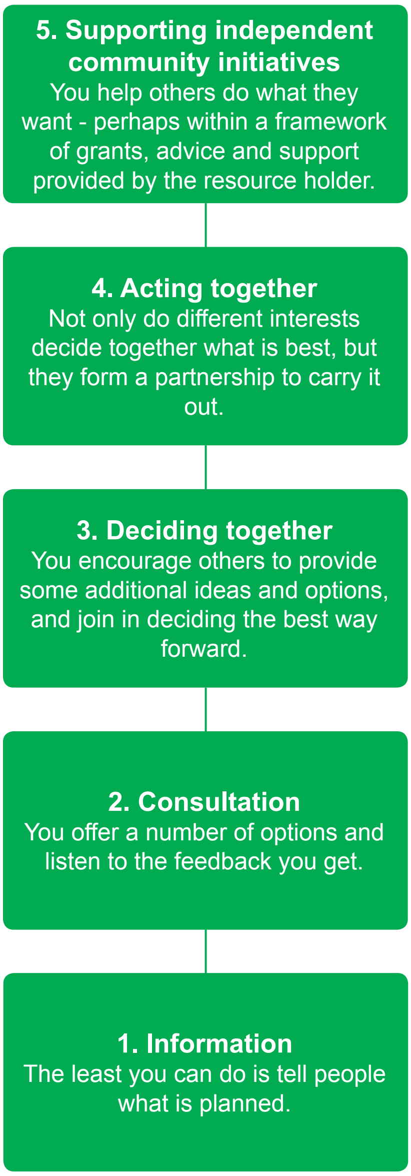



Fig.2: Levels of participation

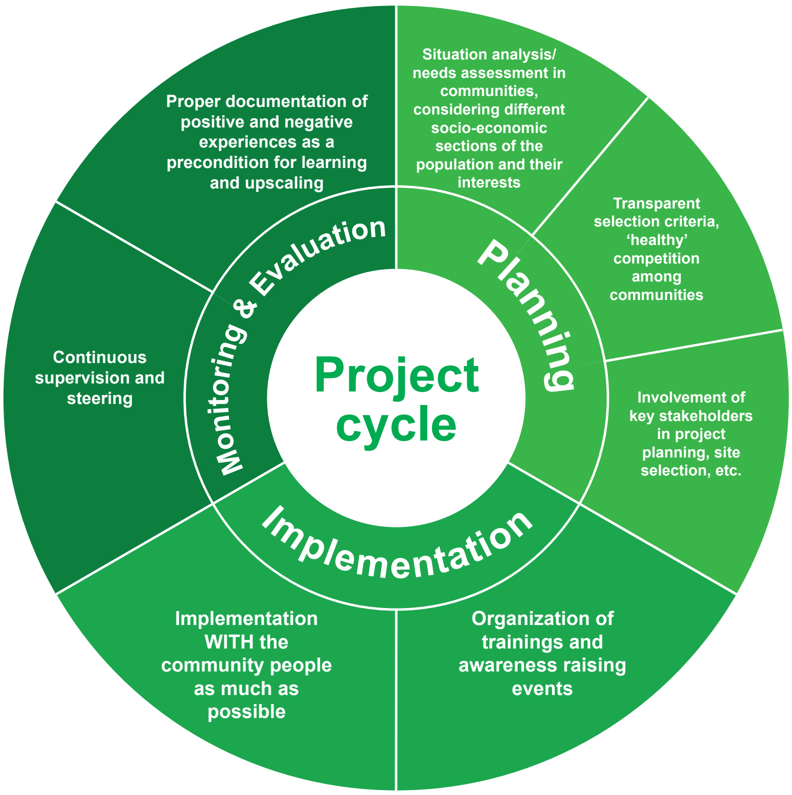



Fig. 3: Participation of stakeholders during different phases of the project cycle

## Ecosystem Services or How Humans Benefit from Nature

**Definition "Ecosystem Services"**

*(Smith, S. et al., 2013)*

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

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.

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).

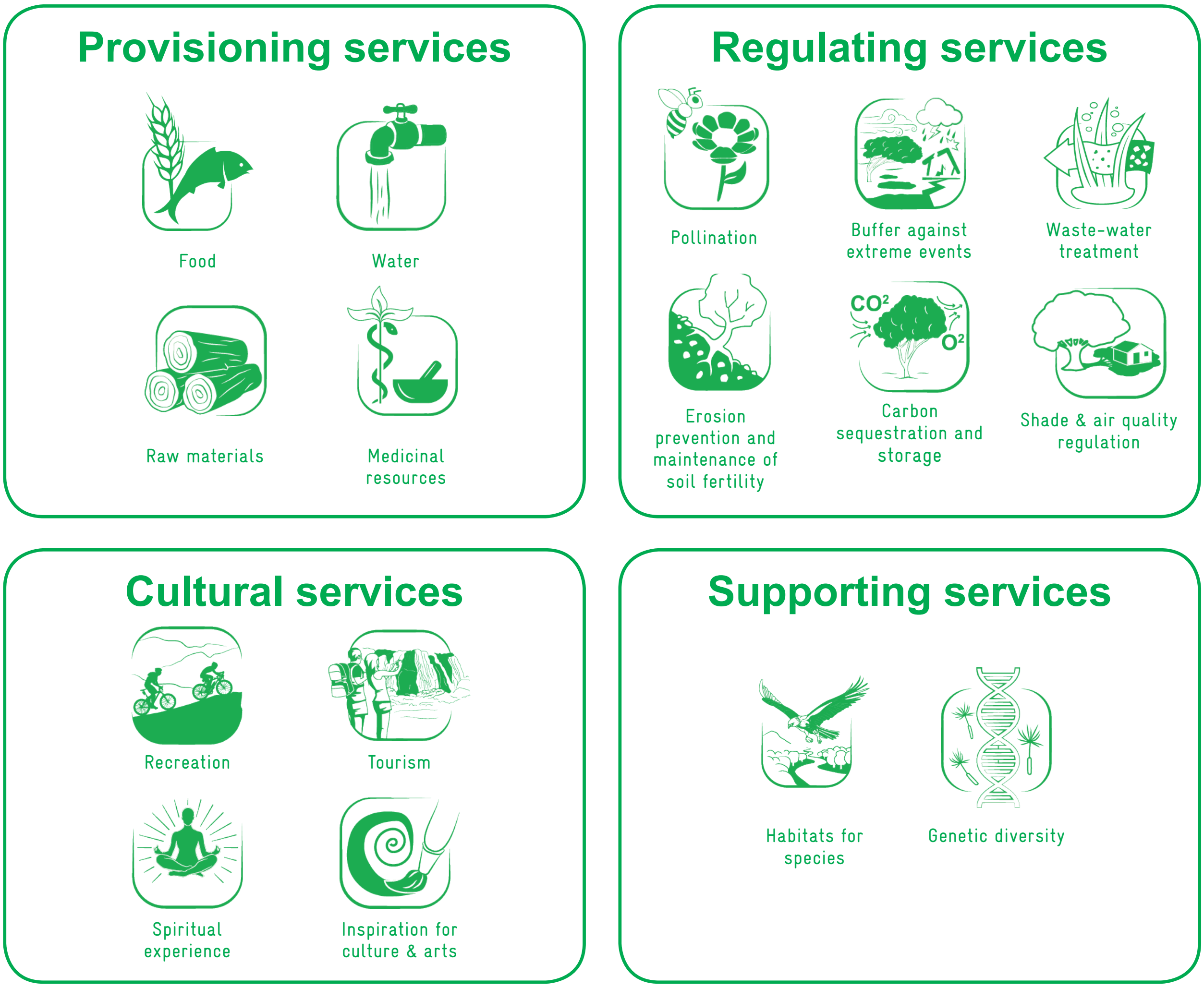
Fig. 5: Degraded ecosystem as a result of destructive management practices

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 own initiative of communities. More options to start erosion prevention or rehabilitation measures are given in the box (right).

*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
- Initiate small-scale implementation with locally available resources
- Lobby for support at local government agencies/marzpetaran
- Contact NGO who 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*

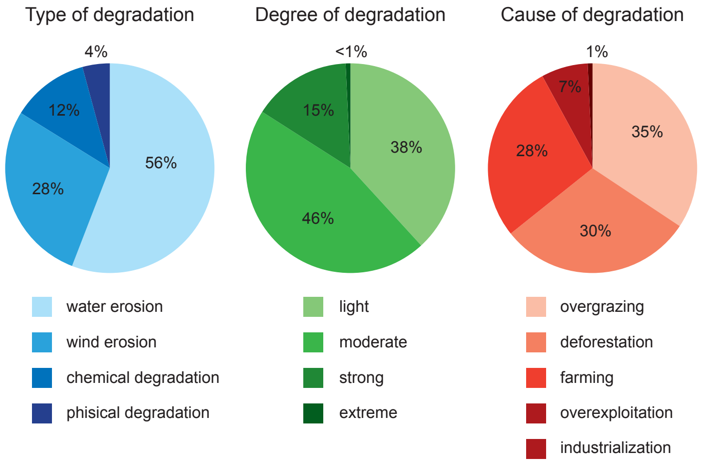



Fig. 1: Types, Degree and causes of global land degradation (Gruver 2013).

Healthy soils are the basis for 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 global ongoing degradation of soils and land is threatening our food security, livelihoods and the functioning of ecosystem services. Main causes of degradation are linked to 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 today a global vision. The so called ´Land Degradation Neutrality´ concept is part of the Sustainable Development Goals (15.3) and a strategic objective of the 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. As land degradation and erosion is usually caused or enhanced by inappropriate land use practices, it is the individual farmer working on a certain piece of land, where things have to be improved. However, favoring legal and political framework conditions and the existence of incentives for a change towards more sustainable practices are key. Raising awareness of local stakeholders can still be a first step. Knowledge on the multiple functions and values of soil, on the causes and influencing factors may already achieve some 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 giving 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*

**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.

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 productivity of land. To maintain the productivity of land for agriculture, pastoralism, and forestry, sustainable land management practices need to be established.

*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 the soil to remain uncovered or only with a scarce vegetation, resulting in less protection against the erosive powers of wind or water.
In the mountainous regions in the Caucasus, water has the highest potential to cause erosion. Wind erosion also occurs, but is mainly affecting arable lands in the lowland-areas. Fig. 2 depicts the main factors that influence soil erosion through superficial water flows.

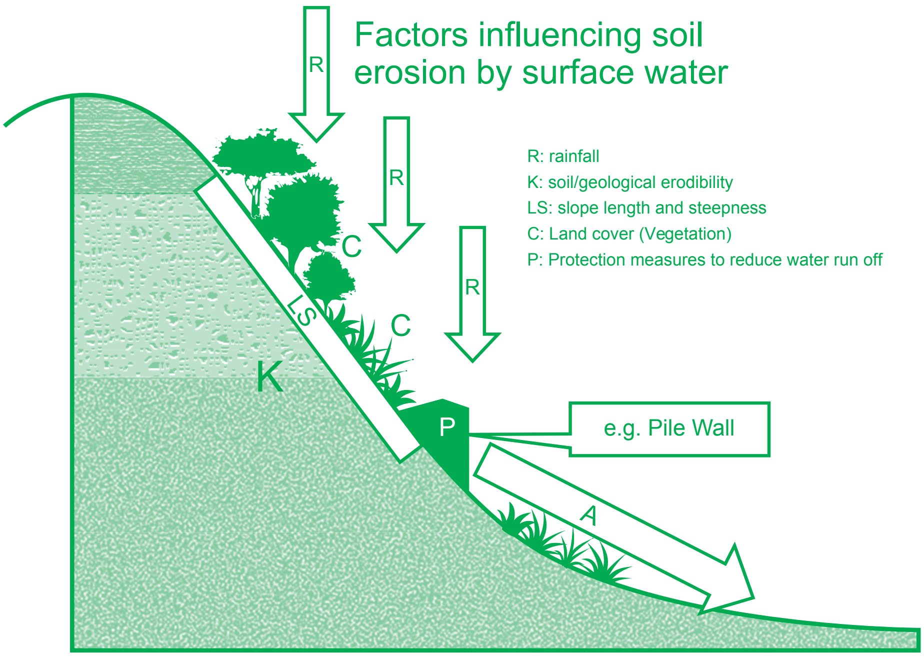



Fig. 2: Schematic figure of factors influencing soil erosion caused by rain and surface run off.

## Rainfall

Rainfall is the first influencing factor: The impact of the raindrops loosens the material and allows 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

How severe the impact of the water run-off is, 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 organic matter content 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 steeper a slope, the higher 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 from vegetation (e.g. intact grassland, bushes) or mulch reduces 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.

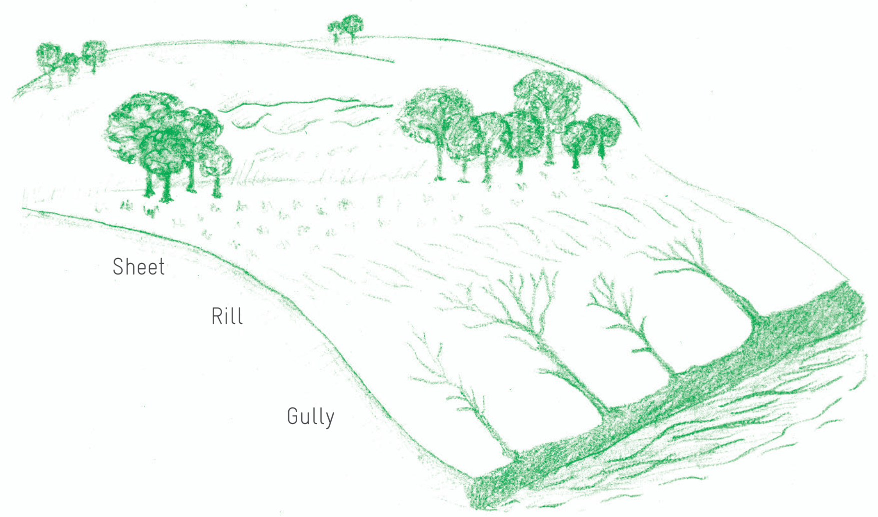



Fig. 3: Types of erosion (adapted from: www.cep.unep.org)

In the mountainous areas of the South Caucasus, three different types of erosion can be observed and 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 to run-off when soils are for example 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 exposed 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**
   When rainfall is not up-taken by the soil, gathers on the surface and flows downhill, it may form small channels. Those rills may dry out after the rainfall, but will still be visible – much more than sheet erosion.
3) **Gully erosion**
   If the formation of rills is not addressed by erosion control measures, they may deepen and grow into larger gullies. This development will accelerate erosion, as more and more surface area is susceptible 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 worse and disturb farming activities, threaten settlements and infrastructure.

## Soil erosion in Armenia

### *Data and information availability*

In the Southern 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 area and quality of forests due to illegal extraction and inappropriate forest management;
- Loss of productive land due to urbanization and conversion into non-agricultural areas.

In general, accurate data on erosion phenomena, their scope and effects for land users is hardly available or even contradicting. Solid research on erosion has not taken place in Armenia since its independence in 1991. Nevertheless, existing sources document that after independence roughly half of the land in use in Armenia was exposed to erosion, especially as a result of intensive and irrational agricultural practices. Only a quarter of arable land was 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, P., 2013, p. 212).

### *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 among the population on this issue.  Simultaneously, erosion control it is not a matter of priority of the Armenian government.
The following two strategic documents deal with the issue of soil erosion on an abstract level.

Practical guidance or a concrete regulation is missing:

- **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 benefit directly from the necessary investments and when those benefits are greater 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)

About 60 percent of the earth's ecosystem services are degraded, largely due to human causes. This is the estimation of the 2005 Millennium Ecosystem Assessment. 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 costs related to 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. To this point, we want to highlight that avoidance should always be the priority over reducing land degradation and the latter should be prioritized over reversing degradation (fig. 4).

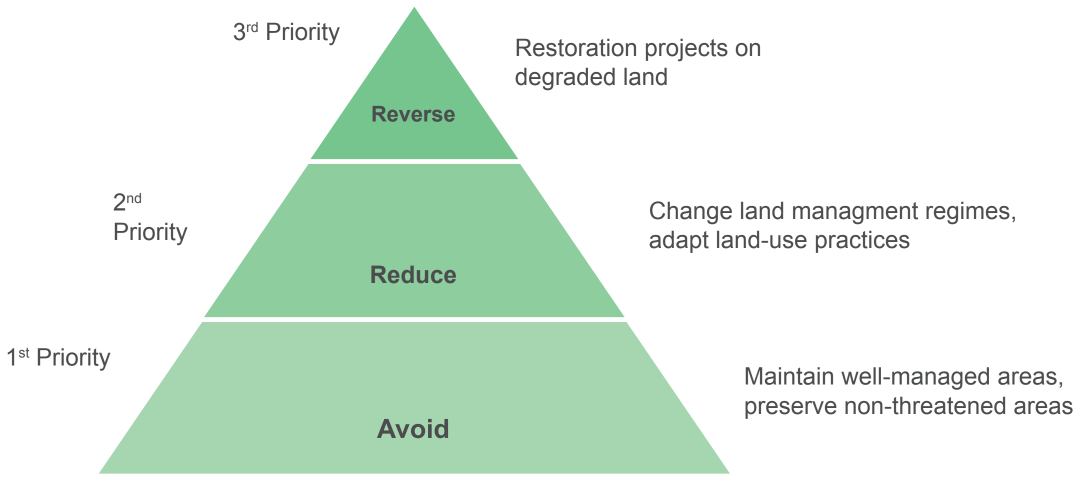



Fig. 4: Priority of measures against land degradation and soil erosion.

### 1st Priority: Avoid

Maintain well managed areas and preserve non-affected areas.

### 2nd Priority: Reduce

Change land management regimes and adapt land use practices that 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. However, activities must be designed based on the given degradation causes, development targets and needs and initiatives of local communities.

### What can be done against erosion

While measures addressing land degradation can be categorized in *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 from erosion or just show few signs of a starting erosion (e.g. accumulation of material on lower parts of a slope) should be subject of preventive measures. An erosion risk assessment will give information on how likely erosion is on that specific site (see Module 3). Preventive measures would comprise – depending on the type of land use – sustainable pasture management (e.g. limiting livestock numbers, introduce rotational system), or the establishment of more sustainable agricultural systems (e.g. by planting windbreaks, diversify 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. At steep slopes, pile walls will reduce erosion additionally and support the rehabilitation of vegetation. More efficient than a temporary exclusion for vegetation recovery, may be a complete change of the land use type: 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 type and degree of erosion |
| Type of measures | Protective measure, to prevent damages; often includes treatment of root causes of erosion | Treatment of occurred damage; mostly focusses on 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-cost (compared to cost for repair or rehabilitation) | Can be very expensive, especially when it comes to engineering works |
| Importance | Not easily visible, therefore not prioritized | Prioritized, if 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 are causing a threat to human settlement or infrastructure.

Table 1 shows the 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 next piece of land.

## Brief description of applied measures in Armenia

### *Communal afforestation for erosion prevention*

Afforestation can both be applied for erosion prevention as well as for rehabilitation purposes. In the case of the pilot sites in Armenia, plots of 1-30 ha 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.

### *Soil Bioengineering*

The bioengineering measures applied in Armenia refer to the rehabilitation of vegetation cover on degraded cattle tracks and gully rehabilitation. The selected sites are small (0.2 – 1 ha) and protected from animals with electric fence. Detailed descriptions and examples are given in Module 5.

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

## Working with local communities

With the experience of 4 years IEC project implementation, it is recommended to consider some issues when working with local communities in Armenia.

### WHO should be involved?

- ☑ Always involve the marz representatives in community meetings as well as in technical delineation of plots (for afforestation and for bioengineering)
- ☑ Emphasize the importance of women's participation in community meetings
- ☑ Involve 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.
- ☒ Don't involve the mayor only, but a group of people with clear responsibilities ('initiative group')

### HOW to start?

- ☑ Be concrete and specific in presenting your ideas towards the community stakeholders.
- ☑ If feasible, organize separate meetings for men and women. Encourage women to express their opinion.
- ☑ Select motivated community people with own initiative for implementation and dissemination of information.
- ☑ Start with small-scale trust-building measures in parallel with awareness raising activities.
- ☒ Don't dictate the project ideas. Be flexible in adjusting the project ideas to the needs of people.
- ☒ Don't underestimate the local capacities in communities
- ☒ Don't give all project inputs for free, but request own contribution

### WHAT else to be considered?

- ☑ Involve reliable community stakeholders in supervision and steering
- ☑ Consider the opinion of 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 activities
- ☑ Respect the limited availability of 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: Erosion assessment

## General introduction

This chapter is meant to give orientation for assessing the erosion risk or gravity of occurring soil erosion for a particular site and to give guidance in deriving the appropriate preventive or rehabilitative measures. Different assessment methods will be presented, including remote sensing approaches for assessments on a larger scale and field assessments used on local level for a concrete site. Further, for each erosion type and erosion gravity, recommendation for how to handle the observed erosion will be given with links to the subsequent handbook chapters and factsheets.

### *Why to assess erosion*

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 protection measures can be applied. In many mountainous regions in the Caucasus, grazing is an important land use. Overgrazing, trampling and driving vehicles are the most common human influences causing soil erosion in those areas.
Remote sensing tools should be used to monitor the change of vegetation cover as an important indicator for soil erosion on a 2-5 years basis. This can help to find regions in a country with emerging erosion problems and to focus activities to these regions.

### *Overview on differentmethodsand their application*

For selecting the appropriate assessment method, ,the spatial scale and on 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 too time and resource consuming and probably not necessary in that accuracy.

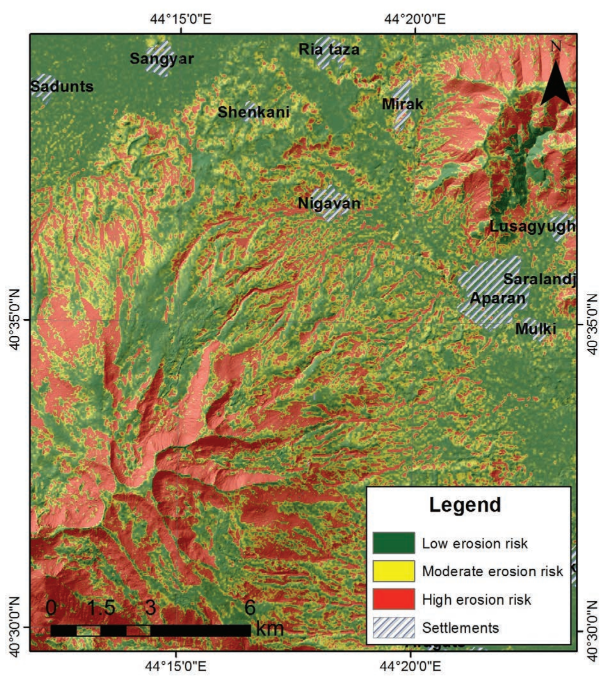



Fig. 1: Map of pilot region with spatial information on vegetation types and erosion gravity derived from satellite imagery.

For generating information for an area of several square kilometers or even a whole nation, 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 (insert our own map!). On the local level, erosion type and gravity or therisk of erosion can be estimated by directly assessing the visible signs of erosion 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 community level. Result could be a sketched map.

## 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 influencing factors for planning appropriate erosion control measures.

As explained in the prior module "Awareness on Erosion", there are three main forms of erosion occurring in the mountainous areas of the South Caucasus:

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

These three erosion types are usually occurring one after another and are caused by superficial water-flows on slopes with a degraded vegetation cover. Usually,it starts with sheet erosion (detached particles form the topsoil are carried away), 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 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 surface covered by vegetation (or fixed stones, that cannot be easily moved away).

We distinguish three levels of sheet erosion:

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

| | | |
|---|---|---|
| > 90 % vegetation cover = no erosion, 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, its speed of run-off is reduced be the resistance of the vegetation. The root system of the grass, shrubs or herbs is fixing the upper soil layer and prevents the washing-away of soil particles. Dead leaves and stems form a litter layer, which is again is protecting the soil and contributes to the development ofa 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 vegetation is reduced. In combination with a steep and long slope, the process of washout of fine but 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, the larger 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 %.

A general rule is, the steeper and longer the slope, the stronger the erosive energy of the down streaming surface water.

### 2) Rill erosion

Fig. 2: Rill erosion caused by overgrazing

If the process of sheet erosion and continuous vegetation damage e.g. by overgrazing 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. The result are more erosion phenomena such as small channels and rills of 10-30 cm depth (fig. 2).

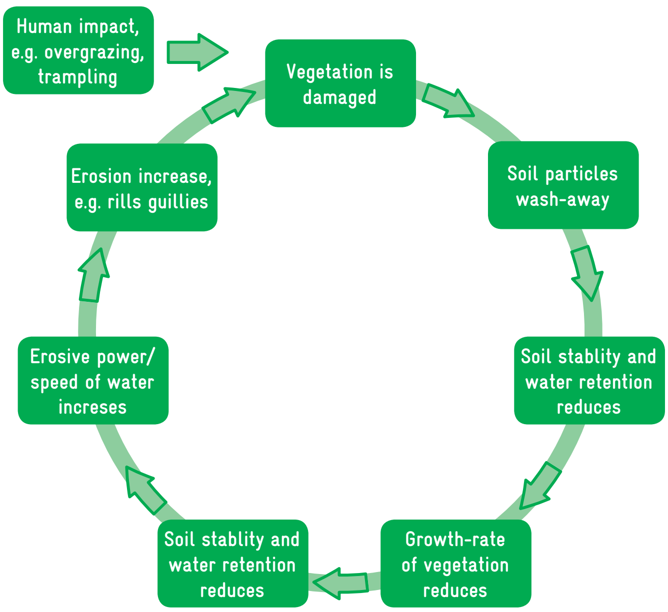



Fig. 3: The self-accelerating process of erosion

### 3) Gully erosion

Fig. 4: Gully erosion

The small rills and channels are collecting 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 accelerate again 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).

## Identifying appropriate erosion control measures

*Measures in case of sheet erosion*

### Case 1: Beginning 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. In this stage, the self-rehabilitation of vegetation is still strong and can be promoted by removing the cause of the vegetation damage (if human made). 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 (e.g. lower livestock numbers).

### 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, seeding, applying fertilizer. The area needs to be excluded from grazing until vegetation has recovered. For very steep slopes, the construction of horizontal pile walls is a recommended measure.

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

*Measures in case of rill erosion*

### Case 3: Rill erosion

Rills should be treated with some erosion control measure, in order to prevent the formation of gullies. Effective measures would be 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, or application of seeds or fertilizer.

Fig. 6: Pile walls to combat rill erosion

*Measures in case of gully erosion*

### Case 4: Gully erosion

If rill erosion is not stopped, most probably it will grow to a gully of 0.3 to several meters depth. At this stage of gully erosion, erosion control measures are very complex and cost intensive. Larger interventions, such as the construction of check dams are needed to stop the dynamic of the gully erosion. 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 is 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). Appropriate measures, depending on the size of the gully, would be either the construction of pile walls or check dams.

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

Table 2: Overview on preventive and rehabilitative measures to control erosion, depending on occurring erosion type.

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

## Remote sensing methods

### *Relevance & preconditions*

To generate remote sensing data for the whole country as well as to inform local administration, municipalities, extension services and farmers how to assess erosion and how to adopt land management to avoid erosion will require organizational infrastructure, human capacities and financial resources. To avoid the irrecoverable loss of fertile soil as a basis for income generation in rural areas and food security, it is important to control soil erosion. Legal frameworks (e.g. laws on soil protection or regulation of grazing intensities) are important as well as awareness raising campaigns and training of extension services and farmers. The establishment of an organizational back bone on national level would help to develop these proves and to coordinate activities on national level (UBA 2015).

### *Technological approach & use*

Remote sensing can help to assess current erosion and erosion risk. 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 the progress of erosion process. 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 can provide current 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 steepness and length of slopes. Based on these input data, the risk of potential soil erosion can be calculated by computer models and maps of sites sensitive to erosion can be produced. The so called "Sensitivity Model" developed by experts from the Caucasus region with the support of GIZ is such 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, 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.

# Module 4: Community afforestation for erosion prevention

## General introduction

> **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."

Forests are – in terms of biomass accumulation and stability -the most successful ecosystems in the world. This is true for all those sites of which 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), forest find their ecological limits.

In the South Caucasus, two natural limits are restricting forest expansion:at 2.300 – 2.600 meter above sea level the upper timber line is visible in the higher and lesser Caucasus; steppe and semi-desert ecosystems form the lower timber line forparts of the South Caucasus. The map of natural vegetation of Europe (fig. 1) depicts the potential natural vegetation cover without any human intervention. In the middle of the 6th millennium BC (Hamon, C. 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.

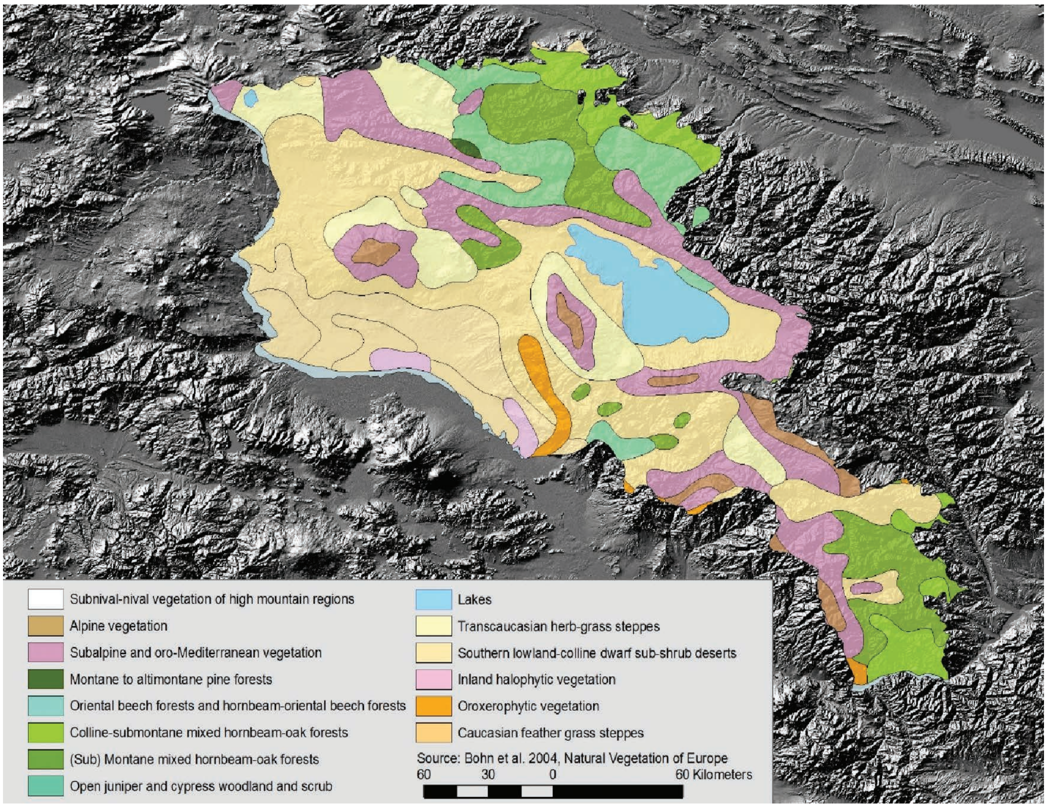



Fig. 1: Potential natural vegetation in Armenia (Bohn et al. 2003)

## Forests for erosionprevention and other ecosystem services

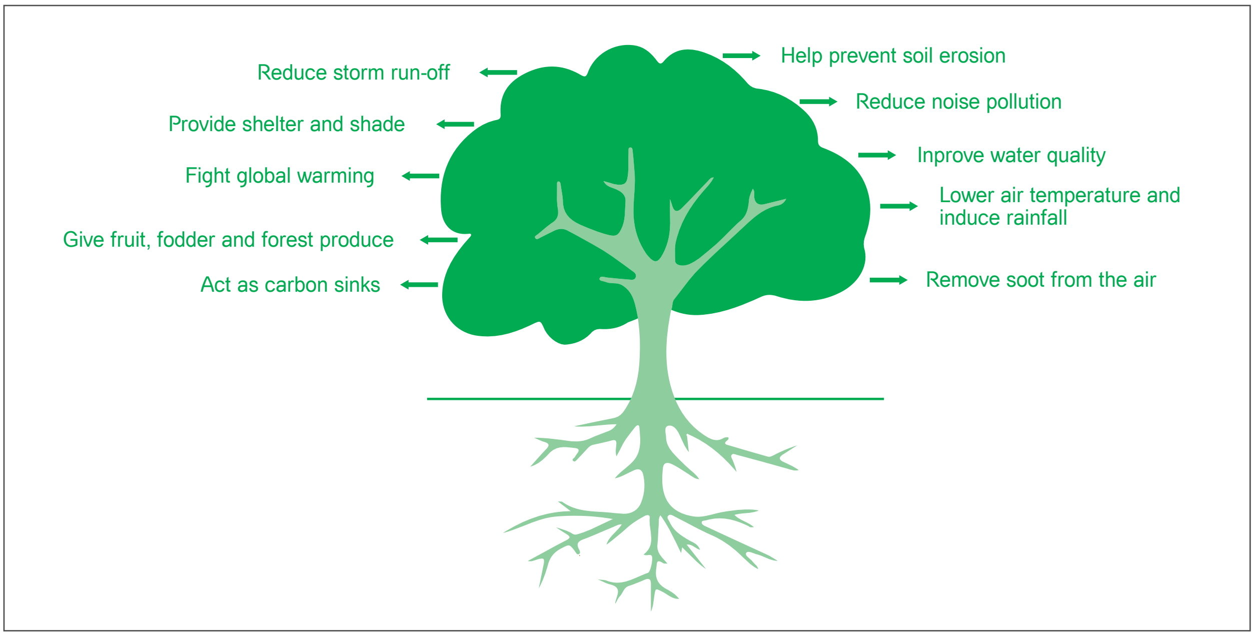



Fig. 2: Multiple ecosystem services of forests (Source: www.grow-trees.com)

Forests form stable ecosystems, which regenerate naturally, persist for long time periods and are resilient to most disturbances. Natural forest ecosystems offer multiple ecosystems services, such as timber and fuel wood provision, water purification, carbon sequestration, recreation etc. (fig. 2). In mountainous landscapes, forests have furthermore a 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 run-off. A closed crown cover of a forest reduces the erosive power of heavy rainfalls by detaining some of the water in the crowns (interception) and by its deep root system that gives stability to the soil and hereby reduces the risk of landslides and debris flows. A closed forest cover can effectively protect villages and human infrastructure from damages through rockfalls or avalanches. Thus, costs for investing into technical means to protect settlements and infrastructure can be saved.

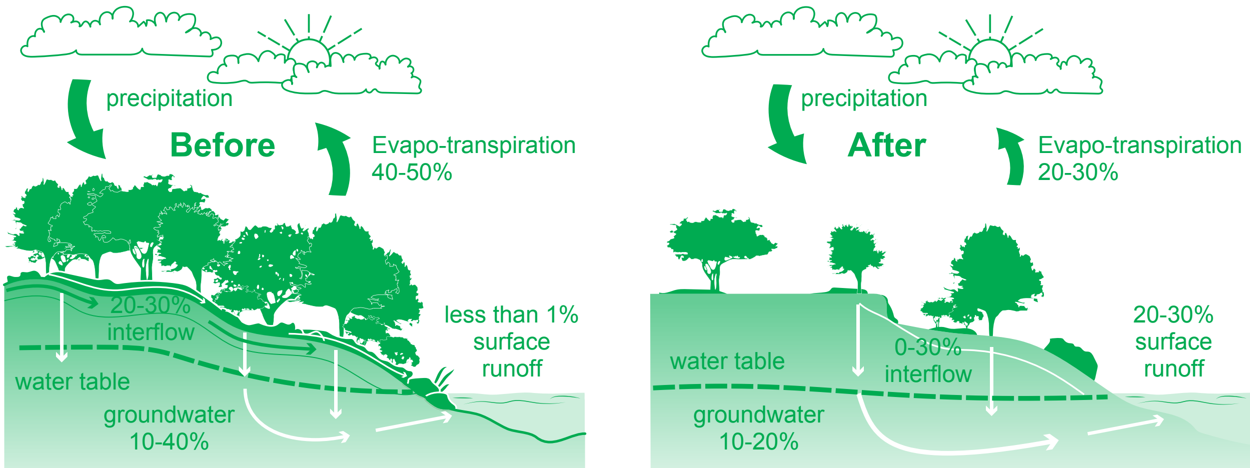



Fig. 3: Under natural conditions, almost all rainfall is taken up by plants, evaporates or infiltrates through the ground. After human intervention (construction, deforestation), surface runoff increases significantly while evaporation and infiltration into the ground decrease.

Source: http://www.ecy.wa.gov/programs/wq/stormwater/images/runoff_illustration.jpg

## Planning & preparing an afforestation project

*The different phases of an afforestation*

**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 an improvement of rural livelihoods.

Afforestation activities can be divided into 3 main phases:

A general rule of any afforestation: Imitate the natural vegetation in terms of species composition and structure

**Afforestation:** selection of tree seedlings, decision on planting scheme, fencing and seedling planting (time: some weeks to several months)

**1. Maintenance:** irrigation, cutting, mowing, etc. (time: ongoing measures after planting of seedlings, 3-10 years)

**Management**: silvicultural measures like thinning, harvesting or regeneration of forests (time: after maintenance phase ongoing).

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

*Checking general framework conditions & availability of resources*

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

- **Availability of financial resources** (determine size, afforestation scheme and maintenance practice);
- **Availability of human resources & in-kind contributions** (local workers from communities, forest experts, scientific staff, volunteers, etc.)
- **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)

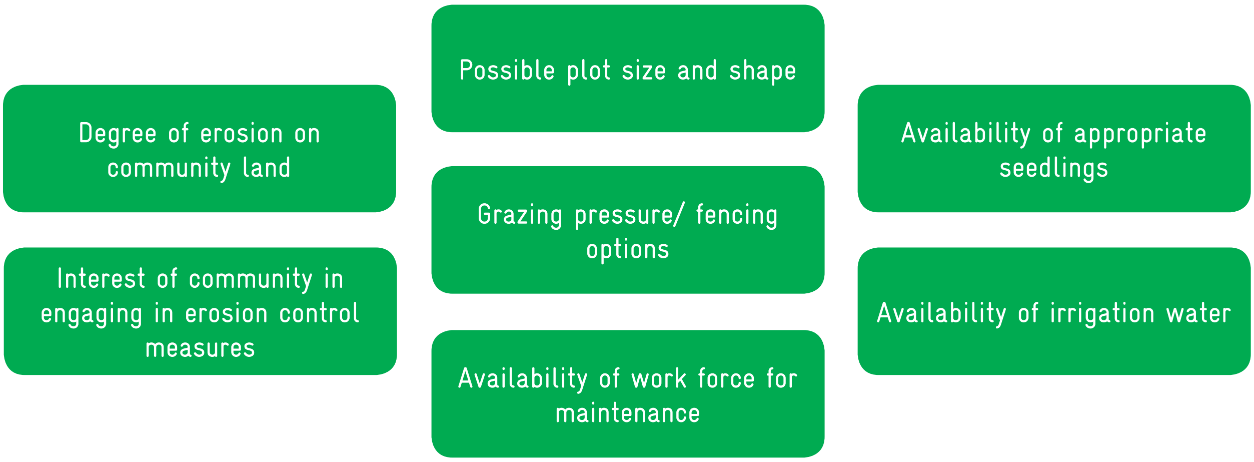



Fig. 4: Main factors to be considered when planning an afforestation plot

*Site selection*

A proper site selection is of upper most importance when starting an afforestation activity that should be successful over many decades and centuries. While in many agricultural activities location might be changed after a couple of years, afforestation activities are bound to the place of 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 ecosystems 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 have an appropriate size and shape?

**Socio-economic site selection criteria:**

- Is the community / land owner supporting the afforestation on her/his land?
- Is there any conflict with other land use (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 qualitative manner and should be based on intensive discussion with all stakeholders in a participatory process.

*Considering shape and size of 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 are decreasing. This is mainly due to the costs for fencing which account for a large part of the total afforestation costs. For increasing afforested areas (in case of square-shaped areas), the relative fence length per hectare decreases. Experiences from Armenia show that the total afforestation costs per hectare

(work and materials for fencing and planting, but without purchasing of seedlings) for sites < 5 ha are three times higher than for 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 not necessarily decreases with an increase of total area. For very scattered or small afforestation areas a protection of individual trees with a mesh wire should be considered.

### *Identifying the appropriate planting season*

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

## 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 seedlings plantation. The costs and advantages of different fencing types are given in Table 1.

Table 1: Costs and advantages / disadvantages of different fence types.

| Fence type | Type of fencing posts | Costs of material | Labour cost 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) | Long durability, effective for small and big animals. Horizontal wires should be used at the top and bottom of the fence to increase stability. 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) | Not easy to construct barb wire fence that is effective against small livestock (goat, sheep). If barb wires are not removed after fence is not needed, it could lead to severe injuries to humans or animals. |
| Electric fence | Plastic | Medium (approx. 1.500 AMD/m) | Low (50-100 AMD/m) | Advantage: Can be easily removed and re-used. Disadvantage: Daily maintenance needed. |

## Tree species & seedling quality

### *Tree species selection*

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

For selecting suitable species, a screening of the wider project area will yield in 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 as main species (see below).

During the Soviet period, large pine plantations (*Pinus sylvestris*) have been afforested. *P. sylvestris* is not a native tree species to the alti-montane forest belt in the Southern Caucasus, but as a pioneer tree and with its broad ecological amplitude, plantations grow up to an elevation of 2.300 m 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, barries, etc.

## Recommended tree and shrub species for afforestation in Armenia

### Main species


(Source: tree-guide.com)

**Persian Oak, *Quercus macranthera***

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

(Source: wikipedia)

**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 16 m high. It is adapted to the climatic conditions of the subalpine level (1.800-2.500 m a.s.l.), not very tolerant to droughts, but resistant to frosts.

(Source: wikipedia)

**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 2.600 m a.s.l.

*Species information from wikipedia and iucnredlist.org*

**Pioneer, fruit and shrub species**


*(Source: wikipedia)*

**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.


*(Source: wikipedia)*

**Mountain Ash,** *Sorbus aucuparia*

The Mountain Ash is a deciduous tree or shrub in 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.


*(Source: wikipedia)*

**Oriental wild apple,** *Malus orientalis*

*Malus orientalis* grows up to 10 m and is mostly found in mountain forests, on forest edges, in glades and along riverbanks. It occurs at elevations up to altitudes of 2.000 m 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*

Species information from 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 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 of bare root of seedlings 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 die-back after 1-2 weeks after 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 18 cm, while pine (*Pinus sylvestris*) is grown in containers with 5x8 units and a depth of 14 cm. The seedlings are grown in the container for 1-2 years until they are transported within the container and can be put into the ground with the root ball including 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 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 a small 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 exactly in 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<br>• Produced in tree nurseries without high infrastructure investments<br>• Root system usually well developed | • Very sensitive to improper handling during transport and planting<br>• 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!)<br>• Roots are protected and get less damaged during planting<br>• Roots stay in their soil environment after plantation, trees show less stress symptoms<br>• Plantation costs can be significantly reduced by using special planting tools | • Production of containerized seedlings needs more investments and leads to higher seedling costs<br>• 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.

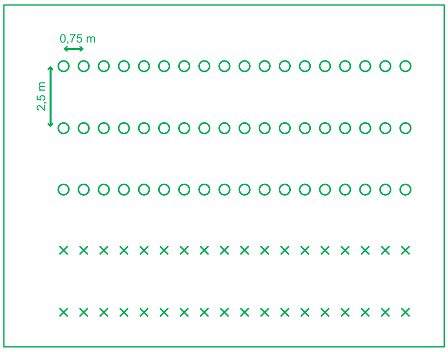
### *Schemes – lines versus groups*

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

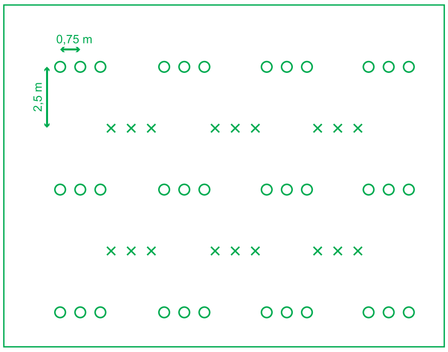
This line approach is usually linked to a high planting density (6.000 - 9.000 seedlings per ha), as a short distance between seedlings is needed for creating a favorable micro climate (e.g. reduction of wind speed). A modification of plantation in lines is the **chess pattern planting design** (fig. 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 more and more **group plantation** (fig. 6C, 6D) over line plantation. Most group plantations are designed in a raster of 10x10 m to 15x15 m, resulting in 100 to 45 raster nodes per hectare. At each node, a group of seedlings is planted in close distance to each other. The groups might be designed in rings or squares with distances of 0.4 m - 1 m between the trees. With 9 to 12 seedlings per group and 10 – 15 m 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.

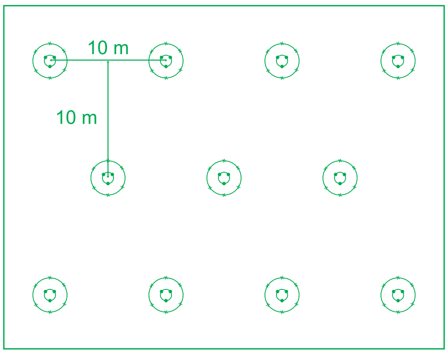



A. Line planting scheme

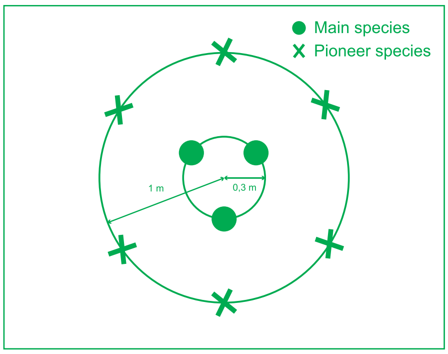



B. Chess pattern planting scheme

Fig. 6: Comparison of different planting schemes




C. Overview of group plantation scheme.




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

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

| | Advantages | Disadvantages |
|---|---|---|
| Line planting | Easy understandable and widely used<br>Easy monitoring of success, as long as same tree species are in one line<br>Mechanical soil preparation (by tractor) possible<br>High planting density will ensure a dense stand, even when high die-back is expected | High costs caused by high number of seedlings<br>High costs for planting and maintenance<br>High amount of irrigation water per hectare needed<br>Mechanized mowing of grass between lines is difficult without damaging seedlings |
| Chess pattern planting | Less seedlings and thus less work for planting required<br>Effective control of surface water run-off<br>Good option for erosion control plantings of large areas | Mechanical soil preparation difficult (staggered trenches)<br>Irrigation is more Labour-intensive |
| Group planting | Reduced number of seedlings reduces costs of afforestation<br>Easier maintenance  less seedlings to be mulched and irrigated<br>Micro-climate function is still given<br>Even with high die-back rates of 60%, at least 3-5 trees (shrubs) per group will survive, which leads to a minimum of 200-500 trees/ha<br>Easy hay cutting between groups | More difficult to irrigate compared to trenches<br>Group planting not known in Armenia, people are skeptical<br>Might take longer time to cover the area with protective trees/shrubs |

### *Technique -Trenches versus holes*

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

An alternative to the trenches are plant holes with a diameter of 20-40 cm and a depth of 30-40 cm (fig. 7B). The plant holes can be used for the line plantation as well as for the group plantation. Deep holes make irrigation easier and give 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

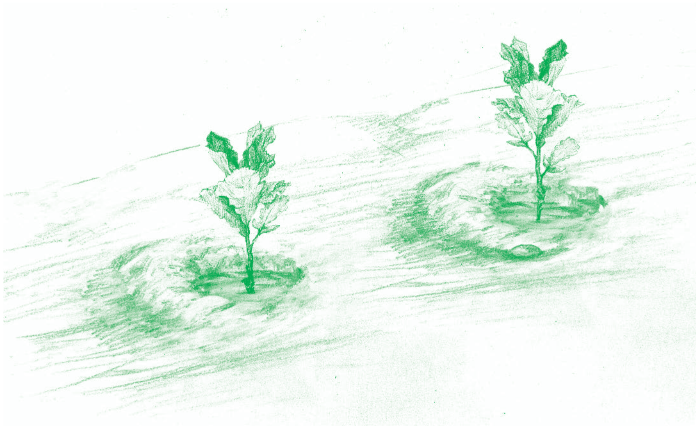


Fig. 7B: Oaks planted in plant holes.

Table 4: Comparison of different planting techniques.

| Planting technique | Advantages | Disadvantages |
|---|---|---|
| Trenches | Trenches can be done by tractor → time and resource efficient<br>Capture run-off water and conserve moisture<br>Easy to plant and irrigate along the trenches<br>Appropriate for high planting density | If not along the contour line → increased erosion in case of heavy rainfall<br>On stony ground difficult to dig<br>Closely planted seedlings compete for sunlight water and nutrients; thinning necessary after some years |
| Plant holes | High flexibility in selecting location of seedling especially in stony terrain and on steep slopes<br>Deep planting holes preserve moisture and protect against wind<br>Flexible in spatial design (lines or groups)<br>Speed for digging can be increased by using a motor-soil drilling machine | Labour-intensive for planting and maintenance (irrigation, grass cutting)<br>Proper depth and shape of holes (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 is established, each tree seedling should at least be supplied with 5-10 litres of water right at the day of planting, unless it is raining or soil is saturated by water from 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 sufficient, 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 cases 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 low water output to speed up the irrigation process.

### *Mulching & weed control*

When soils are fertile, growth rate of herbs and grasses might be higher than those of the seedlings and 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 in higher altitudes (> 1.800 m 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 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).

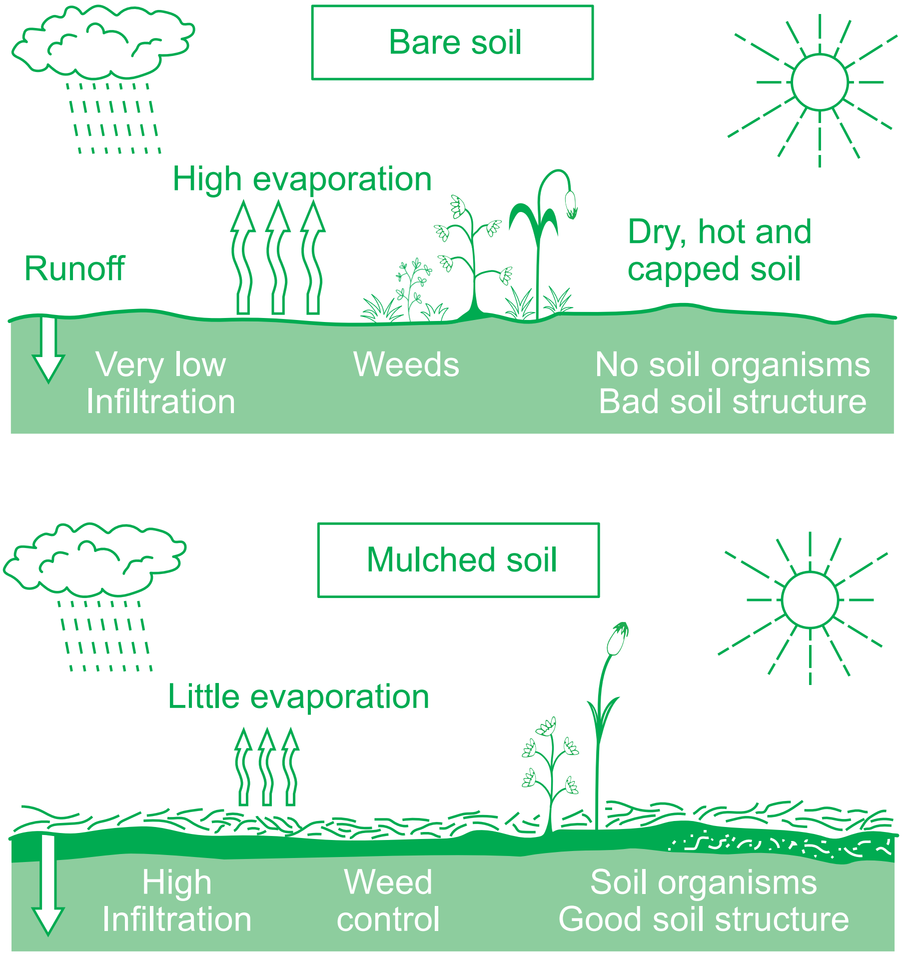



Fig. 8: The effects of mulching
(source: Vukusin H. et al: Production without Destruction, Natural Farming Network ZW)

# 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. Those ´living engineering systems´ are making use of locally available materials, and are often used to increase surface stability and to combat erosion problems.

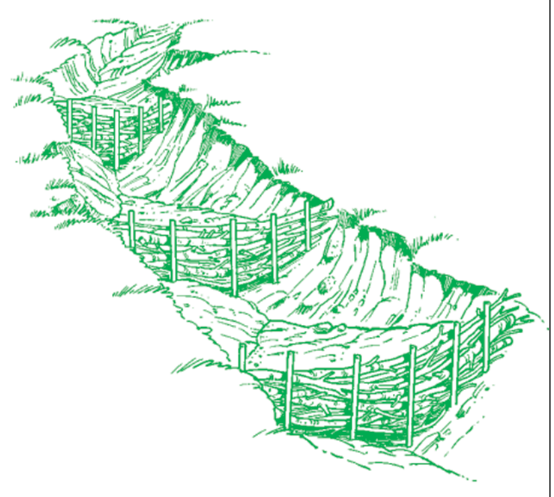


Fig. 1: Gully breaks (source: Polster 2003).

Soil bioengineering refers to measures that combine principles of ecology, hydrology, geology, physics and engineering to construct vegetative living 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 strengthen over the years (Polster 2003).

Bioengineering uses materials which are found in nature and which are combined with technical building materials. Examples are small retaining pile walls on slopes to stop material from rolling 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 technicaland vegetative construction materials, would therefore be an option to achieve immediate results in terms of soil protection and erosion control while fostering a sustainable, ´nature-based´ solution.

## Advantages of bioengineering

**Benefits of bioengineering measures**

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

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 low-cost labour is used e.g. through community engagement. Usually, the low technological requirements i.e. regarding 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 ´near-natural´ landscape structures. Adequate bioengineering techniques, where a vital and dense vegetation is achieved, will result in effective and long-term control of erosion phenomena.

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

| Technical Functions | Ecological functions |
|---|---|
| • Protection of soil surface from erosion by wind, precipitation, frost or flowing water<br>• Protection from rockfall<br>• Drainage<br>• Protection from wind<br>• Reduction of destructive forces of water (rivers, gullies) | • Improvement of water regime by soil interception and storage capacity<br>• Soil drainage<br>• Protection from wind<br>• Mechanical soil amelioration by plant roots<br>• Balancing of temperature conditions in near-ground layers of air and soil<br>• Shading<br>• Improvement of nutrient content in soils<br>• Improvement of productivity of (adjacent) lands (pasture/cropland) |

## 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 and cattle tracks as well as small gullies.

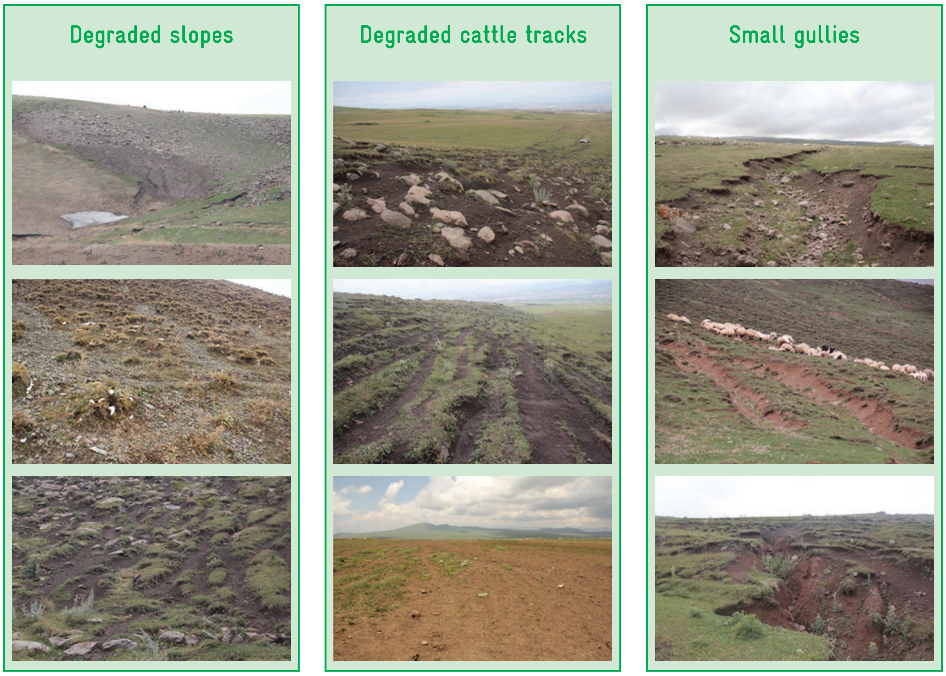



Fig. 2: Frequent soil degradation and erosion phenomena in the South Caucasus that can be addressed with bioengineering.

## 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 is present?**

Erosion frequently occurs on steep or over-used sites. Consequently, the most common areas where bioengineering is an adequate approach, are cattle tracks (particularly around villages), ravines, trenches, gullies with temporary or permanent flow of water, 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, rock fall threaten human life or infrastructures (roads, houses, dams);
  - ✓ Erosion results 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 steepness require more effort. Unless professional companies work on it, such sites should be discarded;
  - ✓ Erosion threatens other ecosystem services or long-term perspectives (gradual degradation of pastures);
  - ✓ At least temporary fencing can be ensured. Bioengineering works with living plants and seeds, which need to be protected from grazing animals. Once having identified the areas to be treated the appropriate measures need to be selected. This process is determined by:

- Type of erosion process
- Natural conditions (inclination, precipitation, natural vegetation, temperatures, water availability, wind, elevation)
- Availability of materials for
  - ✓ construction: rocks, logs, branches etc.
  - ✓ 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 with eventual rockfall | 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. Creativity and improvisation may be required, to match existing resources with the envisaged measures and results. For instance, logs used for pile walls can be replaced by bundles (fascines) made of smaller living branches, e.g. from poplar or willow (fig. 3).

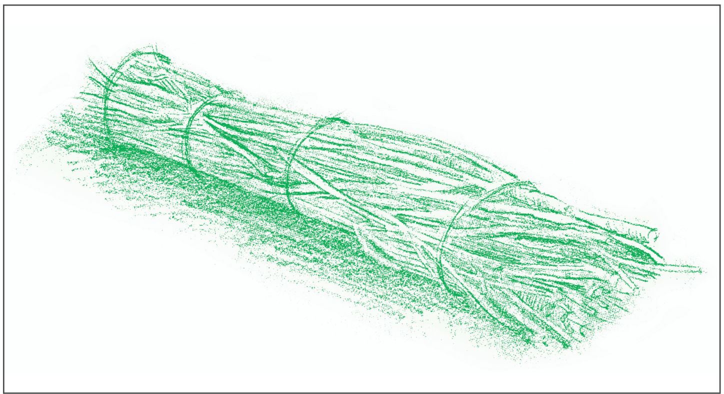


Fig. 3: Bundles of branches (fascines) as alternative to wooden logs

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 | In Armenia |
|---|---|---|---|---|---|
| **Wooden logs** | Diameter: 10 – 20 cm, 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 | none, susceptible to wind (needs to be covered if wind is strong) | available | available |
| **Manure** | 1-2 year old manure from stables | 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 guarantee to have an autochthonous seed mixture, but has the disadvantage of varying amount of seeds.

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 in 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 and 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 can be selected (between late June and late July). This can ensure a maximum of seeds. In general, the earlier it is 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/ 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 slow down vertical water flows. Thus, this technique can also be used at 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*

Iron piles are driven into the ground, fixing a timber log and eventually covered with brush layers (additional cuttings) or hay mulch cover. 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 the longevity, it is recommended to use either pine or acacia wood, but any type of available wood (e.g. poplar) can be used and 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.**

The distribution scheme and amount of pile walls is based on the steepness and 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 be rather 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.

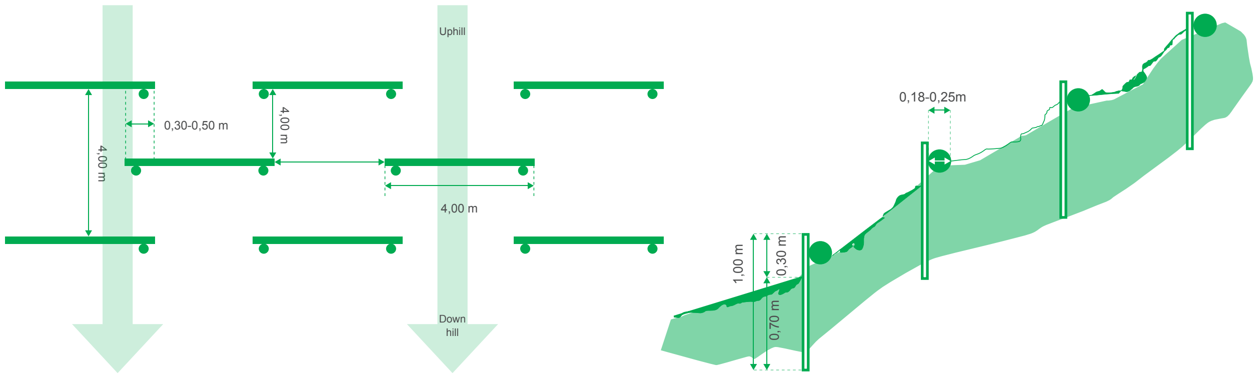



Fig. 6: Scheme of pile wall distribution along the slope. View from above (left) and vertical scheme (right).

## 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 infiltration. Depending on the topography, the amount of precipitation, available material 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).

**Gully plugging**

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).

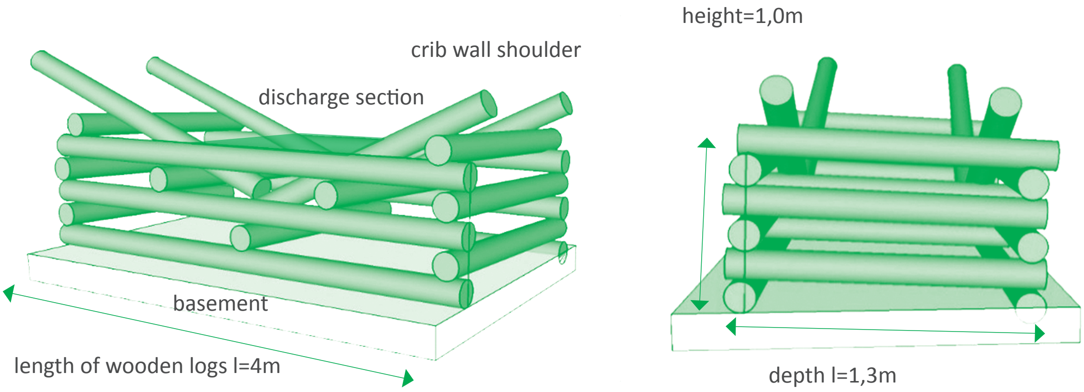



Fig. 8: 3D views of the wooden structure of the vegetated crib wall (Rauch et al. 2016).

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 extent 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, 2005:

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 on upscaling strategies and ideas for their practical implementation. It 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 of similar activities. In particular for pilot measures related to natural resources management (NRM), a tangible impact can only be observed when certain measures or improved practices are applied at 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 (politico-administrative) system will be based on the "local" experience?

3) **(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 conditions in another country or another sector?

Worldwide GIZ projects follow a multi-level approach, 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 in the same pilot communities as well as other communities with similar conditions. Vertical upscaling is envisaged through constant policy dialogue with political partners at the marz and 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 larger scale.
Functional upscaling also happens in the frame of the IBiS programme: as a regional programme working in the three South Caucasian countries, successful measures and approaches are shared and adapted to the specific circumstances, e.g. the application of bioengineering measures in Georgia and Armenia.

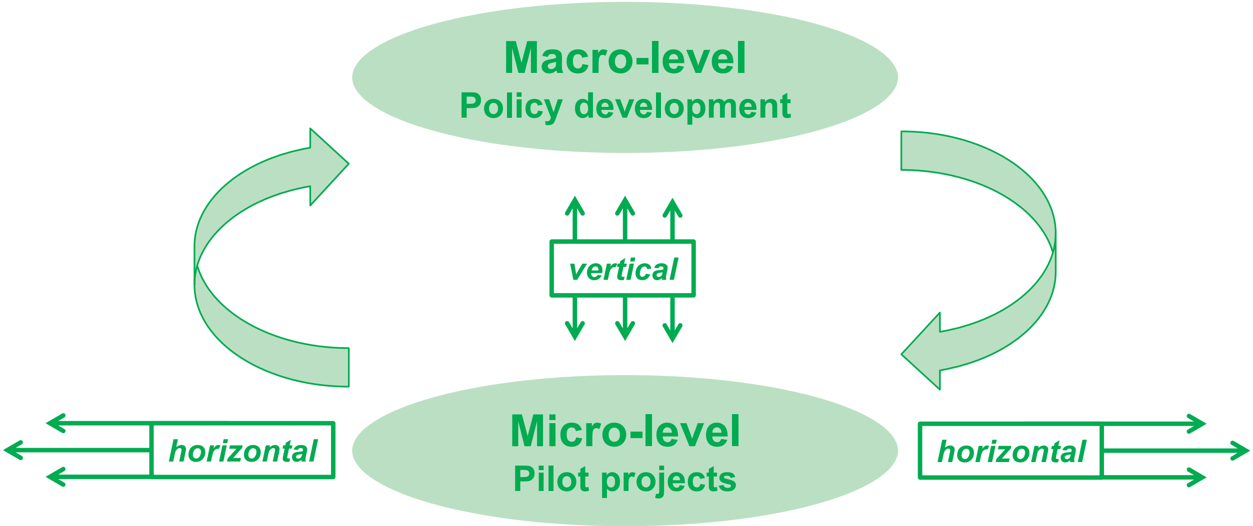



Fig. 1: horizontal and vertical upscaling

## Tool for assessing the upscaling potential of a pilot measure

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

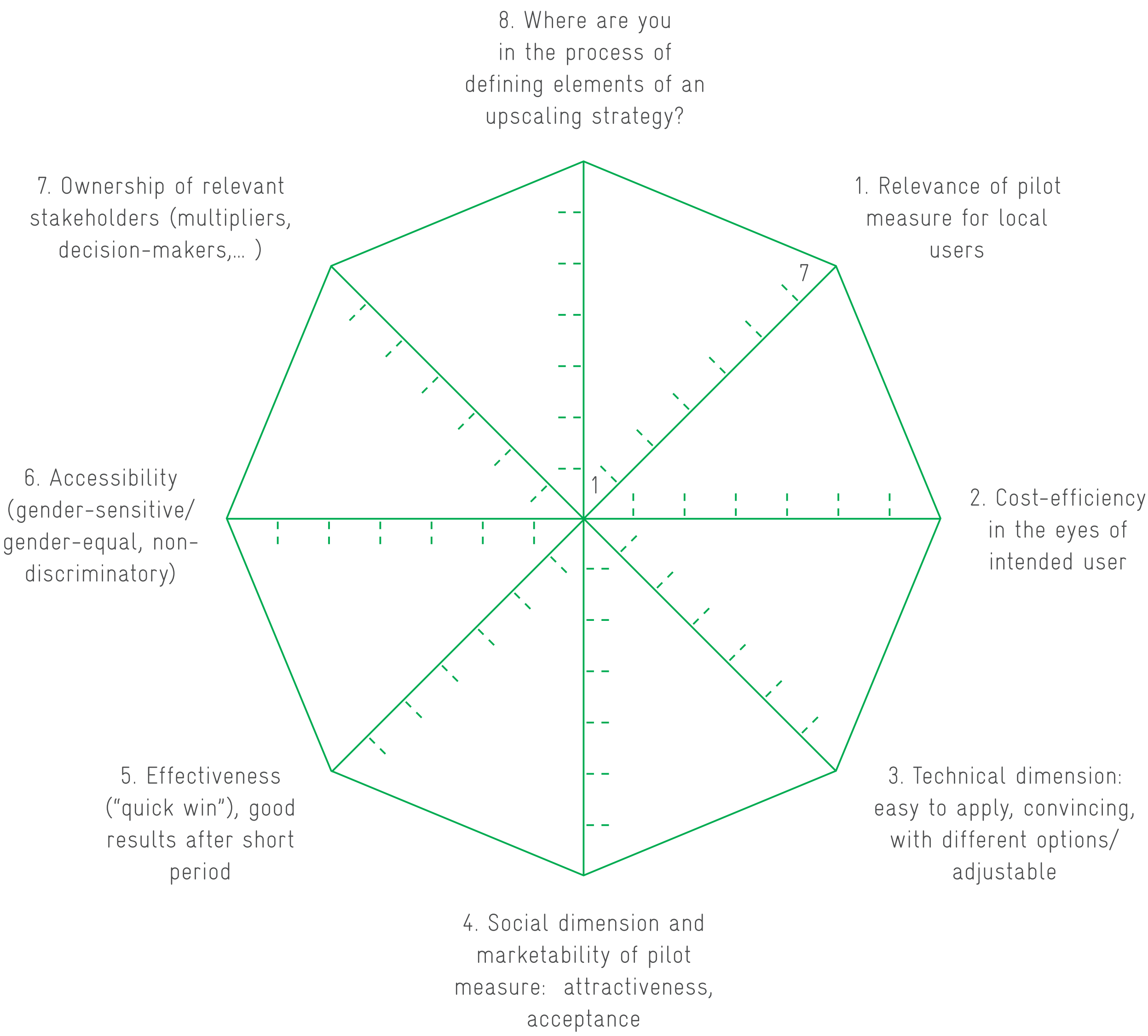
*1. Assessment grid: upscaling potential of a pilot measure*

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 measures 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, with different options, adjustable? | |
| 4 | Check carefully the social dimension of the pilot measure! 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 quick and good results in a short term perspective? | |
| 6 | Check, if equal access (e.g. gender sensitivity and gender equality) is assured, and that pilot measures are not discriminatory e.g. for minorities. | |
| 7 | Check, if the pilot measure ensures ownership by its intended users, but 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 elements of it. There is the necessity of updating 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 weak parts 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 Northwest Armenia. Main income sources of the about 600 households are livestock keeping – mainly cattle and sheep - and the cultivation of potatoes and cereals. Precipitation is about 500 mm on average per year and distributed not proportionally (long drought period). Most sites around the village experience soil erosion mainly caused by the trampling and grazing of livestock.

For demonstrating different measures against soil erosion, one heavily degraded site of about 16 hectares 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 2 kilometres southeast of the village in an altitude of 2.100 – 2.134 m a.s.l.

### WHAT –Implemented pilot measures

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

### WHY – Erosion phenomena & causes

- High grazing pressure on pasture area
- Loss of upper soil layer due to water erosion (initial stage)
- Low pasture quality due to 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

### WHERE

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


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

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

## Methodology

### *Site selection & preparation*

In 2014, a socio-economic assessment was conducted covering 14 villages within the pre-selected pilot provinces Aragatson and Shirak. In Shirak province, Saralanj was identified as one pilot community for implementing afforestation measures for combating the existing soil erosion. The willingness and interest of community representatives served as 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 very much affect daily business (e.g. fencing should not hamper cattle movement)

The selected site southeast of the community Saralanj is strongly 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 climatic conditions – low precipitation and location on 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*

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

About one year after having started with the preparative work (socio-economic assessment, selection of pilot village and pilot sites), the afforestation activities in the community Saralanj started in autumn 2015.
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 from birch, oak and pine (table 1) were obtained from Hrazdan nursery, belonging to Hayantar State Forest Enterprise.
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 in a distance of 2,5 m eased the process (fig. 4).

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

| Species | Latin name | Number planted in 2015 | Number planted in 2016 | Number planted in 2017 |
|---|---|---|---|---|
| Birch | *Betula litwinowii* | 10.000 | 500 | 500 |
| Pine | *Pinus sylvestris var. hamata* | 10.000 | 4,500 | 5500 |
| Oak | *Quercus macranthera* | 6.000 | 1,500 | 1500 |
| Mountain ash | *Sorbus aucuparia* | | 1,000 | |
| Elm | *Ulmus pinnato-ramosa Dieck.* | | 500 | 500 |
| Siberian pea shrub | *Caragana arborescens* | | 1,000 | 1000 |
| Seabuckthorn | *Hippophae rhamnoides* | | 1,500 | 1500 |
| Ash | | | | 1000 |
| **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). For irrigating the seedlings, a pipeline above the afforestation area was used. An irrigation channel with plastic pipes was installed, which then was connected to rubber tubes.

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

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

Community members were paid as an incentive to contribute to the afforestation activity. They were involved into planting as well as the subsequent irrigation of the seedlings.

### *Needed resources*

The table below gives an overview of 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 coming to the practical implementation, some arrangements and adjustments were undertaken. For example, the distance between planting rows was reduced to be 2 m. The distance between seedlings was often much closer than the foreseen 0,75-1 m. 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 was material as well as Labour intensive. 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 responsibility for care taking activities. The mayor recruited 2 employees responsible for mulching and irrigation of the afforestation plots. The community also contributed in 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 of the practical implementation from the foreseen concept emphasizes how valuable a continuous documentation is, to evaluate the pilot activities and to derive lessons learnt. Careful documentation should comprise: Description of implementation process (time, involved stakeholder, disturbances, reasons for deviating from concept), final planting scheme, planted species, costs, Labour and time, 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: By his own initiative, the mayor of Saralanj community achieved the legal basis for establishing a community forest land. The process of changing the land category (from pasture to forest land) is usually very long and complicated. This experience will be important to share with other communities.
- The territorial reform process is perceived as a risk factor in the community: in spring 2018 Saralanj is supposed to be merged into the Artik cluster. Certainly, there will be changes in responsibilities, but possibly also new opportunities. GIZ IBiS will actively seek cooperation with the new leaders of enlarged municipalities and lobby for continuation/ extension of erosion control activities.

# Showcase 2:

## Afforestation of eroded pasture land, Nahapetavan community

### Description

The community of Nahapetavan is located in Shirak marz in Northwest of Armenia. As it is a neighbouring village of Saralanj (showcase 1), the general characteristics are quite similar. Main income sources of the about 1.250 households are livestock keeping – mainly cattle and sheep - and the cultivation of potatoes and cereals. Precipitation is about 500 mm on average per year. Most sites around the village experience soil erosion mainly caused by the trampling and overgrazing of livestock.

Nahapetavan has been 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 the total area of 9,7 ha in close distance to Nahapetavan community have been selected for afforestation activities. The pilot sitesare located on a slope (7,5°-15°) about 0,7 - 1,5 kilometres southeast of the village in an altitude of 2.035 – 2.150 m a.s.l.

### WHAT –Implemented pilot measures

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

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

### WHY – Erosion phenomena & causes

- Moderate to high grazing pressure on pasture area
- Off-road driving across the pasture land
- Low pasture quality due to 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

### WHERE

- Nahapetavan in Shirak marz, Armenia
- Pilot sites: 9.7hectares at degraded slope
- Village pasture on community-owned land

## Methodology

### *Site selection &preparation*

Based on recommendations of the marzpetaran (regional governmental body) and 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 strongly 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 implementation.

### *Implementation*

While preparatory works started in spring 2017, implementation of measures was done in autumn of the same year. The following working 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)
  - ✓ Upper plot: planting in lines. Trenches prepared by tractor.
  - ✓ Middle and lower plot: group planting, using single plant holes
- Planting: Bare-rooted seedlings (mainly from ATP nursery in Margahovit) of the following species were chosen: pine, oak, ash, apple. 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: Established barb wire fence at upper plot in Nahapetavan

**Piloting different afforestation approaches in Nahapetavan**

Following the pilot character of the project, different approaches with regard to fence type and planting schemes were tested. Important conclusions and recommendations for possible replication are expected after the first years of implementation.

Table 1: Tree species and number of seedlings planted

| Species | Latin name | Number planted in 2017 |
|---|---|---|
| Pine | *Pinus sylvestris var. hamata* | 7700 |
| Oak | *Quercus macranthera* | 4050 |
| Raspberry | *Rubus idaeus L.* | 2500 |
| Siberian pea shrub | *Caragana arborescens* | 1000 |
| Seabuckthorn | *Hippophae rhamnoides* | 1000 |
| Apple | *Malus orientalis* | 4000 |
| Ash | *Fraxinus excelsior* | 4000 |
| **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 for all 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 is passing through the second and third plot serves as a source for irrigation water. The installation of pipes will be implemented by the community when it is needed.

Fig. 4: Seedlings prepared for planting (left). Community members get to know a new planting scheme: group plantation (right).

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

Fig. 5: Mulching machine prepares mulch from sanitary cutting residues (left). Tree seedling with applied mulch (right).

## 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 though barb wire fence was used.
- *Barb wire fence:* Concrete posts are difficult to stabilize in stony ground. Barb wire (lowest line) needs to ensure that sheep/goats cannot enter the site.
- *Road crossing through the site is a risk factor:* If 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 from infected trees of the same species (e.g. pine), it can spread diseases over 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 large seedlings need to be observed in the coming year.
- *Impact/effectiveness:* As measures were only implemented recently, it is too early to have concluding results and impact measurements.

## Perspective

- Low-cost approach: the comparably cost-efficient fencing technique and the reduced 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 fall when summer pastures are not used. The carrying capacity is regularly exceeded and pastures are more and more degrading. Indicators of the degradation process are the high density. Starting from 2016, GIZ 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 were established. Accompanying measures comprised temporary electric fencing and application of hay mulch. Major advantages of these measures: they are not expensive as 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

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).

### WHY – Erosion phenomena & causes

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

### 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 at steep degraded slope
- Village pasture on community-owned land

## Methodology

### Planning & preparation

**Main planning & preparation steps:**

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

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 from grazing, electric fencing was chosen. Within the fenced area, a minimum of 38 pile walls should be established in the washed-out rills along the slope to address the water erosion phenomena. Hay mulch application 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 temporary exclusion, the planting of shrubs and trees was not desired.

Regarding needed resources, the community would 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 realized in autumn (September and October) 2016.

### *Implementation*

The selected pilot site measures about 50 m x 30 m. The construction work was implemented together with community members in November 2017. The following working steps were done:

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

1. Preparation of electric fencing (putting wooden corner posts)
2. Construction of pile walls and terracing
   - ✓ Set wooden logs on appropriate positions
   - ✓ Fix 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 the electric fence to protect the site from grazing

The wooden logs were cut to 1-2 m 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 70-100 cm length. The distance between the pile walls varied between 1-3 m, 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.

Filling up the space behind the logs with soil, plant material and rocks was done to stabilize the construction and reduce the risk of water washing out the soil and passing below the logs. In a last step, the terraces were covered with hay to provide protection against precipitation and to accelerate regrowth 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 needed resources – material and labour – for implementing working steps 1 – 4 on 0,15 ha[1]:

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

## Evaluation & lessons learnt

- ***Participatory site selection:*** Areas which require 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*** 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. As bio-degradable nets (e.g. jute-nets) are not available, other solutions for coverage need to be considered.
- ***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.

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

- ***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. This has the following implications:
        - ➢ Wood used for bioengineering measures could be removed by residents for other purposes ->use pine which 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 1 $m^2$ of open soil, 2 $m^2$ 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 determination of the exact location of the logs.
- ***Effectiveness & stability*** of pile walls can be increased by vegetative material. Further, it is important to take care that there is proper filling behind (terracing) in order to avoid underwashing.
- ***Short-term impact:*** Results are already visible after one year

Fig. 5: Vegetation development inside 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 strengthen local awareness and inform the community about the purpose of the bioengineering measure, necessary materials and their costs. Practical "on-the-job" training (participatory implementation) will enable land users to replicate the measure on other eroded areas. Low-cost bioengineering measures are very appropriate to tackle 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 its effects on vegetation and soil; through the ongoing erosion, some parts already became inaccesible.

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

Starting from 2017, GIZ 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

### WHY – Erosion phenomena & causes

- Heavy use by passing livestock
- Destruction of cattle track
- Progressive gully erosion
- Loss of soil cover due to water erosion
- Loss of adjacent pastures due to gully erosion

### 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

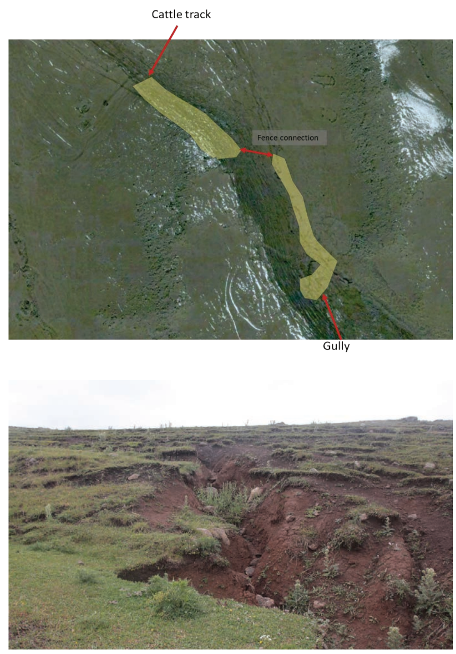



Fig. 1: Map and photo of the gully before treatment.

## 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 above ground connection.

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). The idea of using one solar panel for the 2 sites (approx. 200 m distance) emerged. A technical solution was found: by having an above-ground wire between the 2 sites (fig. 2).

In order to give involved community people a basic understanding of the foreseen gully rehabilitation measure, a practical 'on-the-job-training' was organized initially. The main questions were clarified, such as why, how and when different working steps 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 contains sufficient moisture.

First of all, flattening of gully edges was conducted, as well as collection of stones from the gully site (fig. 3). Then the wooden logs were placed at the determined locations for construction of palisades and fixed with irons. The palisades were constructed using stones at the lower side, and willow cuttings, filled up with soil at the upper side (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 |
| Irons (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 irons from community to gully site | 1 hour / 3 workers |
| Fastening of wooden logs | 1 hour / 2 workers |
| Collection of stones from 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

- Creative solution to use one electric fencing kit for 2 sites
- Willow cuttings should also be planted at the edges of the gully to prevent out washing
- Always start working on the upper section and work your way down to the bottom
- Choose the correct planting and cutting season for wooden parts
- In areas above 2.000 m a.s.l. the use of woody 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 small gullies (less than 1.5m deep and 5m wide), gully plugging can be considered a low-cost technique: mainly locally available materials are 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 obtained results and spread them among communities.

# Module 8: Factsheets

## Factsheet 1: Erosion assessment

### General information

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.

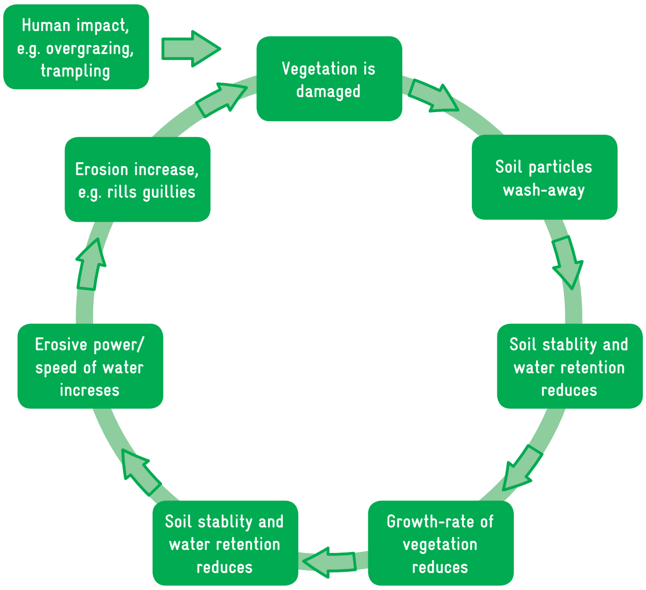



Fig. 1: The self-accelerating process of erosion underlines the importance of early intervention.

### 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

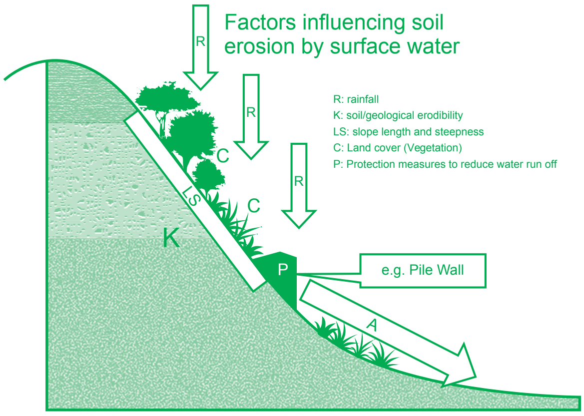



Fig. 2: Factors influencing soil erosion caused by rain and surface run off.

Fig. 3: 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)

## Erosion assessment in the field

| Erosion phenomena | Visual assessment | Appropriate measures |
|---|---|---|
| No erosion<br>> 90 % vegetation cover | <br>Intact vegetation cover. | • No immediate action required<br>• Regular observation, if site has a natural high risk of erosion (e.g. steep slope, heavy rainfalls) |
| Beginning sheet erosion 70-90 % vegetation cover | <br>Reduced vegetation cover with clear signs of erosion. | • Temporary fencing (1-2 years) → vegetation will recover<br>• Reduce grazing intensity → pasture rotation or lower livestock numbers |
| Medium/strong sheet erosion<br>< 70 % vegetation cover | <br>Vegetation reduced to small patches & lots of stones. | • Temporary fencing (1-2 years)<br>• Mulching, sowing of grass of grain seeds, manure application to support rehabilitation of vegetation<br>• Slope > 10°: Horizontal pile walls for water retention<br>• Slope > 30°: Change of land use: hay meadow, forest, no use: |
| Rill erosion | <br>Rills are washed out by superficial water-flow. | • Reduce grazing pressure: Temporary fencing, pasture rotation or reduced livestock numbers<br>• Horizontal pile walls<br>• Mulching, sowing of grass of grain seeds, manure application |
| Gully erosion | <br>Rills are washed out by superficial water-flow. | • Temporary fencing (1-2 years)<br>• Mulching, sowing of grass of grain seeds, manure application<br>• Horizontal pile walls<br>• Check dams (if settlements or infrastructure is endangered) |

# Factsheet 2: Tree planting

## General information

The planting of trees 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, they give stability to the soil and their crown cover and foliage reduces the erosive power of heavy rainfalls and wind. Thereby trees can contribute to a productivity increase of agricultural land and pastures and may protect villages or other human infrastructure from damages through 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 (see module 4+5). The appropriate seasons for tree planting is either spring or autumn.

## Needed material & resources

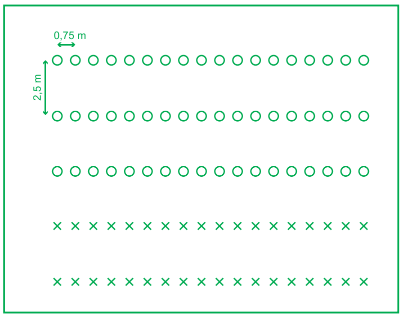
**Needed resources for 1 ha afforestation:**

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

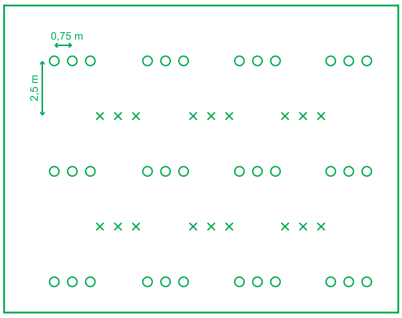
- Tree seedlings: Preferably local species adapted to site conditions.
- Hole driller of spades: Hole driller recommended for larger afforestation activities as it reduces working time substantially.
- Mean of transportation: For seedlings and irrigation water.
- Water: 5-10 l per seedling.
- Labour: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

## Planting scheme

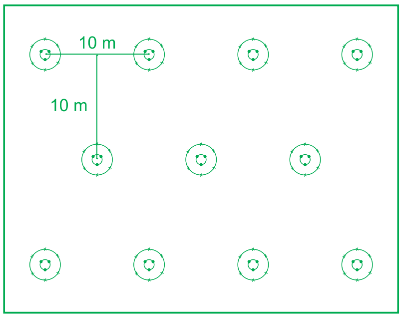
- Afforestation of larger areas
- Select planting scheme according to specific site conditions:



A. Line planting scheme



B. Chess pattern planting scheme

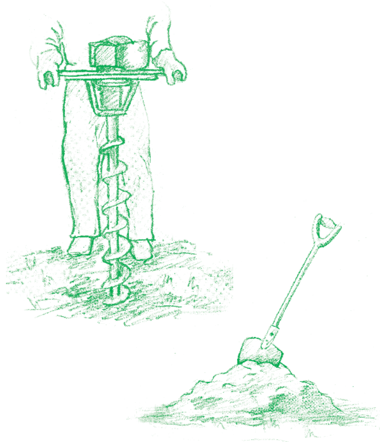
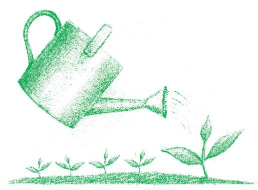


C. Group plantation scheme.

## Preparation of site

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

## Planting

| Working step | Description | |
|---|---|---|
| Transport of seedlings | • Watering of containerized seedlings 24 h before transport<br>• Packaging of bare rooted seedlings in plastic bags<br>• Store seedlings max. 4 days at cool protected place |  |
| Excavate a hole<br>or<br>plough trenches | • Use spade or soil driller for excavating a hole for the seedling<br>• Depth: about 30-40 cm<br>• Diameter: 25 cm<br>• Distance: min. 1 m<br><br>• Prepare 30 cm deep trenches with a single-plough<br>• Distance of rows: 2 m<br>• Application: larger afforestation sites if not too stony or too steep |  |
| Planting | • Place seedling 5-10 cm lower than surrounding area<br>• Keep some space between roots and the ground<br>• Fill the hole up with soil and slightly press it down |  |
| Watering | • Apply 5-10 l of water to each seedling immediately after planting |  |
| Mulching | • Cover the ground around the seedlings with organic material for reducing need of irrigation and weed control |  |

## Maintenance

- Irrigate young seedlings at least 2-4 times per year with 5-10 l each (within first 2 years).
- Protect the area from wild fires, e.g. by preparing fire protection trenches around the site.
- Remove too high vegetation, e.g. mow grass 1-2 times per year.
- Annual renewal of mulch layer (after harvest of hay 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 material and supporting the rehabilitation of vegetation. A typical site for such construction would be a steep slope with scarce vegetation or bare soil, where superficial water run-off together with the impact of grazing animals cause a high risk of rockfalls and/or landslides. Settlements or road infrastructure may be seriously endangered, if located below such an erosive site.

Pile walls slow down the superficial water run-off and support the accumulation of organic material and soil. Thus, they are supposed to stop rocks and stones moved by grazing cattle or erosion processes. By forming small terraces behind the logs and planting tree cuttings, the slope can be additionally stabilized.

## Needed material & resources

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

**Needed resources for 1 pile wall**

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

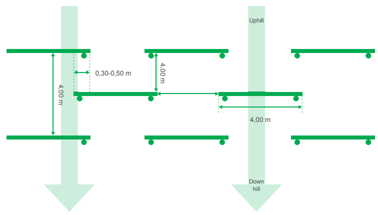
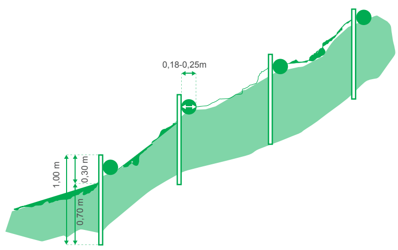
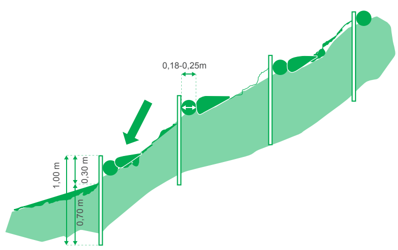
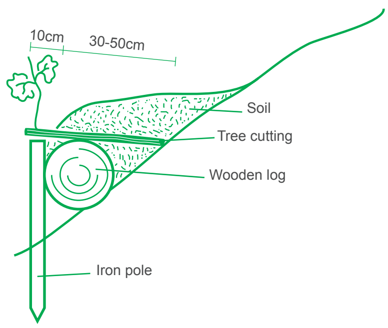
- Iron piles: 70-100 cm length, approx. 2 cm diameter
- Wooden logs: 2-4 m, 20-25 cm diameter,
- Tree cuttings (5 pieces/m, 40-50 cm long, 2 cm diameter, from narrow leaved willow or hazel)
- Labour (2 persons construct 4 pile walls/hour)
- Optional: tree seedlings, hay mulch
- Fencing material (mesh wire or electric fence)

Besides tree cuttings, tree seedlings can be planted on the small terraces formed by the pile walls. Optional is also the application of hay mulch (cut grass or straw) on very degraded areas of the slope with open soil. To prevent the hay mulch from being carried away by wind, coconut nets may be spread on top.

## Preparation of the site

The establishment of a fence is useful to protect the area from trampling and grazing and will enhance the rehabilitation of the vegetation cover. The fence can be either a permanent (mesh-wire) or a temporary construction (electric fencing). However, the fence should remain until sprouts from tree cuttings grow up to 1.3 m height to withstand the grazing pressure from livestock.

## Construction

| Working step | Description |
|---|---|
| Choose appropriate position and length of pile walls | • Scattered, off-set distribution along the slope<br>• On uneven ground, place them predominantly in the depressions with the main vertical water flow<br>• If needed, shorten logs to fit them into depressions<br>• The steeper the slope, the lesser the vertical distance (1-3 m)<br> |
| Fixing logs with iron poles | • Hammer 2 iron poles at both sides of the log (30 cm distance to endings) into the ground<br>• Fix logs behind the 2 poles<br> |
| Terracing | • Water should not be able to pass below the wooden log! -> use large stones to close holes below the log<br>• Fill the space behind the log with soil and plant material (= forming small terraces)<br> |
| Planting tree cuttings | • Place tree cuttings with a slight upwards position on/into the soil of the terrace<br>• Distance between cuttings: 20 cm<br>• Cover the cuttings with soil, so that only 10 cm show out, about 30-50 cm are covered with soil<br>• Attention with the right orientation of cuttings -> check growing direction!<br> |

## Optional measures

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

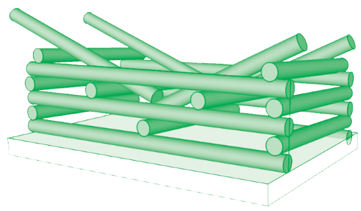
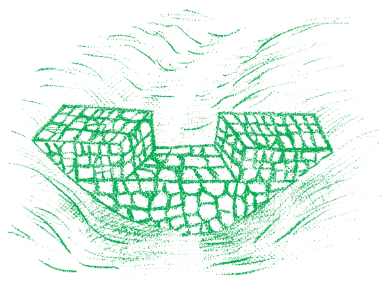
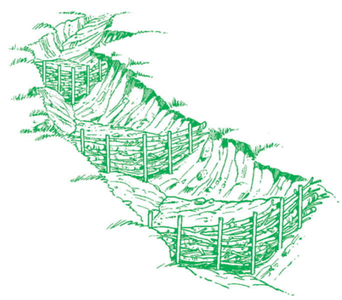
# Factsheet 4: Gully plugging

## General information

Down streaming water has a strong erosive power, being able to 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 small structures built across a gully or channel to prevent it from deepening further. For small gullies (not deeper than 1,50 m and less than 5 m wide) the water velocity can be reduced significantly with relatively little efforts. Depending on the available material, 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 material

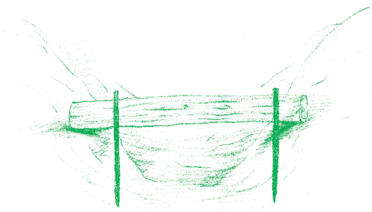
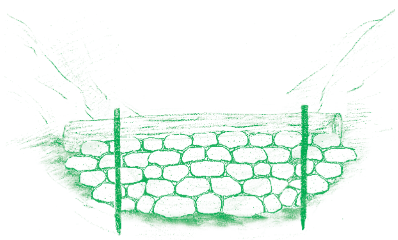
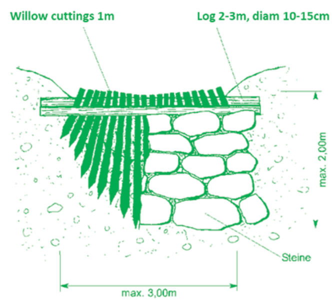
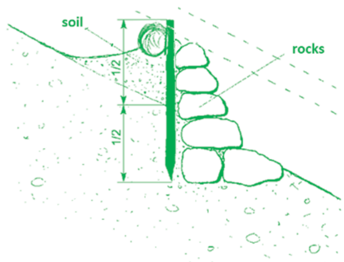
Depending on the topography of the eroded site (e.g. depth and width of gully) and the available material, check dams can be constructed in different ways. In the following, three examples are presented. Be aware, that every situation may require its own improvised approach!

| Type of construction | Used material | |
|---|---|---|
| Option 1:<br>Wooden check dam | • Wooden logs<br>• Living branches<br>• Stones & soil |  |
| Option 2:<br>Gabion check dam | • Large stones<br>• Mesh wire fence<br>• Thin iron piles |  |
| Option 3:<br>Palisade/ wattle fence | • Cuttings of rapidly rooting branches, including:<br>• Stakes (100cm long, 4-6cm diameter), sharpened at the bottom<br>• Wooden logs or cuttings of long and flexible material (>60cm long, 2-3cm diameter) |  |

## Construction of a palisade check dam

### Material for 1 unit:

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

| Working step | Description | |
|---|---|---|
| Fix wooden log | • Select appropriate position for the log: transverse to the gully, blocking the complete gully width, about 20-50 cm above the gully bottom<br>• Fix the wooden log with 2 iron piles (60-90 cm long)<br>• Wooden log should be burrowed into the side walls of the gully |  |
| Reinforce with rocks | • Pile up large rocks and stones on the front (downhill) section of the construction |  |
| Establish palisade with living branches | • Put tree cuttings in a row behind the wooden log slightly into the soil (uphill-side)<br>• Distance: approx. 5 cm between cuttings |  |
| Cover branches with soil | • Fill up the space hind the wooden log with soil (min. 50 cm high)<br>• Cuttings should show out max. 10 cm |  |

### Optional measures

- Flatten the surrounding gully shoulders to support re-vegetation
- Plant cuttings/seedlings on the shoulders and cover additionally with grass

# Fact sheet 5: Electric fencing

## General information

Electric fence systems are a useful tool 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 usually 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, mulching or sawing, or for flexible pasture rotation systems.

## Needed material

- Energizer (P3800, P2500, P1500), including metal box (fig. 1) and 1-3 earth stakes
- Solar panel (40 W, 25W, 15W), including rechargeable battery (12 V)
- Metal wire (2-4 times of total fence length, fig. 2)
- Wooden posts (4 for each corner + 2 for the gate)
- Fiber or plastic posts (amount: fence length divided by 5)
- Gate(s)
- Isolation rings for wooden posts
- Fence Tester (Volt measure)

Fig. 1: PATURA 3800 multi-function energizer for 230 V/12 V, including box and stake for maximum fence lengths up to 25 km (multiple wires)

## Selection of the appropriate system

Energizer and solar panels for electric fence systems exist in different power levels. Planned fence length and the intensity of vegetation determine the selection. The correct connection of the energizer with the fence wire and the earth stakes is depicted on the figure below.

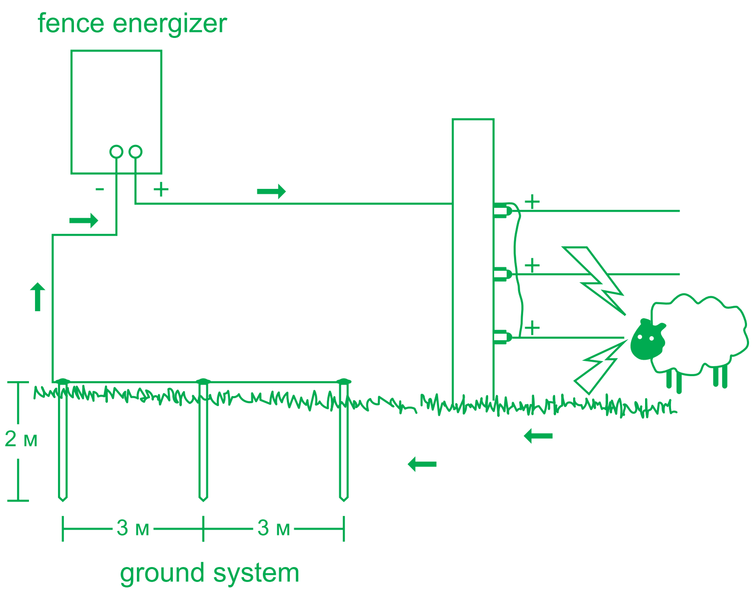



Fig. 2: Overview of an electric fencing system. (source: http://www.jdmop.com/ZWxlY3RyaWMgZmVuY2Ugd2lyaW5nIGRpYWdyYW0g/)

**Specification for fence system:**

**Sheep:**

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

**Cattle:**

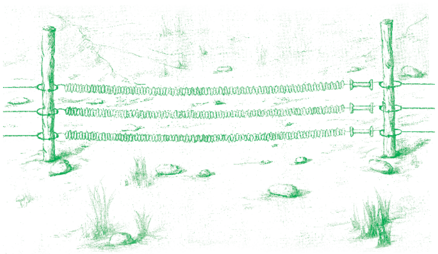
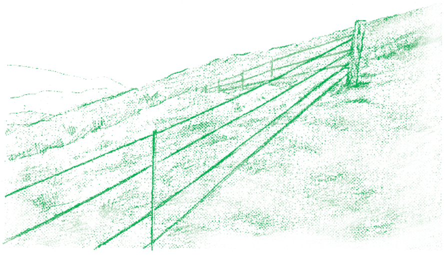
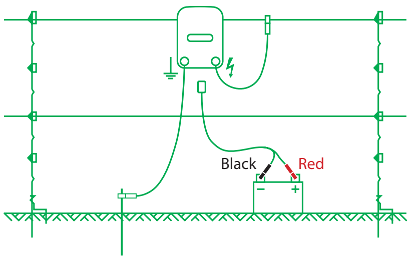
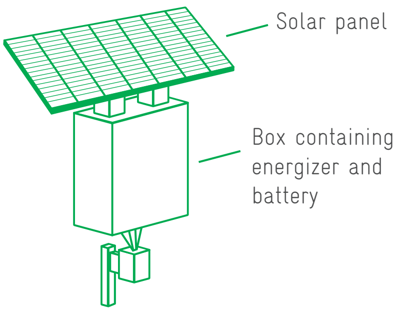
- 3 wires, heights: 30, 60, 90 cm.
- Or: 2 wires; heights: 45, 90 cm.

**Sheep and cattle:**

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

Fig. 3: Number and height of fence wires for different livestock types.

## Set-up of an electric fence

| Working step | Description | |
|---|---|---|
| Installation of wooden posts | • Set-up 4 wooden posts at the corners of the preselected area<br>• Select position of gate (3-5 m width)<br>• Install 2 wooden posts for the gate |  |
| Install upper wire | • Attach 2-4 electrically isolated rings at each post on correct heights<br>• Install upper wire at 90 cm above the ground |  |
| Set-up fiber/ plastic posts | • Set-up fiber or plastic posts along the straight line of the upper wire<br>• Distance: 5 m to each other<br>• Install all lines of wire at corner and plastic posts |  |
| Establish electric system | • Connect energizer to 1-3 earth-stakes (green cable)<br>• Connect battery and solar panel<br>• ->+ to + (red to red) and – to – (black to black)<br>• Connect energizer to fence (red cable) & activate energizer by closing the box |  |
| Final check | • Measure voltage at different places of fence (> 4.000 Volt)<br>• Wire: straight with slight tension, no knots or disturbances<br>• Energizer: connected to ground (green) and to fence (red)<br>• Battery: connected correctly with solar panel and energizer |  |

## Maintenance

- Weekly: check wire, energizer, and battery and their correct connection.
- Remove too high vegetation that is touching the wires.
- Winter season: dismount complete system and store it at 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 | Կենսահամակարգ | An ecosystem is a community of all living organisms in a given area (habitat). |
| 6 | Ecosystem services | Կենսահամակարգային 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. of 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.<br><br>Containerized seedlings are produced in special growing containers, usually in nurseries equipped with green houses and irrigation systems. |
| 20 | Soil bioengineering | Բիոինժեներիա<br><br>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.<br><br>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

| N | Scientific name (latin) | English name | Հայերեն անվանումը |
|---|---|---|---|
| 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 |

# Annex 3

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