HANDBOOK ON INTEGRATED EROSION CONTROL

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

First Edition

TBILISI 2019

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Handbook on Integrated Erosion Control.

A Practical Guide for Planning and Implementing

Integrated Erosion Control Measures in Georgia - Tbilisi. Integrated Biodiversity Management, South Caucasus (IBiS)

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This handbook was developed within the frame of the development cooperation programmes, “Integrated Erosion Control” (IEC) and “Integrated Biodiversity Management, South Caucasus” (IBiS) funded by the German Federal Ministry of Economic Cooperation and Development (BMZ) and implemented by GIZ and its partners between 2014 and 2019.

The handbook is based on the experiences from the pilot projects on integrated erosion control in Tusheti, Georgia.

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CONTENT

ACKNOWLEDGEMENTS

This handbook represents the capitalization of knowledge and experiences gained during the development cooperation programmes, “Integrated Erosion Control in Mountainous Regions of the South Caucasus” (IEC) and “Integrated Biodiversity Management, South Caucasus” (IBiS), which were implemented by GIZ and its partners between 2014 and 2019, funded by the German Federal Ministry for Economic Cooperation and Development (BMZ).

Many people directly or indirectly contributed to the project and the preparation of the handbook.

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1. PROJECT BACKGROUND

1.1. Background and objective of the handbook

This handbook was developed within the frame of the development cooperation programmes, “Integrated Erosion Control Project” (IEC) and “Integrated Biodiversity Management, South Caucasus” (IBiS), based on the experiences from the pilot projects on integrated erosion control between 2014 and 2019. It includes showcases from the pilot region, covering two communities in Tusheti, Georgia ***(Figure 1).***

The handbook reflects on the planning and implementation processes of erosion control measures that were designed and tested in Georgia and the South Caucasus and may serve as an example for other areas.

It is designed as a training manual for multipliers, such as:

- Training and education institutions
- Local, national, regional NGOs
- Government agencies with a mandate for erosion control measures (e.g., agricultural extension services, administrations and staff of protected areas)

The different **Modules** of the handbook intend to give guidance on designing suitable training courses related to raising awareness on soil erosion and implementation of soil 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.

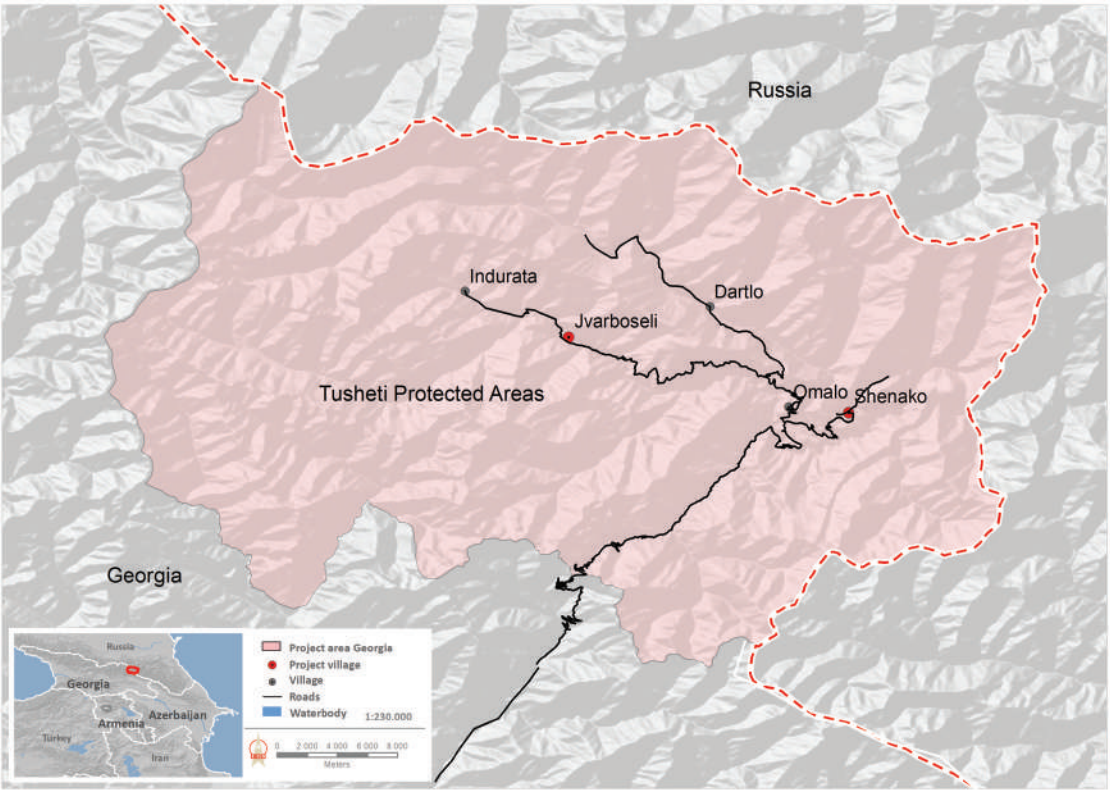


Figure 1: *Pilot region of IEC measures, Georgia (Shenako and Jvarboseli)*

WHY THIS HANDBOOK?

- → It raises awareness on soil erosion processes in Georgia and ways to mitigate their negative effects.
- → It supports capacity building by providing technical background information and didactical explanations for training institutions or NGOs working with land users.
- → It presents showcases that serve as containers for lessons learned collected from the pilot area.
- → It contains information on planning, implementation and upscaling of the pilot activities.
- → It provides factsheets for farmers and landowners to foster practical implementation in the field.

1.2. Brief project description

The Integrated Erosion Control Project (IEC) was implemented in Georgia by GIZ and its partners from 2014 – 2017. Apart from the political partners at the national level, the community administrations and the Akhmeta Municipality were important stakeholders. Different Georgian NGOs, such as NACRES - Centre for Biodiversity Conservation & Research and Friends Association of Tusheti Protected Areas (FATPA) were crucial for the implementation.

Until December, 2016, the implementation of the project was outsourced by GIZ to a consortium consisting of three international consulting companies: ECO Consult, E.C.O. and AHT. Starting from January, 2017 and ending in November, 2019, GIZ was directly implementing the IEC component within the IBiS programme.

The expected outputs of the project in the pilot area were:

- → Local maps on soil erosion risks for the pilot communities
- → Afforestation of selected eroded areas for slope stabilization
- → Bioengineering measures implemented for the rehabilitation of the eroded land
- → Enhanced awareness on natural resource management at the local level
- → Capacity building and regional exchange on integrated erosion control measures
- → Strengthening institutional, legal and policy frameworks
- → Documenting all pilot measures in a practical IEC handbook

1.3. Principles and approaches

GIZ aimed at improved management of natural resources in the country, following an advisory approach applying three key principles:

- → Partner orientation: IBiS was guided by the visions and needs of its partners. Selected relevant processes for better conservation of biodiversity and ecosystem services were jointly screened in the annual operational planning. All IEC measures in Tusheti were planned and implemented in a highly participatory manner.
- → Sustainability: To ensure long-term impact beyond the programme's lifetime, IBiS spent considerable effort on institutionalising joint results through policies, legislation or curricula. Networking with other organizations (e.g. NACRES or FATPA) helped to upscale and replicate successful pilot measures and approaches.
- → Capacity development: IBiS aimed at improving the capacities of its partners. Classical trainings, institutionalized education programmes, but also learning by doing through grants to local NGOs along with international backstopping contributed to the development priorities of partners.

By integrating stakeholders from different levels (local, regional, national), as well as from different sectors (forestry, agriculture, nature protection), IBiS intended to mainstream biodiversity and natural resource management in a sustainable and holistic way.

2. WHAT IS EROSION?

2.1. The global challenge of land degradation

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

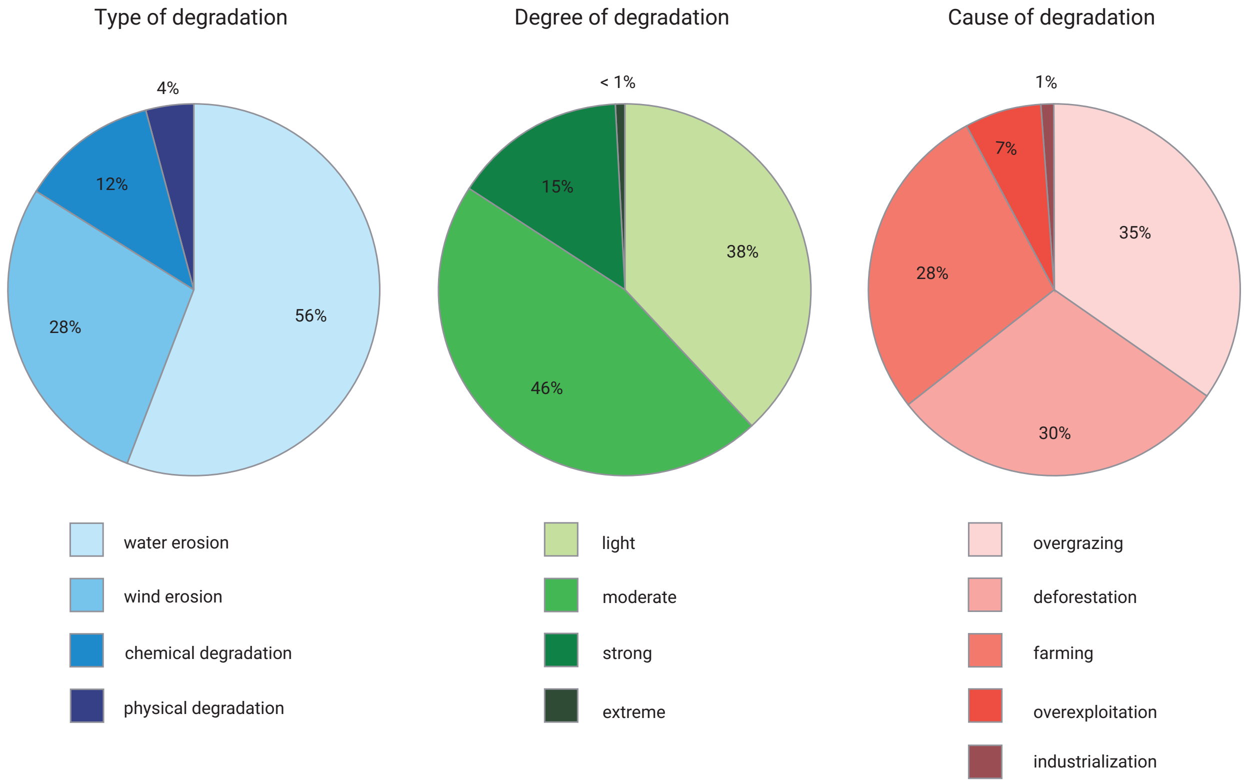


Figure 2: *Types, degree and causes of global land degradation (Gruver, 2013)*

The continuous global degradation of soils and land threatens our food security, livelihoods and the functioning of ecosystem services. The main causes of degradation are linked with unsustainable land-use practices, such as overgrazing, deforestation, and unsustainable agriculture. The result are soils without a protective vegetation cover that are highly susceptible to wind and water erosion. Some statistics can be found in ***Figure 2.***

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

2.2. Soil erosion

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

2.2.2 Causes & influencing factors

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

In the mountainous regions of the South Caucasus, water has the highest potential to cause erosion. Wind erosion occurs as well, but it mainly affects arable lands in the lowland-areas. ***Figure 3*** depicts the main factors that influence soil erosion through superficial water flows.

Rainfall

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

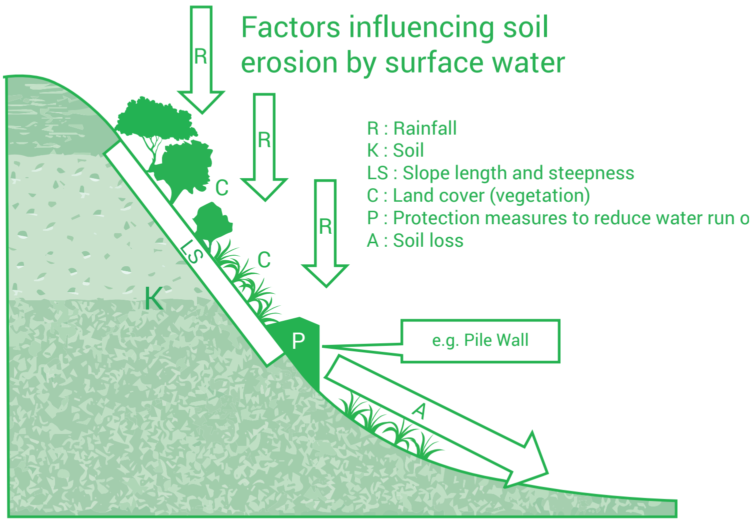


Figure 3: Schematic figure of factors influencing soil erosion caused by rain and surface run off

Geological erodibility

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

Topography

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

Vegetation Cover

If vegetation is scarce or non-existent, there is neither a protective cover reducing the erosive power of heavy rainfalls, nor a root system giving stability to the soil. A soil cover composed of vegetation (e.g., intact grassland, bushes) or mulch reduce the erosion potential.

Protection measures

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

2.2.3 Types of erosion

In order to identify appropriate and effective erosion control measures, it is important to understand the different types of soil erosion ***(Figure 4)*** and recognize them in the field.

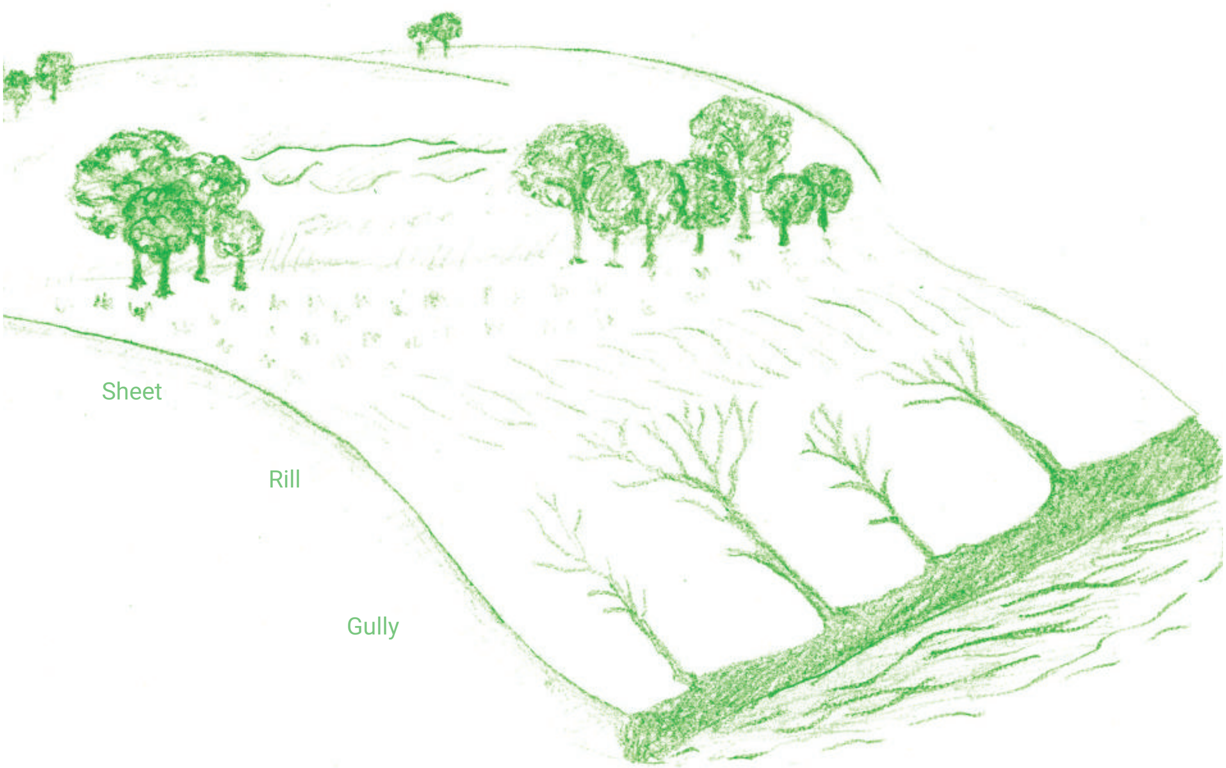


Figure 4: *Types of soil erosion (Source: www.cep.unep.org)*

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

→ Surface/sheet erosion

Sheet erosion is a gradual removal of topsoil in thin layers of the soil surface. It often covers large areas and remains undetected for quite some time, even though it sometimes becomes visible by soil accumulation at the bottom of a slope. It occurs evenly over an area and is caused by a superficial water run-off when soils are saturated after heavy rainfalls. Areas with impermeable or compacted soil layers as well as bare soils have a reduced capacity to uptake or retain water and are, therefore, very much susceptible to sheet erosion. Soil particles are loosened by the erosive power of the raindrops and carried away by the down streaming water.

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

If the process of sheet erosion and steady vegetation damage continue, soil erosion will self-accelerate ***(Figure 5)***: 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 rates and thus to a reduced vegetation cover. The lower the vegetation cover, the less stable the soil, the lower the retention of water leading to higher speeds of superficial water flows. This results in more erosion phenomena such as small channels and rills of 10-30cm depth.

→ Rill erosion

Rainfall, that is not up taken by soil, accumulates on the surface and flows downhill, sometimes forming small channels. Those rills may dry out after the rainfall but will still be visible.

→ Gully erosion

Without erosion control measures, recently formed rills may deepen and grow into larger gullies. This process will accelerate erosion, as more and more surface area will be prone to disturbance. Gully erosion is a highly visible form of soil erosion. It occurs when surface runoff water accumulates and rapidly flows in narrow channels during or immediately after heavy rains or melting snow. This type of erosion removes soil to a considerable depth, often until the underlying rock layer is reached. If water runoff enters from the sides, additional gullies may form.

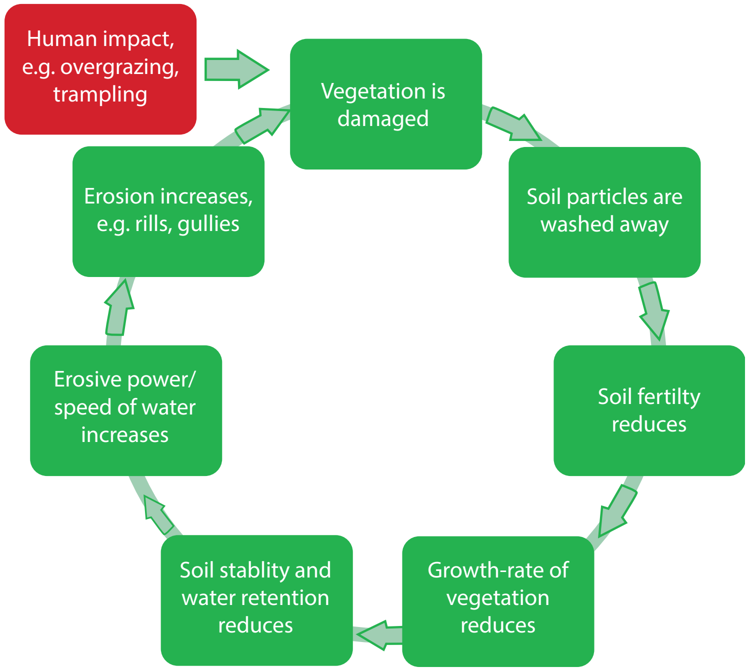


Figure 5: *The self-accelerating process of erosion*

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 permanent rills formed on the surface. Gullies that become continuously larger require attention, if they disturb farming activities or threaten settlements and infrastructure.

2.3. What can be done against erosion?

While measures addressing land degradation can be categorized as avoidance, reduction and reversal of degradation, the term erosion control combines two aspects: preventing and controlling/reducing erosion.

The immediate triggers 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 uncontrollable 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 control of land users and, thus, can be adjusted to avoid or control/reduce erosion.

2.3.1 Prevention

Sites which are yet unaffected by or show few signs of erosion (e.g., accumulation of material on lower parts of a slope) should be subject to preventive measures. An erosion risk assessment will give information on how likely erosion is on that specific site ***(see Module 3)***. Depending on the type of the land use, preventive measures can comprise sustainable pasture management measures (e.g., limiting livestock numbers, introducing a rotational system) or establishment of sustainable agricultural systems (e.g., planting windbreaks, diversifying crop rotation).

2.3.2 Rehabilitation

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

Gully erosion needs to be addressed with the construction of check dams. Such bioengineering activities will most likely be implemented, if the effects of erosion cause 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 analyse 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) remains unchanged, erosion will simply shift to the adjacent piece of land.

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

Table 1: *Erosion prevention versus rehabilitation of eroded land*

2.3.3 Awareness raising

Providing incentives

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

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

As estimated by the Millennium Ecosystem Assessment (2005), about 60 per cent of the earth's ecosystem services are already degraded. According to the recent IPBES report (2019), the degradation is ongoing, largely because of human impact. The costs of this global degradation could amount to US $66 billion per year (IFPRI & ZEF, 2011).

To encourage countries to act, a calculation of costs of action in contrast to that of inaction can be useful. Similar to other environmental phenomena, it is generally much easier and cheaper to prevent erosion than to repair the damages once they have occurred. The correct calculation should use information about the costs related to prevention or mitigation of land degradation (action) versus continued degradation (inaction), considering also the immediate and underlying causes of degradation (IFPRI & ZEF, 2011).

Concrete numbers would be a valuable incentive for decision-makers to start dealing more intensively with the challenge of erosion. Avoidance should always be prioritized over reducing land degradation, and the latter should be prioritized over reversing degradation ***(Figure 6).***

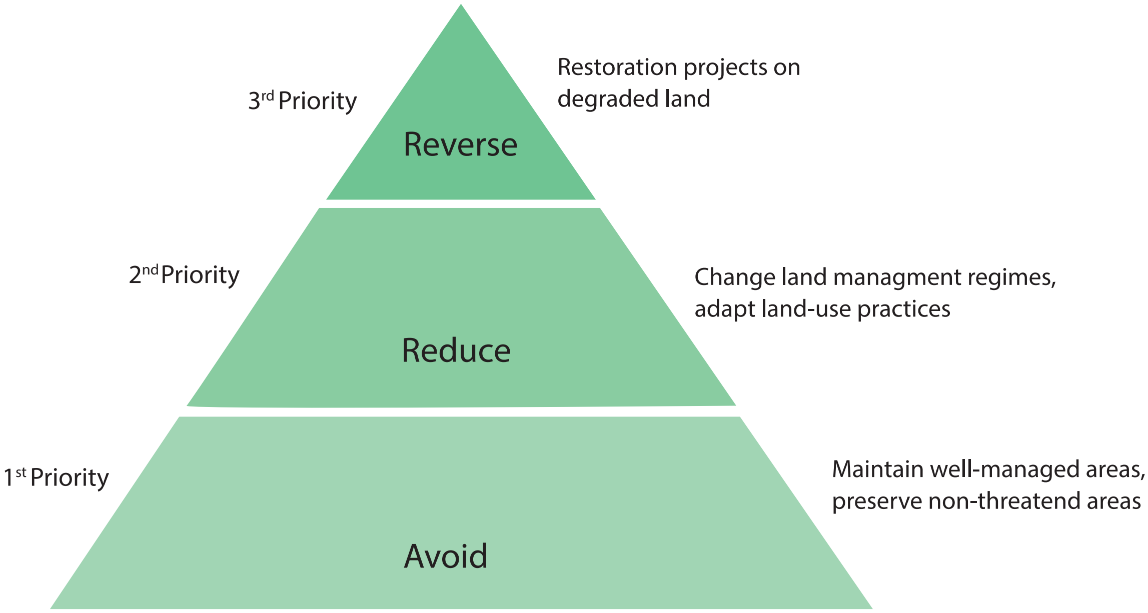


Figure 6: *Priority of measures against land degradation and soil erosion*

1st Priority: Avoid

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

2nd Priority: Reduce

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

3rd Priority: Reverse

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

2.4. Integrated erosion control measures in Tusheti

Any planned erosion prevention measure must consider site-specific conditions. In the pilot regions in Tusheti, the high altitudes, short vegetation period, limited accessibility (May-October), ongoing grazing, as well as the availability of materials (e.g. logs, stones and smaller rocks) are important limiting factors for afforestation and bioengineering. The following IEC measures were successfully applied in the villages of Jvarboseli and Shenako:

2.4.1 Afforestation on community land

Afforestation measures can be applied for both erosion prevention and rehabilitation purposes. In case of the pilot sites in Tusheti, small plots of several hectares were fenced and afforested, mainly as an erosion prevention measure at the head of large gullies.

2.4.2 Soil Bioengineering

The bioengineering measures applied in Tusheti had the purpose to rehabilitate the vegetation cover and to stabilize gullies on steep slopes. Planting, seeding and establishment of pile and crib walls aimed to stop soil erosion and protect threatened villages or roads. The selected sites were small (0.2-1ha) and were protected from grazing animals by an electric fence.

2.4.3 Improvement of pasture management

In the pilot region of Tusheti, unregulated grazing is a major driver for erosion. Thus, the productivity of pastures was analysed to define their carrying capacity, sustainable livestock numbers and appropriate grazing schemes. The information was presented in the so-called pasture passports. A key measure was the introduction of flexible electric fences as a basis for any grazing management.

2.4.4 Data and information availability

It is estimated that already 15 years ago at least 35% of the country's farmland were affected by degradation making soil erosion a priority topic for the Government of Georgia (Government of Georgia, 2002). In mountain areas, a particularly high grazing pressure contributes to land degradation, whereas in lowlands and Eastern Georgia grazing, inappropriate agricultural methods, and climate change accelerate erosion. Nevertheless, only little research was conducted on erosion in Georgia since its independence in 1991. In addition to a significant lack of accurate data on erosion phenomena, their scope and effects for land users, existing data contains contradictions. Hence, in recent years, there were numerous efforts to map and document erosion and land degradation in Georgia, currently continued by the Land Degradation Neutrality Initiative of UNCCD (Huber et al., 2017).

2.4.5 Political and legal framework

Although soil is acknowledged as a precondition for livelihoods, and soil erosion threatens agricultural production, infrastructure and livelihoods, there is yet a low level of awareness on this issue among the population. At the same time, in the past years, soil and land degradation increasingly gained attention of the Government of Georgia facing salinization of soils, degradation of pastures and loss of agricultural land.

The following (strategic) documents address the issue of soil erosion on an abstract/concrete level:

- Law of Georgia “On Conservation of Soils and Reclamation and Improvement of Soil Fertility”, 2003 (with amendments)
- Law of Georgia on “Soil Protection”, May 12, 1994 (with amendments)
- 2nd National Action Programme to Combat Desertification (2014-2022) approved by Resolution of Government of Georgia N742, 29.12.2014 (in accordance with UNCCD’s 10 years strategy)
- LDN Programme
- Agriculture Development Strategy (2015-2020) approved by resolution of Government of Georgia N167, 11.02.2015
- State Programme on “Soil Conservation and Improvement”, approved by Order #2-93 of the Minister of Agriculture of Georgia, 05.05.2014
- “Assessment of Soil fertility and Monitoring of Soil Conservation and Fertility”, rules approved by Resolution of Government of Georgia N415, 31.12.2013
- Recommendations on “Erosion Control Complex Measures” approved by Order #2-277 of the Minister of Agriculture of Georgia, 25.11.2005

Drafts:

- New Draft Law on “Soil Protection” (2019)
- “National indicators of land degradation and methodology of their identification” (2017) to be approved by Resolution of Government of Georgia

3. HOW TO CONTROL EROSION?

The following modules provide information on how to deal with erosion. First, it is necessary to identify erosion, select suitable measures ***(Module 1)***, and then to plan and implement them ***(Module 2-4)***.

3.1. Module 1: Erosion assessment and selection of erosion control measures

3.1.1 General introduction

This chapter is meant to give an orientation for assessing the erosion risk or the gravity of occurring soil erosion for a particular site and to give guidance in elaborating appropriate preventive or rehabilitative measures. Different assessment methods are presented, including remote sensing approaches for assessments on a larger scale and field assessments used on local level.

Why assess erosion?

As soil cannot be restored easily once it is lost, it is of utmost importance to avoid soil loss by erosion whenever possible. The earlier the problem is observed, the easier are the protection measures to be applied. In many mountainous regions of the Caucasus, grazing is an important land-use type. In those areas overgrazing, trampling and driving vehicles are the most common human influences causing soil erosion ***(Figure 7)***.

The systematic assessment of erosion is the basis for the prevention of erosion, as well as for the planning, implementation and monitoring of erosion control measures. It helps to detect critical developments at an early stage - when mitigation measures are still easy and cheap to accomplish - and to identify priority areas for erosion control measures. Particularly, during rehabilitation measures the assessment allows to evaluate the efficiency of the measure (e.g. slow-down or halt of erosion processes; increase of vegetation cover) and supports the detection of further needs for action (e.g. change of approach, adaptation of measure, use of different plant species).

__Figure 7:__ 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)

Overview of different methods and their application

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

For generating information for an area of several square kilometres or even a whole country, remote sensing tools can be used. As a rough benchmark, sites larger than 100km² are assessed by remote sensing yielding spatial data on an approximate scale of 1:25,000. Remote sensing tools are particularly useful to identify regions with emerging erosion problems, to monitor changes in vegetation cover at larger scales and to direct activities and resources towards priority regions.

At the local level, erosion type and gravity, or the risk of erosion can be directly assessed in the field. Thus, precise information can be collected on a scale of 1:1,000 up to 1:10,000, which is useful for planning concrete erosion control or prevention measures, for example, on the community level.

3.1.2 Field assessment

In the field, the stage of erosion can be assessed by estimating the vegetation cover or by other visible signs of erosion, such as the occurrence and gravity of rills and gullies. Further information can be obtained in the pasture monitoring manual (Etzold, 2013) and the related BioTopic on assessing soil erosion risk (Etzold et al., 2019). The field assessment method described in this chapter is based on the observation of erosion signs and potential causes. It aims at understanding the influencing factors for planning appropriate erosion control measures.

Figure 8: Degradation of slopes caused by cattle

Sheet Erosion Assessment and Selection of Measures

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

Three levels of sheet erosion are differentiated:

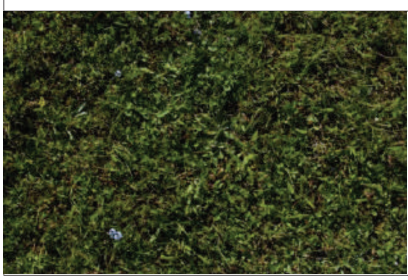
> 90% vegetation cover = no erosion, the vegetation protects the upper soil layer	30% - 90% vegetation cover = clear signs of erosion, soil particles are detached and moved	< 30% vegetation cover = severe erosion, upper soil layer is exposed to the erosive power of wind and water
		

Table 2: Different levels of vegetation cover and resulting sheet erosion

Early sheet erosion can be easily tackled by making use of the self-rehabilitation potential of the vegetation and eliminating the causes of the vegetation damage (mostly certain land-use practices such as overgrazing or trampling). Stopping further degradation of land and the self-accelerating process of erosion can be achieved at this stage, for example, by temporary fencing of the area until the vegetation has recovered or by reducing the grazing intensity. In the case of medium to strong sheet erosion additional vegetation rehabilitation measures (e.g. mulching or sowing of grass seeds), simple technical measures (e.g. pile walls) or temporary exclusion from grazing are necessary.

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

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

Figure 9: *Medium-strong sheet erosion*

The more severe the erosion process is, the larger are the loose stones on the surface. While the fine material is washed away, the loose stones are left on the soil surface between the vegetation patches. ***Figure 9*** gives an example of a site with accumulated stones and a vegetation cover of <30%.

Rill erosion assessment and selection of measures

Small rills and channels collect surface water and are usually oriented in the direction of the slope ***(Figure 10)***. Sometimes, the development of rills is enhanced by the trampling of cattle, which may lead to rills with other orientations. The concentration of surface water in the rills accelerates the erosive power of the water. If no active measure is taken to stop the accumulated flow of surface water, the rills will grow into larger gullies ***(Figure 11)***. At this stage, numerous measures are available such as construction of pile walls, control of grazing (temporary fencing or less grazing pressure) and support of the rehabilitation of vegetation through mulching, application of grass seeds or organic fertilizer.

Figure 10: *Rill erosion caused by overgrazing*

Gully erosion

The formation of gullies is often triggered by rill erosion or disturbances such as trampling caused by cattle. The cheapest and best way to tackle gully erosion is prevention. Appropriate measures to stop the dynamic of gully erosion relate to different types of construction of horizontal barriers to slow down the water flow in the gully (e.g. palisades or check dams). Observation and assessment of gully dynamics are critical particularly if settlements or infrastructure is threatened. Usually, the cost-of-action exceed the costs-of-inaction on the short-term (damage to infrastructure and houses) and on the long term (loss of pastures or arable land).

3.1.3 Remote sensing methods

Relevance & preconditions

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

- a supportive legal framework[1]
- an organizational infrastructure
- human capacities (at local administrations, municipalities, extension services etc.)
- access to technology
- financial resources

Figure 11: *Gully erosion*

Technological approach & use

Remote sensing can help to assess the current erosion level and erosion risk ***(Figure 12)***. The methodology of remote sensing is proposed to prepare maps indicating areas affected by erosion. This information will help to develop strategies to adapt land use to control erosion and to monitor erosion processes over time. The time series could be used to monitor changes in erosion. On the one hand, the success of erosion control measures can be monitored on a national level. On the other hand, new eroded sites or increase of spatial cover of erosion can help to prioritize activities. Consequently, developing and implementing a remote sensing technology to produce maps with spatial information on erosion risks (the potential of soil loss) can support the monitoring of changes in erosion risks.

Satellite images provide actual information on vegetation cover by analysing different spectral bands of the images (red, near-infrared). Climatic data and maps on precipitation give the amount of rainfall for specific regions and digital elevation models can provide information on the degree of inclination and the length of slopes. Based on these data, computer models can identify sites that are sensitive to erosion. The so-called “Soil Erosion Risk Model” developed by experts from the Caucasus region with the support of GIZ is one of available tools to produce erosion risk maps (Mikeladze & Nikolaeva, 2016).

The advantages of applying remote sensing 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 the resulting data can be processed using a PC and then combined with other geographic layers in a GIS. However, resulting maps are not direct samples of the phenomenon: 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. Therefore, the maps must be calibrated against reality through some sort of ground-truthing.

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[1] *All spatial information derived from remote sensing needs to be in line with the official Georgian National Spatial Data Infrastructure (NSDI), which is currently under development.*

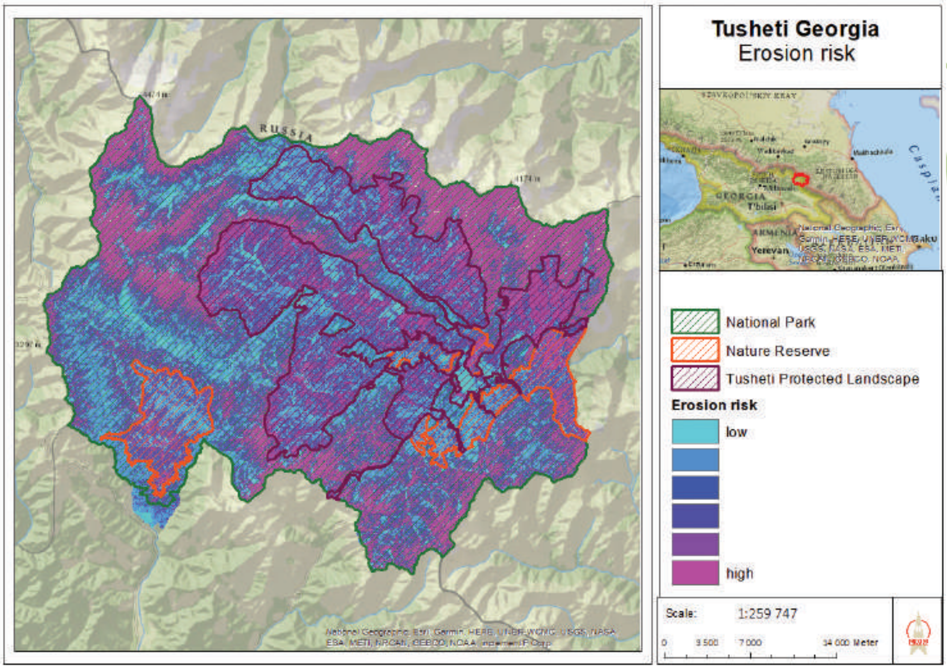


Figure 12: Erosion risk map of the pilot region derived from satellite imagery

3.1.4 Suitable control measures

Table 3 provides an overview of preventive and rehabilitative measures to control soil erosion:

TYPE OF EROSION	POTENTIAL MEASURES	LINK TO HANDBOOK CHAPTERS
Early sheet erosion	• Temporary fencing (1-2 years) • Reduce grazing pressure less animals shorter grazing periods -> pasture rotation	• Module 2 • Showcase 2 • Factsheet 5
Medium/strong sheet erosion	• Temporary fencing (1-2 years) • Mulching • Seeding • Fertilizing • Horizontal pile walls	• Module 2 • Showcase 1 • Showcase 2 • Factsheet 2 • Factsheet 3 • Factsheet 5
Rill erosion	• Control of grazing temporary fencing less grazing pressure • Support the rehabilitation of vegetation mulching application of seeds or fertilize • Palisade construction	• Module 2 • Module 3 • Module 4 • Showcase 1 • Showcase 2 • Factsheet 2 • Factsheet 4 • Factsheet 5
Gully erosion	• Temporary fencing (1-2 years) • Mulching • Seeding • Fertilizing • Check dam construction • Palisade construction	• Module 2 • Module 3 • Showcase1 • Showcase2 • Factsheet4 • Factsheet5

Table 3: Overview on preventive and rehabilitative measures to control erosion

3.2. Module 2: Pasture management

Livestock breeding plays an important role in agro-economy and food security. In Georgia, about 1 million cattle, 900,000 sheep and 60,000 goats are born annually (Geostat, 2016). Livestock breeding contributes significantly to food production. About 530 thousand tons of milk are produced annually by cows and buffalos and 9 thousand tons by sheep and goats. Meat production is about 21.5 thousand tons for cows and 4.6 thousand tons for sheep and goats.

However, the National Biodiversity Strategy and Action Plan (NBSAP) of Georgia, 2014 – 2020 (Decree N343, 2014) states several challenges linked with unsustainable livestock grazing:

- "Over-grazing by livestock (cattle, sheep, goats and pigs) poses a serious threat to Georgia's forests. In certain locations — especially around human settlements and on summer and winter pastures — excessive numbers of livestock result in non-sustainable grazing in nearby forests.
- The root-causes for overgrazing include rural poverty and a lack of alternative livelihood opportunities; insufficient funding and support for the sector; and limited awareness among shepherds and livestock owners that hampers the adoption and implementation of more sustainable and efficient practices.
- Overgrazing in the forests causes the compaction of soil, which in turn can cause erosion and a decline in the forest's natural regeneration capability. All of this often leads to irreversible processes."

In the same document (p41-42) it is stated that overgrazing and degradation of natural grasslands are mainly linked to the following factors:

- lack of an institutional and legal framework for the sustainable use of common pastures
- lack of knowledge among livestock farmers
- many pastures were privatised or leased out without adequate planning and a targeted approach
- no control mechanisms of pasture management.

3.2.1 Ownership and legal background

Smallholders and family farms contribute significantly to Georgia's production of agricultural products. More than three-quarters of the country's holdings cultivate agricultural land of less than 1ha.

The structure of land ownership has changed in recent decades. During the Soviet era until 1991, there was no private land ownership in Georgia. After the collapse of the Soviet Union, the land was in the hands of the Georgian state and a privatisation process was initiated. The homestead lots (1.25ha) that mainly contained arable land were made available to almost every citizen (Raaflaub & Dobry, 2015). Privatisation of pastures was not intensive and stopped in 2008. So up to now, most of the pastureland in Georgia is still state-owned. Svanadze (2015) gives a comprehensive overview of the legal situation of the pastureland, the strategic goals, the national goals, as well the objectives and actions for managing pastures. According to his analysis, the issues of pastures is not regulated by specific Georgian legislation. The National Public Registry defines pastures as one of the possible categories that can be addressed to a land plot, but a clear definition of pastureland by law is lacking.

The process of pasture privatisation or transfer of ownership from state to self-government units has changed in jurisdiction several times in the last two decades. The NBSAP also addresses the lack of a clear legal and institutional framework for the sustainable use of common pastureland.

Neither privatisation nor leasing procedures took care of the knowledge and experience of the new owner or tenant in pasture management, which, together with the lack of management regulations and responsible institutions, leads to inefficient use of pastures, local overgrazing and degradation.

The NBSAP formulated a strategic approach in the context of the legal framework of pasture management: "The legal and institutional framework needs to be improved to facilitate the conservation of agricultural ecosystems and natural grasslands as well as to minimise environmental pollution from agriculture."

In the current situation, the state is still legally the owner of large amounts of pastureland, but de facto the municipalities decide on its use. While construction sites and arable land were already properly registered, most of the pastureland remain unregistered.

Certain mountain pastures are often used informally by local farmers or as summer pastures of transhumant shepherds, without paying tax or leases. The process of registering and establishing a coherent lease and tax system is ongoing. The introduction of tax or lease payment on pastureland, which was used free of charge until now, will certainly lead to resistance from land users. It must be demonstrated that the new regulation also benefits land users by ensuring long-term land use rights or the improvement of infrastructure (e.g. road access, water availability etc) by the entity receiving the tax/lease.

3.2.2 Current state of pasture management

Compared to perennial or annual crop production, livestock breeding on (common) pastureland is a low investment activity. While livestock breeding in the lowlands is a side activity to other, more economically attractive agricultural activities or activities in other sectors, livestock herding in the mountain regions is, alongside tourism, one of the major economic activities and closely linked to cultural heritage, social identity and traditions.

Raaflaub & Dobry (2015) categorise Georgia's pasture and haymaking practice as follows, based on the results of the interviews:

- village pastures
- pastures outside villages including mountain pastures
- hayfields

The **village pastures** are common lands around the settlements which are used by the local farmers of the village. Sometimes the pastures are separated from the arable fields by (natural) fences and the cattle graze without control over the village pastures, in other cases shepherds take care of the herds. Only in rare cases is the pasture irrigated. Usually there is a lack of maintenance measures such as weed control or the clearing of shrubs and tree seedlings that invade the pastures.

The **pastures outside the villages** are usually part of a transhuman grazing system. This complex traditional system is described in more detail in the next paragraphs. While in the Soviet era the pastureland of summer and winter pastures was regulated according to delineated pastures (with pasture "numbers"), currently a self-regulating grazing approach can be observed. The shepherds lead their livestock to the most suitable grazing areas and organise the spatial allocation of the land plots themselves informally. Traditional grazing territories for certain villages or families exist in some regions but are rarely documented.

The most limiting season to livestock breeding is wintertime when the climate conditions (cold, dry) give only limited access to free-range grazing. To overcome this season, hay is an important source of fodder. **Hay production** is mainly done by the individual farmers on private land. Hay production in 2016 amounted to about 55 thousand tons on an area of 15 thousand hectares. 90% of the hay is produced on perennial hay fields and 10% as cash crops on arable land (annual grassland). The total area of hayfields slightly increased over the years. The average yield is 3.6-4.7 tons/ha. The yield is mainly limited by precipitation and soil moisture. Hay cutting usually takes place at a very late stage, which leads to a decline in nutritional values. While the total biomass increases during the season, the net energy content for milk production (MJ/kg dry biomass) decreases. The optimal time of hay cutting is in the phase between the development of the pre-bud and the bud of grass (late boot - grasses) and the beginning of the flowering period (first flower) of the legumes. ***Figure 13*** illustrates the degree of ripeness at harvest to maximize the yield of digestible dry matter for legumes and grasses.

Apart from the lack of adequate machinery, farmers rely on stable, dry weather for several weeks. This usually leads to a late harvest in summer or autumn and low nutritional value of the hay.

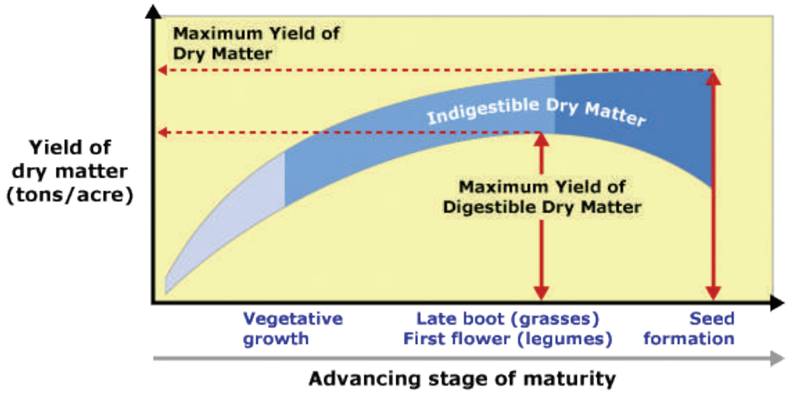


Figure 13: *Degree of ripeness at harvest. Source: https://courses.ecampus.oregonstate.edu/ans312/four/forage_nutrition_trans.htm*

3.2.3 The tragedy of the commons

The term "tragedy of the commons" was introduced to the scientific community in 1968 by G. Hardin in the Science Journal. Hardin explained in his article that free public access to a common property leads to its ruin. He referred to the overfishing of the sea and an old example of pasture management in Britain (documented already in the 19th century). However, later empirical evidences presented by E. Ostrom and colleagues (1999) pointed out that Hardin actually described the tragedy of an unregulated access to common property. According to Ostrom communities can avoid overexploitation of common resources through the regulated number of livestock and their spatial distribution, as well as the times of grazing periods. These regulations usually need a common perception and acceptance by the land users, regulation of the access using fences, and some means of monitoring and penalising of infringement.

In the past, most grazing communities of Georgia developed their local or regional regulation system to avoid overgrazing and soil productivity degradation. However, the immense changes in social structures, traditional regulations and land use forms during the Soviet era for about 70 years led to the replacement of traditional regulations of the land-use systems. After the collapse of the Soviet regulation system, access to common pastureland was largely unregulated. Although the number of livestock fell (e.g. sheep population from 2 million to 0.9 million, Raaflaub & Dobry, 2015, Geostat, 2016), the unregulated access to common pastures led to overgrazing and erosion on some locations. Especially grazing areas close to the villages or farms are exposed to a higher risk of overgrazing, as those areas are more frequently assessed than the remote pasture lands.

3.2.4 Transhumant grazing systems

The term transhumance describes the seasonal movement of people with their livestock between summer and winter pastures, or between different pastures according to other climatic imperatives (Raaflaub & Dobry, 2015).

In Georgia, transhumant grazing systems are still common. While the livestock grazes in the high mountain summer pastures in the Greater and Lesser Caucasus, the winter pastures are located in the semi-arid step-ecosystems in the lowlands of East Georgia. Migration routes of 100-400km length connect the summer and winter pastures. The two most important sheep breeds (Tushuri-sheep – semi-fat-tailed-sheep breed and the Imeruli sheep) are well adapted to these long migration routes.

> **Definition: Transhumance (Raaflaub & Dobry, 2015)**
>
> The term transhumance describes the seasonal movement of people with their livestock between summer and winter pastures, or between different pastures according to other climatic imperatives.

In the 21st century, the transhumant system in Georgia faces several challenges. Conditions along migration routes are deteriorating: access to drinking water for animals is no longer being maintained, former public land is being sold to private individuals and access by migratory shepherds is limited, conflicts with the local population and their interests are increasing, the risk of pests and infections is increasing, be it through limited vaccinations or new obstacles on motorways (Edward Hamer LTD, 2014).

The challenges for traditional transhumant livestock breeding are not limited to the Caucasus but are typical for many mountain areas of the world. In the Alps, the more than 50km long transhumance system disappeared almost completely in the first half of the 20th century. In the Pyrenees and in the Carpathians some last long-distance migration routes are still used, but they need public support. Additionally, it is difficult to find farmers willing to continue the old practice. Along the migration routes, the farmers and residents in the villages show a lower acceptance for the animals that cross their (private) possessions, block roads and leave excrement residues on their way. The shepherds face a life outside a permanent homestead, living 2-6 months without a family and a broader (real) social network. It is a livelihood concept outside the modern standards of 40h per week and without sharing evenings and weekends with family and friends.

Also in Tusheti, land-use practices have changed considerably in recent centuries. The situation in the village of Shenako is used to demonstrate the development over the last centuries ***(Figure 14)***. Until the beginning of the 20th century, the permanent settlement was in the villages up in Tusheti. The land use at that time was a combination of sheep and cattle breeding, hay production, crop and vegetable growing near the villages. Although the villages were situated at an altitude of 1800-2300m above sea level, barley or potatoes were grown, apple and plum trees were planted. While the main part of the cattle remained in the mountain villages in winter and had to be fed with hay, which was harvested during the summer, the flocks of sheep migrated in winter to the pastures in the lowlands (Vashlovani region). Villagers report that during that time the very steep and dry southern slope near the villages was used for hay and grain production and not as pasture (as it is used today).

In the Soviet times, the Tush population was resettled (mainly in the period of 1950-1970) in newly created settlements in the lowlands (Alvani). Their complex traditional land use of pastures, hay meadows, and arable land was replaced by pure sheep breeding. In addition to lamb-meat and milk production, wool was an important by-product of fabric production ("felt"). The entire

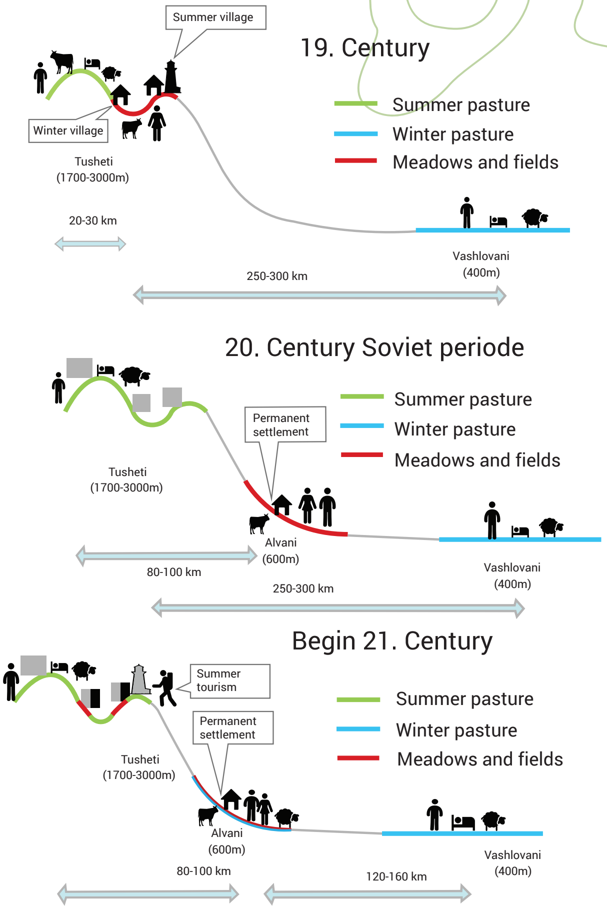


Figure 14: *Change in land use practice in Shenako from the 19th to 21st Century (own scheme)*

territory of Tusheti was organised in about 160 pasture units ("numbers"), sized approximately 600ha on average. Only the Tusheti Strict Nature Reserve was excluded. The units included the grassland, former arable land, village areas, forests and shrublands as well as rock and boulders above the grassland.

After the Soviet era, land use changed again, due to designation of Tusheti Protected Areas (comprised with different categories). Tourism, and mixture of sheep and cattle breeding developed. However, grazing is not applied in a traditional or regulated form, leading locally to overgrazing and erosion, especially of steep pastures near villages.

Tourism opened up new income opportunities for local stakeholders. The experience in the Alps showed that mountain pastures were more likely to be maintained if additional income from tourism was generated (Drapela et al., 2000). Additional income by tourism can help to improve road infrastructure and housing and opens new market options for shepherds and farmers to sell their products to guest-houses or tourists. This can help to create a better income with lower numbers of livestock. Degraded pastures with signs of erosion are unattractive to tourists. This can lead to a higher awareness of erosion problems by the local communities and a common interest to avoid erosion to present an attractive country sided.

3.2.5 Management approaches to grazing

Holechek et al. (2011) summarised the grazing strategies in dry areas into 3 approaches:

1. continuous grazing
2. rotational grazing
3. centripetal grazing

Continuous grazing is the most common strategy found in Georgia. The livestock grazes on the same large pasture for the whole season.

Advantages: Since no fence infrastructure is required, no investment is needed. No shepherd is needed on many communal village pastures. If the pastures are more remote, a shepherd is responsible for leading the livestock from the village to the pasture.

Disadvantages: Since the grazing area is unlimited, the livestock will select areas with better fodder quality and avoid unfavourable plants. This leads to a positive selection of unfavourable plants (weeds). If access to water is unregulated, the areas around the water are often overgrazed and trampled and suffer from erosion.

Rotation pastures systems operate with several pasture units divided by fences. While one pasture unit (paddock) is used, the grasses and herbs can grow back on the other paddocks. As a large number of livestock graze a relatively small pasture unit, the grazing pressure at the end of the grazing period is very high and even non-preferred plants such as thistles are searched by the cattle. After this intensive grazing, the paddock is left without pasture for a few weeks (4-6) to regenerate before being grazed again.

The rotational pasture system has two advantages:

1. During the rehabilitation phase of 4-6 weeks, much more biomass can grow back than on permanently grazed pastures.
2. A high grazing intensity in a short period of time leads to the cleaning of unfavourable herbs and grasses so that less maintenance is required for humans. This can lead to higher productivity (fattening, milk production) as shown by Chen & Shi, 2018.

But rotational pastures also require additional investments and workload:

1. Fences must be bought, built and managed.
2. Drinking water must be provided for each paddock.
3. A farmer/shepherd is needed to bring the cattle out of the fenced paddock every morning and evening.

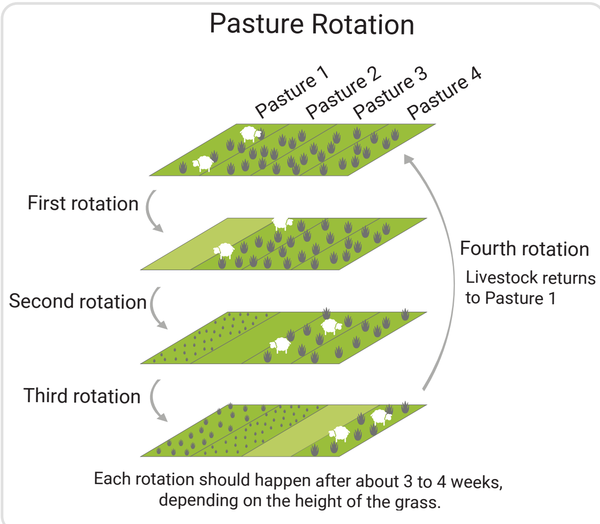


Figure 15: *Pasture Rotation*

The rotational pasture system has advantages in heterogeneous pastures where different habitats require different grazing approaches (e.g. different optimal grazing time, sensitivity to trampling…). It works better in humid areas where grass can regrow throughout the season.

In the **centripetal grazing strategy** (Holechek et al., 2011), grazing is started in drier pastures at a greater distance from water sources during the rainy season and approaches more humid grasslands near water when the weather becomes drier. It is assumed that the livestock will live in better conditions during the rainy season and will be able to walk greater distances to water facilities and that the fodder quality in the wetter parts of pastures will be available longer in the season than in dry areas.

Advantages: The fodder availability between drier and wetter parts of the pastureland will be used more efficiently during the season and trampling damage and overgrazing at the water facilities will be avoided.

Disadvantages: Shepherds or fences are needed to regulate access to the different parts of the pastureland.

In a long-term study (2018-2017) in tallgrass prairie in the USA, Zhou et al. (2019) have shown that rotational pasture systems under variable climate conditions have improved grassland productivity and higher stocking capacities than continuous grazing systems. The rotational paddock system also enabled more effective adaptive grazing management (by adapting stocking density and grazing season/time) to changing climatic conditions.

Given the heterogeneous landscape in the mountainous summer pastures with steep and dry southern slopes along the valleys and wetter grasslands at the bottom of the valleys, rotational pasture systems in Georgia could be an effective pasture strategy for village pastures. In remote areas, continuous grazing with shepherd control seems to be the preferred approach to avoid areas of high erosion risk (steep slopes with rare vegetation cover). On dry winter pastures, the concept of centripetal grazing could be a favourable concept.

3.3. Module 3: Bioengineering measures

3.3.1 General introduction

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

Definition: Soil Bioengineering (Polster, 2002)

"Soil bioengineering is the use of living plant materials to construct structures that perform some engineering function. These "living engineering systems" make use of locally available materials and are often used to increase surface stability and to combat erosion problems."

Bioengineering uses materials, which are found in nature and combines them with technical building materials. Examples are small retaining pile walls on slopes to stop stones and soil from moving down, or gully breaks to slow down the velocity of water movement ***(Figure 16)***.

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

__Figure 16:__ Gully breaks (Polster, 2003)

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

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

Technical Functions

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

Ecological functions

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

3.3.2 Fields of application & natural limits

Bioengineering methods can be applied wherever the plants, which are used as a 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 degraded slopes, cattle tracks, and gullies - erosion phenomena frequently occurring in the mountainous areas of the Southern Caucasus.

Gullies

Degraded slopes

Figure 17: *Frequent soil degradation and erosion phenomena in the South Caucasus that can be addressed with bioengineering*

3.3.3 Selection of bioengineering sites and appropriate measures

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

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

Erosion frequently occurs on steep or over-used sites. Consequently, the most common areas where bioengineering is appropriate, are cattle tracks (horizontal paths by livestock trampling), ravines, trenches, gullies with temporary or permanent water flow, overgrazed areas with a visible share of open soil, slopes along roads and trails, riverbanks 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 (work power, materials). Therefore, sites should be selected based on the following criteria:

→ Potential risk to human life or infrastructures (roads, houses, dams) posed by erosion, mudflows, rockfall

→ Risk of an adverse economic impact (e.g., loss of soil/pasture productivity, threatening of livestock, blocking of cattle tracks) resulting from erosion

→ A realistic chance to regenerate. Sites with only 10-20% of vegetation cover left, intense use and high inclination require more effort. Such sites should be handed over to professional companies to work on them

→ Threat to other ecosystem services or long-term perspectives (gradual degradation of pastures)

Once the areas to be treated are identified, appropriate measures need to be selected. This process is determined by:

→ The erosion type,

→ Natural conditions (inclination, precipitation, natural vegetation, temperatures, water availability, wind, elevation),

→ Availability of materials for construction (rocks, logs, branches, etc.) and rehabilitation of vegetation (seeds, hay, grass, cuttings, seedlings, etc.).

Figure 18: *Bundles of branches (fascines) as alternative to wooden logs*

General rule

Have a look around and make use of the materials you have!

For specific erosion phenomena and natural conditions, different measures may be appropriate or could even be combined ***(Table 4).*** Usually at least temporary fencing needs to be ensured, since bioengineering works with living plants and seeds, which need protection from grazing animals.

The availability of materials will influence the final selection of measures. An overview of the most commonly used materials is given in ***Table 5.*** To match existing resources with the envisaged measures and results, creativity and improvisation may be required. For instance, logs used for pile walls can be replaced by bundles (fascines) made of smaller living branches from poplar or willow.

TYPE OF EROSION PROCESS & NATURAL CONDITIONS	BIOENGINEERING OPTIONS
Degraded cattle tracks and paths	Temporary fencing, pile walls, hay/grass mulch, seeding
Overgrazed slopes	Temporary fencing, hay/grass mulch
Rocky, low productive slopes inclined to rockfalls	Temporary fencing, palisades/ check dams, flattening of steep edges, hay/ grass mulch, planting of shrubs
Gullies	Temporary fencing, pile walls, hay/grass mulch, planting of shrubs, check dams

Table 4: *Bioengineering options for different erosion processes and natural conditions*

TYPE OF MATERIAL	DESCRIPTION	USE	LIMITATIONS	AVAILABILITY IN TUSHETI	AVAILABILITY IN GEORGIA
Wooden logs	Diameter: 10-20cm, Length:< 4m	All types of construction, e.g. pile walls, crib walls, check dams	None	Limited	Available
Branches of woody species	Living or dry, 1-3cm diameter	Cuttings for planting, long branches for fascines	Availability of locally adapted species (for arid or cold conditions)	Limited; only willow, rosehip, poplar suitable	Available
Hay or cut grass	Dried or fresh grass (cut after seed development!)	Re-establishment of vegetation on bare soil	None	Available	Available
Straw	Remnants of crop harvest	Mulching	May need coverage in case of strong winds	Available	Available
Manure	1-2 year old manure from cows or sheep	Fertilizing of degraded soils	Fresh manure is not suitable	Available	Available
Seedlings of selected species	Seedlings of willow *(Salix sp.)*, rosehip *(Rosa sp.)*, mountain ash *(Sorbus aucuparia)*, 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) Sainfoin *(Onobrychis sp.)*	Re-establishment of vegetation on bare soil	Availability of adapted species	Extremely limited, alpine species required	Currently not available (exception sainfoin)
Rocks	In mountain areas	For all type of constructions and barriers	None	Abundant	Abundant

Table 5: *Characteristics of the most commonly used materials for bioengineering*

3.3.4 Detailed description of three selected bioengineering measures

Hay or grass mulch application

Field of application

The application of hay or grass mulch is an appropriate method for rehabilitation of extreme locations, such as high altitudes, steep slopes, dry sites. Covering the open soil provides mechanic protection against erosion. Additionally, 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 an 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, use of additional seeds is recommended. Use of local hay is advantageous as it provides a guarantee to have an autochthonous seed mixture, but its disadvantage is that the amount of seeds is variable.

Before application, it is recommended to prepare the soil - remove stones and cut steep edges along gully erosion- to support vegetation establishment. The best time for mulch application is early spring or late autumn. If there are periods with seasonally strong winds, those periods should be avoided, unless additional fixing, e.g., with decomposable nets or small rocks is done (Huber, 2016). ***Figure 19*** provides examples of decomposable coconut-nets ***(left)*** that can be used for protecting hay mulch from being blown away, and of a manure-mulch mixture from composted manure as well as barley straw including seeds ***(right)***. If grain seeds are foreseen to germinate and grow to serve as green manure, the seed-containing mulch should be applied in early spring, so that enough moisture is available for growth before the dry summer season starts.

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

Figure 19: *Decomposable nets to cover hay mulch (left), manure-mulch mixture (right)*

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

Technical description

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

Figure 20: *Examples of pile wall implementation. Establishment of pile walls (left) and coverage with hay mulch (right)*

The distribution scheme and amount of pile walls are based on the degree of inclination and the character of the terrain. To reduce the water velocity, the pile walls should be established offset to each other ***(Figure 20 left and Figure 21 left).*** In case of uneven slopes, the construction should rather be made in the depressions where the main water-flow occurs (***Figure 20 right*** and ***Figure 21 right***).

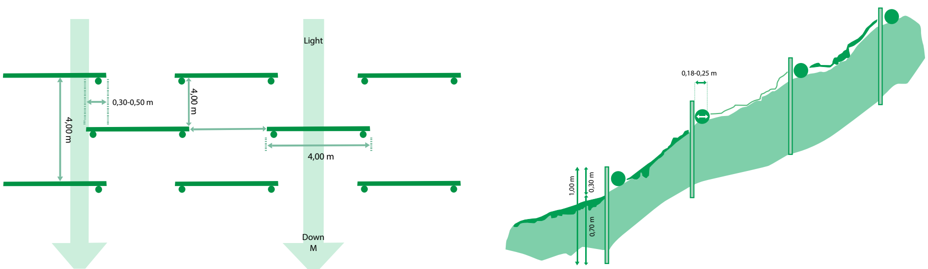


Figure 21: *Scheme of pile wall distribution across the slope. View from above (left) and vertical scheme (right)*

Depending on the available material, the wooden logs can be replaced by bundles of branches (fascines). Wherever possible, vegetated pile walls should be given priority as their roots provide additional stability to the ground. The establishment of pile walls should always be accompanied by some terracing to "optimise" the slope and provide good starting conditions for vegetation regrowth.

Gully plugging with check dams

Field of application

Simple measures such as palisades and planting of shrubs can immediately stop erosion processes of small gullies, usually less than 1.50m deep and 5m wide. Gully plugs, also called check dams, are simple engineering constructions to prevent erosion and to settle sediments in larger gullies. Furthermore, they help to keep soil moisture through an increased water infiltration. Depending on the topography, the amount of precipitation, available materials and financial resources, there are several methods to construct a gully plug out of wood, branches, rocks or a combination of different materials ***(Figure 22).***

Figure 22: *Gully plugs constructed with different materials*

Technical description

Vegetated check dams are used as a transverse structure for bed consolidation and slope stabilization in steep gullies. Double-walled crib walls 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.

Following the same principle, the check dam can also be constructed with gabions (filled rock boxes) or for smaller sections with palisades (vertical wooden branches or logs). The larger the gully, the larger and more complex the required check dam structure.

The construction of check dams is usually accompanied by supporting measures, such as cutting the steep edges of the gully, re-establishment of vegetation on the gully slopes, filling of the gully bottom with rocks or branches or planting of shrubs. The selected combination of measures is defined by the dimension of the gully and whether there is a permanent or periodic flow of water).

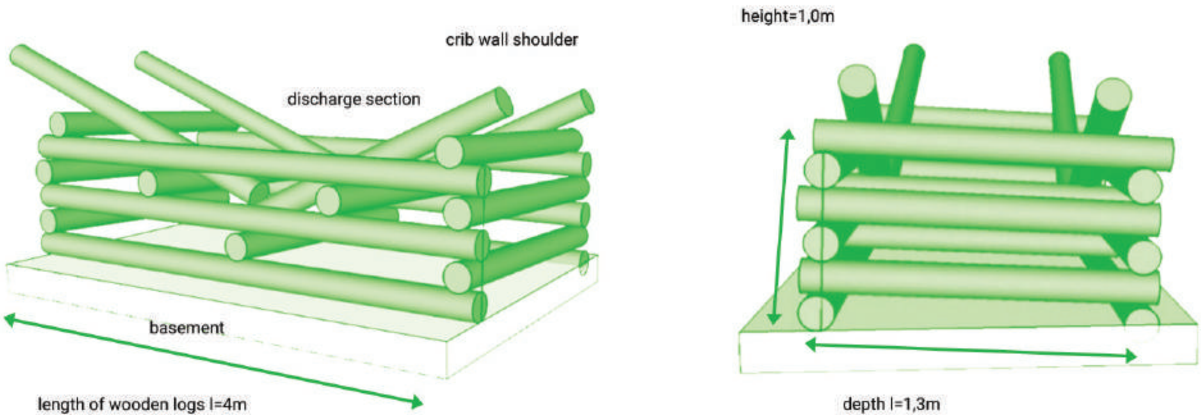


Figure 23: 3D Views of the wooden structure of the vegetated crib wall (Rauch et al., 2016)

Further reading

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

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

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

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

3.4. Module 4: Afforestation

3.4.1 General introduction

Forests are the most successful ecosystems in the world in terms of biomass accumulation and stability. This is true for all sites where climate and soil conditions allow growth of trees. Forests face their ecological limits in places, 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 unsuitable (bogs, fewer nutrients).

In the South Caucasus, two natural limits restrict forest expansion: the upper tree line is visible at 2,300-2,600m.a.s.l., whereas steppe and semi-desert ecosystems form the lower tree line.

> **Definition: Forests (Draft Forest Code of Georgia, 2019)**
>
> Forests are land plots with the minimum width of 10 meters and the minimum area of 0.5 hectare covered with one or several forest forming timber species, where the density of standing trees per area unit is not less than 0.1.

The map of natural vegetation of Europe ***(Figure 24)*** depicts the possible natural vegetation cover in Georgia without human intervention. In the middle of the 6th millennium BC (Hamon, 2009), human intervention started to change and reshape the natural forest cover. Forests were cleared for gaining arable land and pastures. Open landscapes were expanded, especially after a huge forest clearance at the end of the 20th century.

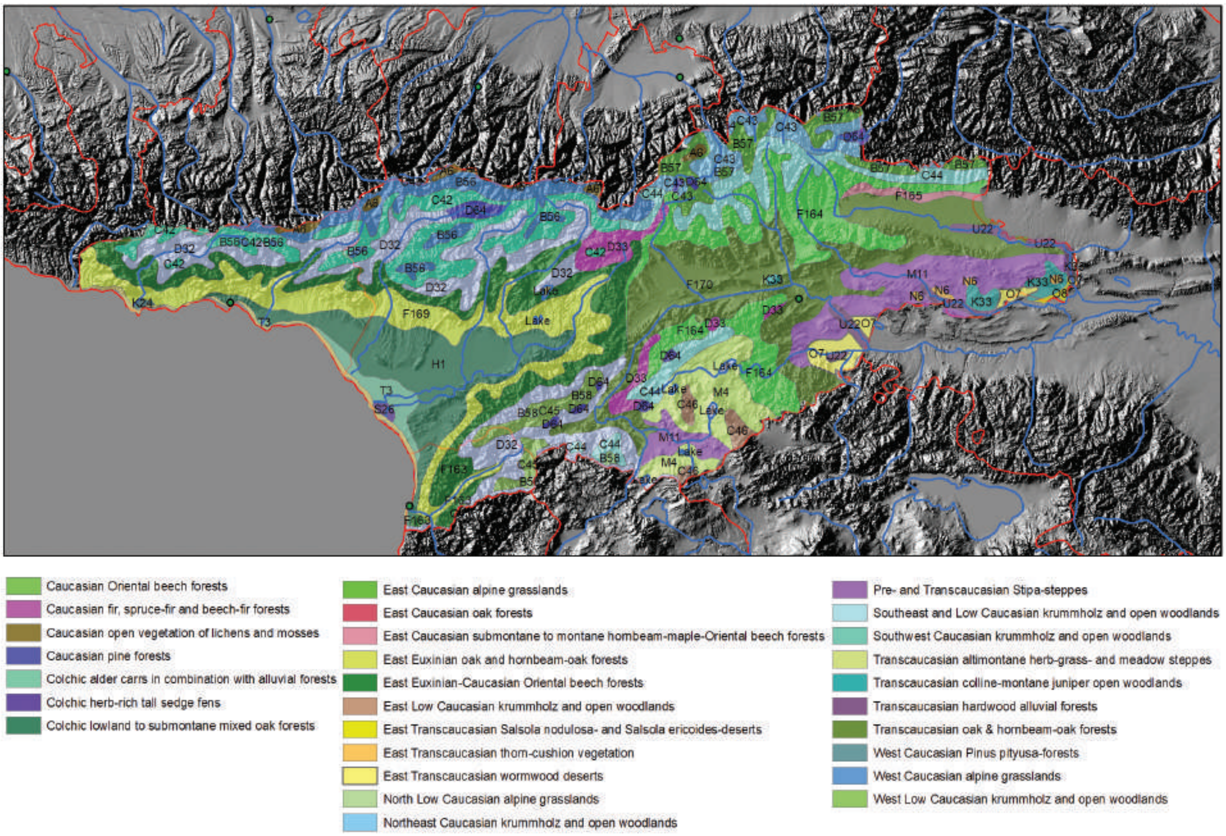


Figure 24: *Potential natural vegetation of Georgia (Bohn et al., 2007)*

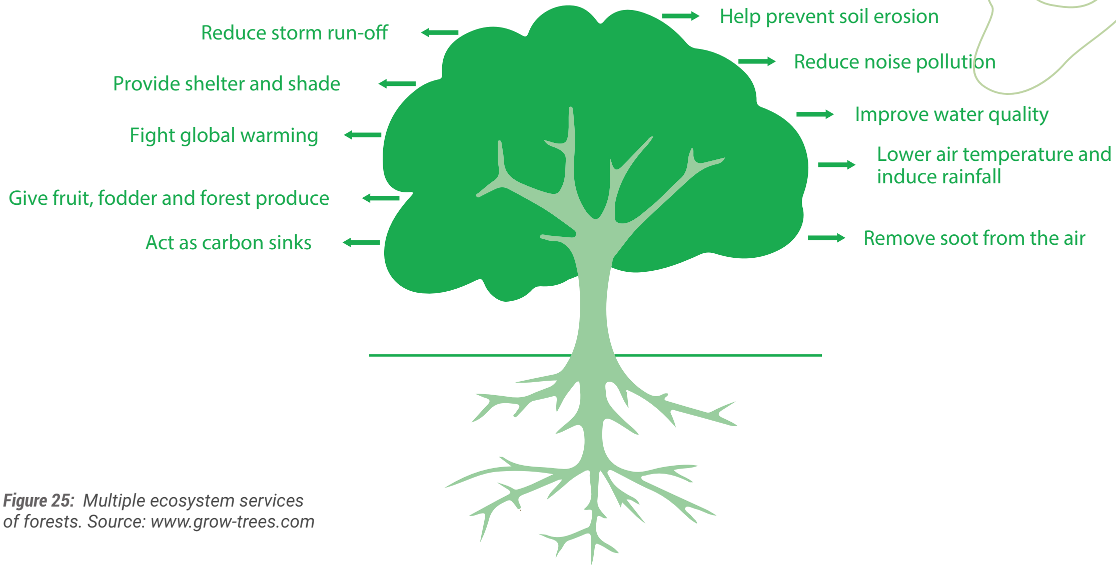


Figure 25: *Multiple ecosystem services of forests. Source: www.grow-trees.com*

Forests form stable ecosystems, which regenerate naturally, persist for long time periods and are resilient to most disturbances. Natural forest ecosystems offer multiple ecosystem services, such as timber and fuelwood provision, water purification, carbon sequestration, recreation, etc. ***(Figure 25).*** In mountainous landscapes, forests have an additional protective function against erosion and natural hazards (e.g., avalanches, landslides, debris flows or rockfalls).

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

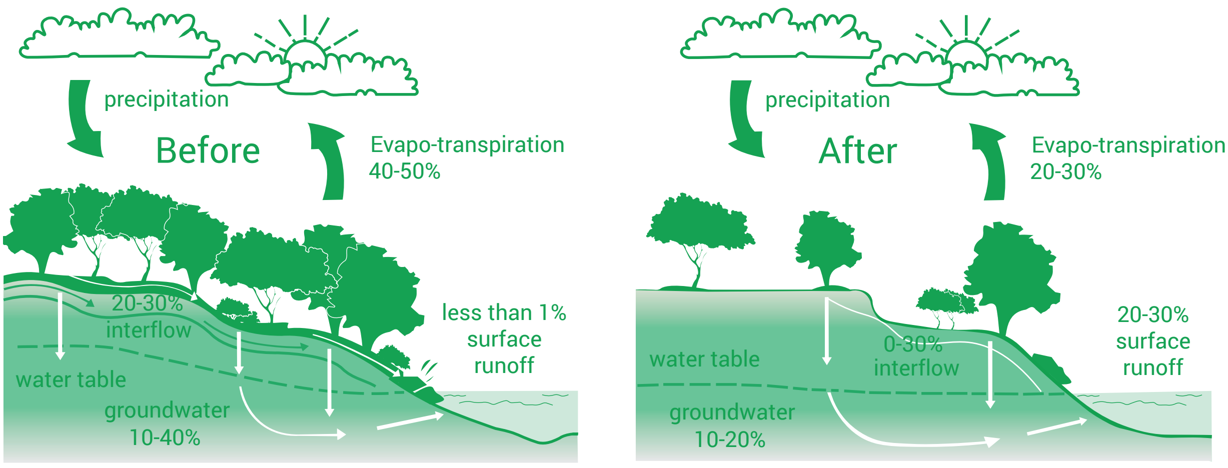


Figure 26: *Water cycle before and after human intervention, Source: http://www.ecy.wa.gov/programs/wq/stormwater/images/runoff_illustration.jpg*

3.4.2 Planning & preparing an afforestation project

In the mountainous areas of the South Caucasus, sites that suffer from erosion and overgrazing can be rehabilitated through planting of tree seedlings and fencing as protection from livestock. The advantages of such interventions are manifold, as grown-up trees not only stabilize the soil and have a water retention function but can also contribute to the improvement of rural livelihoods.

Afforestation activities can be divided into 3 main phases:

Afforestation: Selection of planting scheme and species, fencing and planting of seedlings. Implementation time lasts from several weeks to several months;

Maintenance: Irrigation, cutting, mowing, etc. Time-wise this phase should be continued for 3-10 years after the planting of seedlings;

Management: Silvicultural measures like thinning, harvesting or regeneration of forests. This is an ongoing process that shall take place after the maintenance phase.

General rule

Imitate the natural vegetation in terms of species, composition and structure!

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

Checking general framework conditions & availability of resources

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

→ **Availability of financial resources:** determine the plot size, the afforestation scheme and maintenance practices

→ **Availability of human resources & in-kind contributions:** local workers from the communities, forest experts, local materials such as seeds, seedlings, mulching material

→ **Time frame:** afforestation is a long-lasting process, taking 10-30 years until the first timber can be harvested

→ **Long-term rights, beneficiaries and responsibilities:** setting-up binding agreements with local communities and/or authorities for assuring long-term maintenance and management

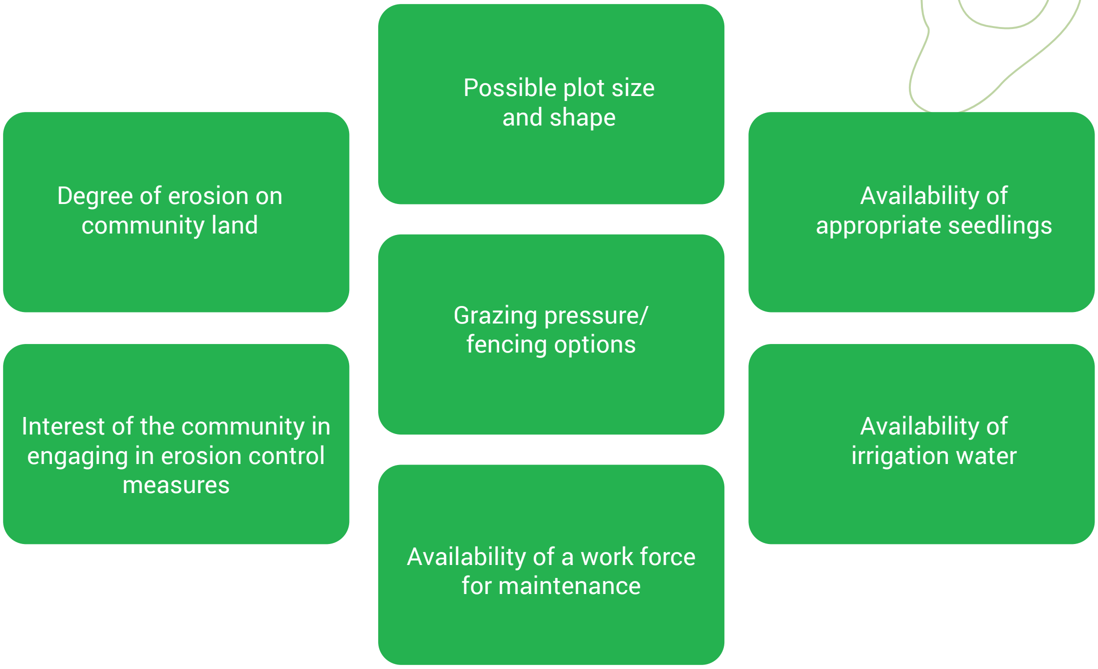


Figure 27: *Main factors to be considered when planning afforestation*

Site selection

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

Technical/ecological site selection criteria:

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

Socio-economic site selection criteria:

- Does the community/landowner support the afforestation on the selected piece of land?
- Is there any conflict with other land use types (e.g., loss of pastureland or hay meadows, blocking of cattle tracks)?

- → Do the expected positive effects of the new forest ecosystem exceed the benefits of the current land use? Is the investment in afforestation justified?
- → Are legal requirements in place, which allow a land category change from non-forest to forest?

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

Considering the shape and the size of the site

The total afforestation costs per hectare are inversely linked with the absolute size of the site: with an increase of the total afforestation area, the costs per hectare decrease. This is mainly due to the costs for fencing which account for a larger part of the total afforestation costs. Consequently, larger plots are cheaper than several smaller plots.

Identifying the appropriate planting season

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

3.4.3 Fencing

In many cases, afforestation sites are located on pastureland. To protect the planted seedlings from browsing by livestock or wild game, it is recommended to fence the afforestation site before starting the plantation of the seedlings. The costs and advantages of different fencing types are given in ***Table 6.***

FENCE TYPE	TYPE OF FENCING POSTS	COSTS OF MATERIAL	LABOUR COSTS OF CONSTRUCTION	ADVANTAGES / DISADVANTAGES
Mesh wire fence	Metal or wooden (or combination of both	High (GEL 12-24/m)	High (especially when using cement for fixing the posts, GEL 13-24/m)	Advantage: long durability, effective for small and big animals. Disadvantage: hard to be removed and re¬used after afforested seedlings are grown up.
Barb wire fence	Concrete	Low (ca. GEL 5.5/m)	Low (GEL 2-3/m)	Disadvantages: not easy to construct an effective barb wire fence against small livestock (goat, sheep). If barb wires remain longer than needed, it could lead to severe injuries to humans or animals.
Electric fence	Plastic	Medium - low (ca. GEL 8/m)	Low (GEL 0.5/m)	Advantage: can be easily removed and re-used. Disadvantage: daily maintenance is needed.

Table 6: *Advantages and disadvantages of different fence types*

3.4.4 Tree species & seedling quality

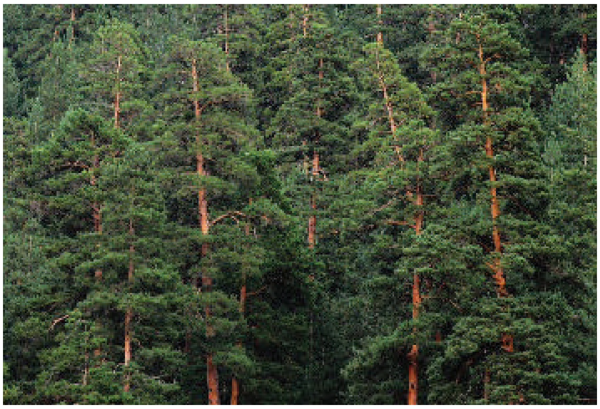
Tree species selection

It is recommended to use different local tree species for any afforestation activity, as they can cope best with the given environmental conditions and, therefore, are more resilient towards pests and climatic variations. The wider project area should be screened for species, that 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, landslide, fire), include pioneer trees (e.g., *Populus tremula, Betula litwinowii*) and shrub species (e.g. raspberry, rosehip, juniper) in the set of selected afforestation species. *Acer trautvetteri* and *Betula litwinowii* are suitable on sites at high elevations with high water availability and long snow cover during winter.

Checklist: Tree species selection

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



Scots Pine, *Pinus sylvestris var. kochiana*

[syn. P. sosnowskyi]

The Scots Pine grows naturally in a variety of habitats, and is the most widespread of all pines, occupying many millions of hectares across Eurasia. It grows well on soils with nutrients deficiencies. In the Caucasus, it ascends to 2,600m a.s.l.

Caucasian Maple, *Acer trautvetteri*

The Caucasian Maple, which is endemic to the Caucasus and the pontic coast of minor Asia, grows with a large crone up to 16m high. It is adapted to the climatic conditions of the subalpine level (1,800-2,500m a.s.l.), not very tolerant to droughts, but resistant to frosts.

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

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

Mountain Ash, *Sorbus aucuparia*

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

Rose, *Rosa sp.*

Juniper, ***Juniperus sp.***

Table 7: Tree and bush species for afforestation

3.4.5 Seedling selection - bare-rooted versus containerized seedlings

Tree seedlings provided by tree nurseries can be either bare-rooted or containerized. **Bare rooted seedlings** are usually grown in tree nurseries on the fields. The infrastructure costs for tree nurseries to produce bare-rooted seedlings are lower than containerized ones. For transportation from the tree nursery to the final place of afforestation, seedlings are removed from the ground without soil and packed carefully into plastic bags. The time until they are planted should not exceed 1-2 days. During this time neither the root systems nor the transport bags should be exposed to the sun. Exposure to open air leads to fast damage of fine roots and limits the uptake of water and nutrients after plantation. Seedlings with damaged root systems often die 1-2 weeks after the plantation.

Figure 28: *Pinus sylvestris var. kochiana [syn. P. sosnowskyi] seedlings collected from the forest in Tusheti*

Alternatively, seedlings and seeds from local trees from the local forest can be used to minimize transportation distance. Both seeds and seedlings from local forests are well adapted to specific local conditions.

Containerised seedlings are usually produced in nurseries equipped with greenhouses and irrigation systems. Deciduous trees (oak, ash, birch, maple) are usually grown in containers with 4x7 units and a depth of 18cm. Scots pine (*Pinus sylvestris var. kochiana [syn. Pinus sosnowskyi*) is grown in containers with 5x8 units and a depth of 14cm. The seedlings are grown (1-2 years) and transported in the container. They can be put into the ground with the root ball and the soil from the container. Special tools can be used to make plant holes according to the size of the root-soil aggregate formed by the container. This is advantageous especially in dry areas, as the root ball has a soil compartment that can keep moisture better than the bare root systems.

The disadvantage of containerized seedlings is the possibility of root deformations, if the container is too small and the saplings are kept in the container for too long. Root deformations might lead to decreased vitality and growth rate and even to death after some years when the root system cannot develop properly. Another disadvantage of containerized seedlings might be the long transportation from lowlands to mountains, including layovers at various places. Long transportation from lowlands to mountains might contribute to stress and low survival rates of the seedlings. However, this holds for long transportation of bareroot seedlings, too.

Figure 29: *Containerized oak seedlings, one year old (left) versus 2.5-year-old bare rooted oak seedling (right)*

SEEDLING TYPE	ADVANTAGES	DISADVANTAGES
Bare rooted	• Usually cheaper • Produced in tree nurseries with low infrastructure investment • Usually well-developed root system	• Very sensitive to improper handling during transport and planting • Might have long roots (>20cm) that need deep plant holes and proper planting procedure
Containerized	• More robust for transport and storage over several days (need watering!) • Roots are protected and get less damaged during planting • Roots stay in their soil environment after plantation, trees show fewer stress symptoms • Plantation costs can be significantly reduced using special planting tools	• Production of containerized seedlings requires investment and leads to higher seedling costs • Root deformations might occur, if seedlings are kept too long in the container

Table 8: *Comparison of bare rooted versus containerized seedlings*

3.4.6 Planting schemes & techniques

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

Schemes - lines versus groups

The traditional scheme is a plantation in lines, ideally parallel to the contour lines. The planting scheme for this approach would describe the spacing between lines and between the trees within a line (see ***Figure 30A***). If different tree species are included, the order of the tree species is given as well. Usually, each line consists of one species, but an alternation of species is possible, too. The more complex a planting scheme is, the more difficult its implementation in the field.

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

The **line approach** is usually linked to a high planting density (6,000-9,000 seedlings per ha), as a short spacing between seedlings is needed for creating favourable microclimate (e.g., reduction of wind speed). This planting technique was applied for small-scale afforestation in Tusheti.

A modification of plantation in lines is the chess pattern planting design ***(Figure 30B).*** 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 have the tendency to favor **group plantation *(Figure 30C, D)*** over line plantation. Most group plantations are designed in a raster of 10x10m to 15x15m, resulting in 100 to 45 raster nodes per hectare. At each node, a group of seedlings is planted in close spacing to each other. The groups might be designed in rings or squares with spacings of 0.4m-1m between the trees. With 9 to 12 seedlings per group and 10-15m between the centers of the groups, each hectare displays 45-100 groups and a total number of 500-1,200 seedlings.

Planting schemes which follow irregular patterns are more challenging with regards to success monitoring. In regular patterns dead saplings are easily visible, in contrast seedlings planted in groups or irregular patterns. This needs to be considered when setting up success monitoring.

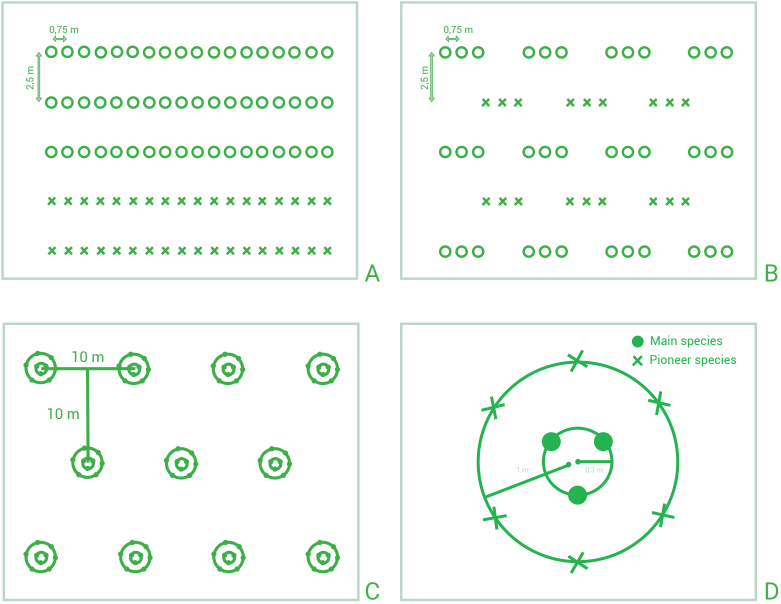


Figure 30: Comparison of different planting schemes: line planting (A), chess pattern (B), and group planting (C, D). Circles are main species, while crosses represent pioneer ones.

	ADVANTAGES	DISADVANTAGES
Line planting	• Easily understandable and widely used • Success is easy to monitor, as long as the same tree species are in one line • Mechanical soil preparation (by tractor) is possible • High planting density ensures a dense stand, even when a high level of dieback is expected	• High costs caused by the number of seedlings • High costs of planting and maintenance • A large amount of irrigation water per hectare needed • A mechanized mowing of grass between the lines is difficult without damaging the seedlings
Chess pattern planting	• Fewer seedlings and thus less work for planting activities • Effective control of surface water run-off • A good option for erosion control plantings for larger areas	• Mechanical soil preparation is difficult (staggered trenches) • Irrigation is more labour-intensive
Group planting	• A smaller number of seedlings reduces the afforestation costs • Easier maintenance: fewer seedlings to be mulched and irrigated • The micro-climate function is important • Even with a high level of dieback rates (60%), at least 3-5 trees/shrubs per group survive, which leads to a minimum of 200-500 trees/ha • Easy hay cutting between the groups	• More difficult to irrigate compared to trenches • Group planting is unknown in the Caucasus, and people are sceptical about this method • It might take longer for an area to be covered with protective trees/shrubs

Table 9: Comparison of advantages and disadvantages of different planting schemes

Technique – trenches versus holes

Starting from the Soviet times and up to now, a common afforestation technique is digging **trenches** parallel to the contour lines (30cm wide, 35cm deep) with 2-3m between the trenches, depending on the inclination (the steeper the slope, the shorter the spacing). In these trenches, seedlings are planted at 30-50cm intervals, resulting in 6,000-9,000 tree seedlings per hectare ***(Figure 31 left).*** With this high planting density, one would aim at a quick closure of the crown layer of the young trees to avoid the growth of other plants.

> **General Rule**
>
> Dig trenches and plant holes directly before planting of seedlings in order to keep the moisture and have favourable soil conditions!

An alternative to trenches are **plant holes** with a diameter of 20-40cm and a depth of 30-40cm ***(Figure 31 right)***. Plant holes can be used for the line and group plantations. Deep holes make irrigation easier and provide wind protection. At the same time, they increase the risk of being overgrown by surrounding vegetation.

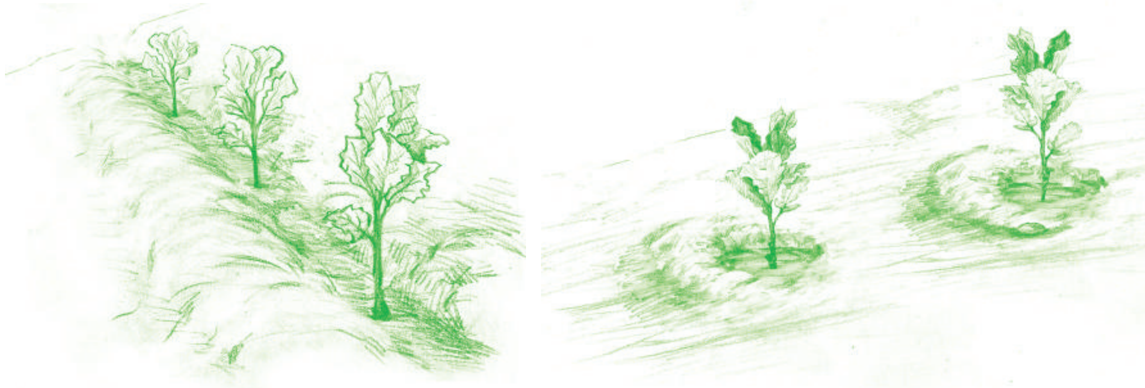


Figure 31: *Oak seedlings in a trench plantation (left) and oaks planted in plant holes (right}*

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

Table 10: *Comparison of different planting techniques*

3.4.7 Maintenance

Irrigation

Irrigation may support the root development of the seedlings in the first 1-3 years and increase the survival rate. If no permanent irrigation system is established, each tree seedling should be supplied with at least 5-10 litres of water right on the day of planting, unless it is raining, or the soil is saturated with water from the previous rain. Irrigation 1-4 times during the summer drought with 10 litres/tree will support growth and survival rate. Drip irrigation systems are most efficient but very costly. Irrigation by hand with buckets or rubber tubes seems more realistic, as irrigation should be limited to the first 1-2 years (in case of low growth rates up to 3 years). It can be meaningful to install mobile water tanks of 1.5-3m³ for gathering water from sources with lower water output to speed up the irrigation process.

Mulching & weed control

When soils are fertile, the growth rate of herbs and grasses might be higher than of the seedlings, casting additional shade. Depending on the growth conditions, weed-control (cut back of grass and herbs) might be needed 1-3 times a year. Sites on higher altitudes (> 1,800m a.s.l.) and low precipitation might need one intervention per year. The frequency of hay cutting in nearby meadows can be used as an indicator of how often weed control might be necessary. The cut hay can be used for mulching (covering the ground around the seedlings). By reducing water evaporation from the soil, mulching reduces irrigation requirements and also counteracts weed growth ***(Figure 32).***

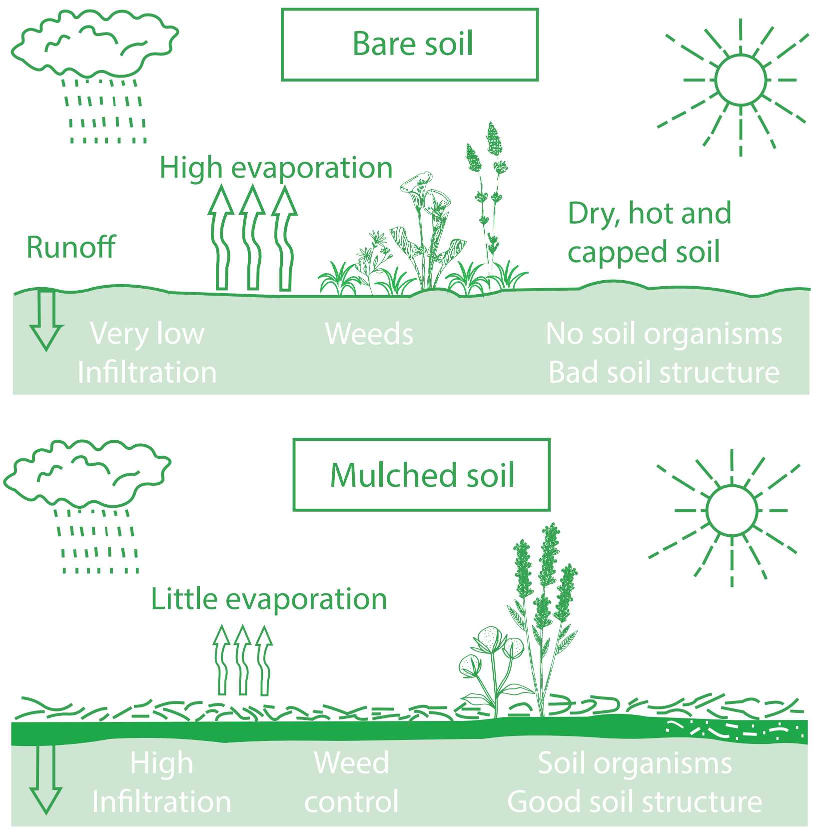


Figure 32: *The effects of mulching (source: Vukasin et al, 1995)*

4. SHOWCASES FROM TUSHETI

4.1. Showcase 1: Bioengineering – Wooden Check Dams

Description

In 2004, right above the western part of the village of Jvarboseli in Tusheti, a major landslide led to the formation of a gully. To avoid further erosion, four concrete check dams were built in the lower part of the rill. Around these structures, the area was already covered with pioneer vegetation, but the deepening of the gully continued. The upper part, however, was too steep and unstable for natural regeneration of vegetation and showed open soil. Bioengineering measures such as wooden check dams and hedge bush layers were recommended to stabilize the starting area of the erosion rill and to avoid deepening of the gully.

After a feasibility assessment, the gully was stabilized with bioengineering structures between 2017 and 2019.

WHERE

- Village of Jvarboseli in Tusheti
- Upper section of the erosion gully above the village

Figure 33: Gully erosion, view from above, July 2016

WHY – Erosion phenomena & causes

- Deepening gully after landslide threatening the village
- Steep inclination, superficial water flows
- The deforested area at the gully starting point

WHAT – Implemented pilot measures

- Construction of vegetated wooden check dams
- Establishment of hedge brush layers
- Planting of cuttings
- Hay seeding
- Rounding of overhanging edges

Figure 34: Gully erosion, view from the village, July 2016

WHO – Main stakeholders involved

- Local population of Jvarboseli
- Local staff and experts from FATPA – Friends Association of Tusheti Protected Areas
- Local staff and experts from TPLA – Tusheti Protected Landscape Administration
- Local staff and experts from Tusheti Protected Areas Administration
- GIZ IEC/IBiS program staff & international experts

Methodology

The unsustainable use of pastures and forest areas leads to erosion, degradation, desertification and loss of biodiversity in the high mountain regions of the South Caucasus. In the village of Jvarboseli, Tusheti, there is a significant gully directly above the western part of the village. This gully is the result of a severe landslide in 2004. The gully erosion itself starts at an elevation of 2,010m above sea level and extends all the way down to the village (big tube with 100cm diameter under a road) at an elevation of 1,910m. The total length of the gully is approximately 300m. After two field trips and multidisciplinary assessments in 2015 and 2016 focused on geomorphology, geotechnical failure processes, hydrological condition, soil texture and specifically existing and potential botany, the site was considered an adequate pilot area to implement specific soil bioengineering measures.

For Jvarboseli, the following soil bioengineering techniques were selected for different sections of the gully:

- vegetated wooden check dams (Section B and C)
- rounding of overhanging edges (Section A)
- vegetated palisades (Section A)
- hedge brush layer (along the rill)

In addition to the bioengineering approach, an electric fence was set up to exclude the animals from grazing around and above the rill (at least for some time). The area above the rill was also afforested with local tree species.

According to the measurements from August, 2019, as a result of the bioengineering constructions, the slope of the gully decreased from 35% to 25% in the upper part and from 80% to 30% in the lower part.

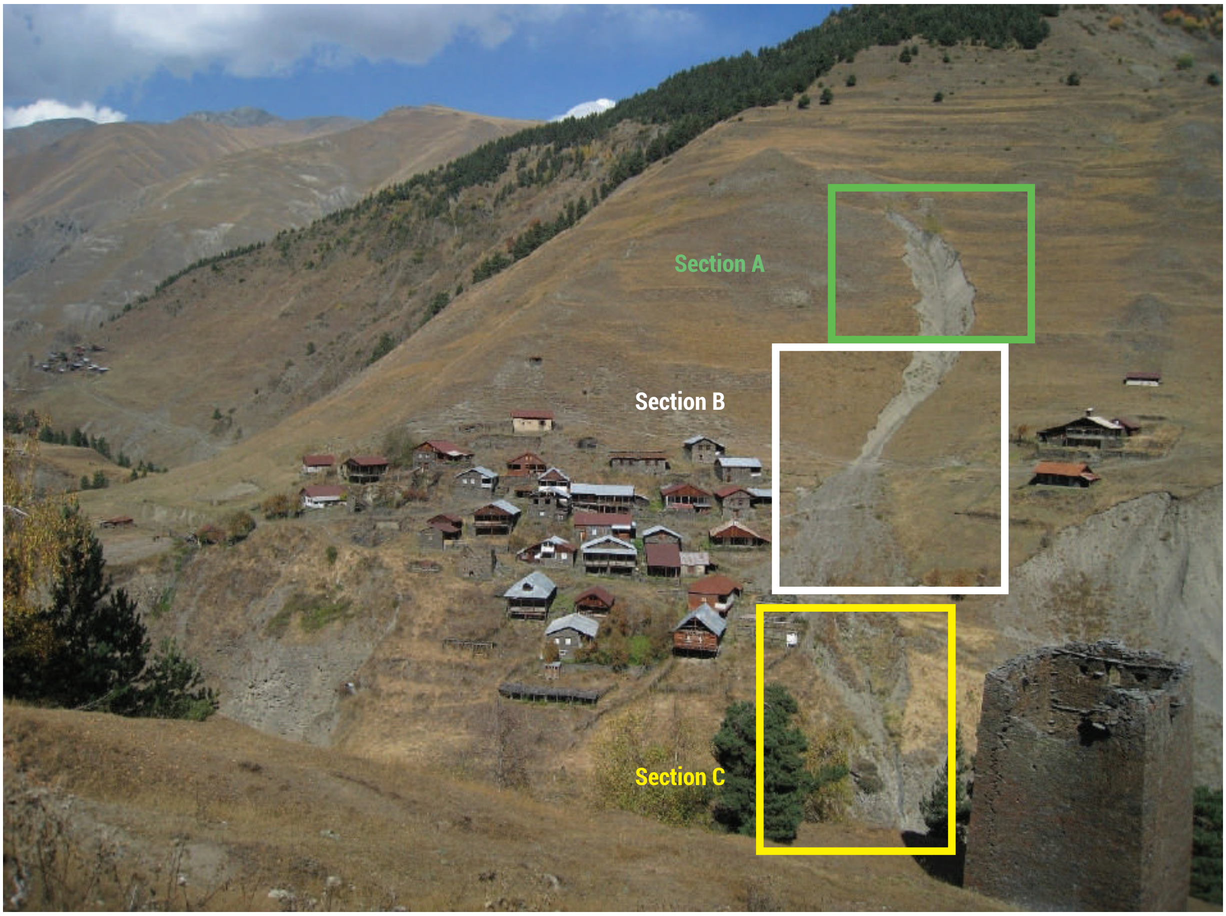


Figure 35: *Overview of the various sections in Jvarboseli*

Implementation

Vegetated Wooden Check Dams

Vegetated wooden check dams are used as transverse structures for slope and bed stabilisation in steep gorges. The construction consists of three horizontal log-layers which were filled with drainage material; living branches or rooted woody plants were inserted into the side walls without blocking the discharge section. Locally available stones were used to prevent erosion of the wooden structure. The flowing water is being concentrated in the discharge section which is enforced by the shoulders of the structure to prevent alongside erosion processes.

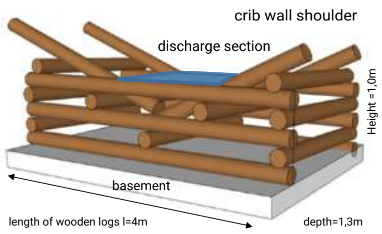



Figure 36: *Vegetated wooden check dams*

In total, 14 vegetated check dams were built in Section B and 11 in Section C. The slope in Section C was significantly steeper compared to the other sections. Therefore, although the general design of the check dams is similar, the structures in Section C were built higher to obtain a balance slope. Additionally, three crib walls, check dams without wings, were built.

Vegetated palisades

In the upper part of the gully, 13 vegetated palisades were constructed. These constructions work like the wooden check dams, but the dimensions are smaller. The construction material for one structure consists of a wooden log with a length of around 3.4m and approximately 50 pieces of cuttings.



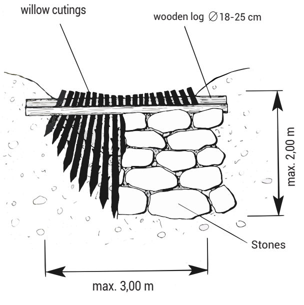


Figure 37: *Vegetated palisades*

First an excavation was carried out to allow the positioning of the horizontal wooden log and its integration into the side areas. Then the willow cuttings were set vertically to reduce the slope. Finally, the vertical cuttings were filled with the excavated soil, and stones are put in front of the structure. The construction is very simple, with a height of around 60cm, and suitable for smaller gullies with less load and flow.

Rounding of overhanging edges

Characteristic of the gully were the overhanging edges, preventing development of vegetation at its steepest parts. Hence, the edges were rounded off on 400 running meters, improving stability of the underlying slope and preparing it for replanting or bioengineering measures.

Hedge brush layer

The hedge brush layering techniques were applied in the upper part of the gully. This technique helps to stabilise unconsolidated rock and to initiate pioneer plant species there, thus supporting and accelerating reforestation of such areas. The willow cuttings, rooted plants and brush layers were placed on terraces at least 50cm wide, transversely to the wooden logs and with a counter fall to the main slope. The structure was filled up with the excavated material from the terrace above. Not more than 10% of the cuttings may be visible from the outside.

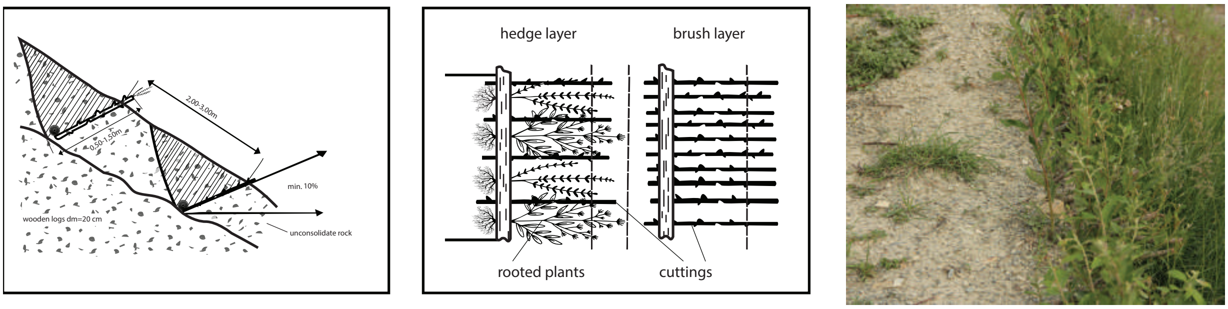


Figure 38: Hedge brush layers

In Section A, a total of four rows of the hedge brush layers were constructed: one 12 running meters to the left of the slope and three 10 running meters each to the right of it. Later, local plants cultivated in the nursery were propagated along the whole gully for further stabilization.

Plant species

For both, crib wall as well as hedge brush layer, the selection of species used as living construction material is most important. Living local materials, i.e. plants, seeds, parts of plants and plant communities from the construction site itself and from close around, are always suited best because they have already adapted to the site conditions. The following table gives an overview about the local plants which were used in September, 2016 for the implementation work.

SPECIES NAME	APPLICATION	TYPE
Goat willow (*Salix caprea*)	cutting	vegetative reproduction
Mountain ash (*Sorbus aucuparia*)	rooted tree	adventitious root sprouting
Birch (*Betula litwinowii*)	rooted tree	adventitious root sprouting
Raspberry (*Rubus idaeus*)	cutting	vegetative reproduction
Scots pine (*Pinus sylvestris var. kochiana [syn. P. sosnowskyi]*)	rooted tree	planting, seeding

Table 11: Plant species and their application

Evaluation & Lessons learnt

Disregarding the short time of one construction week and the difficult local situation, a lot of soil bioengineering work could be implemented. It shows that if well organised and properly planned, this measure can be rather quickly implemented with a low input of machines and using local tools and materials. The personal effort of all local farmers was very high, which shows a high level of identification with the work and is very helpful to build local capacity and create local awareness about the planning and implementation of selected bioengineering measures.

The transverse structures (palisades and check dams) reduce flow velocity and drag force, thus, preventing the gully from deepening. The palisades in the upper part already retain most of the sediment. This protects the settlement from mudslides and floods as well as from further cuts in Section C.

The biggest benefit of these structures is, however, that with simple machinery and few resources, effective soil erosion control measures can be taken. The material, except for iron that supports the structure, can be locally sourced and easily transported. The integration of living plants ensures that this barrier is effective, even if the wooden logs are already rotten.

Thus, besides stability as part of the engineering effect, the ecological effect of the measures was manifested through habitat creation. Requiring little energy, bioengineering is also climate-friendly and supports maintenance of the landscape's aesthetical value.

In the following, the lessons learnt are presented:

- ✓ The structure must be embedded into the ground to prevent scouring phenomena around the foundations.
- ✓ The cuttings should preferably be used in spring or late autumn to reduce the risk of drought and should be used as soon as possible after cutting.
- ✓ Hedge brush layering is efficient, but the implementation time (due to drought) is most important.
- ✓ Hay-seeding: The hay layer should have a thickness of only about 1cm and should be evenly distributed over the area.
- ✓ For all implemented measures it was most relevant that the plants are protected against grazing livestock by an electric fence.

4.2. Showcase 2: Pasture rotation & electric fencing

Description

The unsustainable use of pastures and forest areas leads to erosion, degradation, desertification and loss of biodiversity in high mountain areas of the South Caucasus. Sound pasture management is a significant approach to prevent further damages. In Shenako, a village in Tusheti, principles and benefits of rotational pasture management were introduced to deal with starting erosion and improve the pasture quality for grazing livestock.

WHERE

- Village of Shenako in Tusheti
- Pilot sites: 1 site north (22.3ha), 1 site west (6.4ha) of the village

WHY – Erosion phenomena & causes

- Sections of open soil on steep slopes due to overgrazing
- Spreading of non-palatable plants due to lack of pasture management
- High pressure on pastures near the village centre

WHAT – Implemented pilot measures

- Fencing with electro fence
- Implementation of a pasture rotation system

Figure 39: Selected pastures for rotational grazing in Shenako

WHO – Main stakeholders involved

- The local population of Shenako
- Local staff and experts from FATPA – Friends Association of Tusheti Protected Areas
- Local staff and experts from TPLA – Tusheti Protected Landscape Administration
- Local staff and experts from Tusheti Protected Areas Administration
- GIZ IEC/IBiS program staff & international experts

Methodology

Site 1 is located on a steep slope north of the village with severe ongoing surface erosion. The area is unproductive and contains a high biodiversity level. It is separated into four paddocks (compartments) A, B, C, D. The compartments have different characteristics (A: more productive, faster growth, medium size; B: smaller than others, lower productivity, C: big in size, lower forage). In total, 22ha were fenced for pasture management.

PADDOCK	PERIMETER (M)	HA
A	1,800	7.6
B	999	4.4
C	1,101	7.3
D	841	3.0
		22.3

Table 12: Size and perimeter of the fenced area (Site 1)

SITE 1	22 HA	PRODUCTIVITY
forage dry mass	5dt/ha	very low
cattle need	12kg/day	average
utilization rate	50%	low
grazing duration	90 days/year	average

Table 13: Site 1 presumptions

Site 2 (6.4ha) was established together with the village stakeholders west of Shenako. The purpose of site 2 is to set up a pasture rotation scheme for calves of the village population. The improvement of the local grazing situation should compensate the limited access to Site 1 for grazing. The area is productive, has only a few steep slopes, yet contains a lower biodiversity. It is separated into three paddocks (X, Y, Z) with different size conditions (X: very small, Y and Z quite the same size).

PADDOCK	PERIMETER (M)	HA
X	420	0.6
Y	860	2.8
Z	1,060	3.0
		6.4

Table 14: *Size and perimeter of the fenced area (Site 2)*

SITE 2	6 HA	PRODUCTIVITY
forage dry mass	30dt/ha	quite good
dairy cows need	15kg/day	average
utilization rate	70%	quite good
grazing duration	90 days/year	average

Table 15: *Site 2 presumptions*

With the presumed data and a simplified formula, the stocking rate can be roughly calculated:

Live weight x 0.04 = kg fodder/day (dry weight)

Cows and sheep need as much fodder (dry weight) per day as 4% of their live weight. A cow weighs around 300 kg and a sheep around 50kg. The calculation for cows is therefore 300kg times 0.04, and the required fodder (dry weight) per day is then 12kg. With this information available and considering the biomass of the pastureland and the amount of livestock, the rotation cycles and the days of grazing per paddock can be set.

Implementation

While fences were established in 2016, the training of farmers on the rotation pasture system was conducted in 2017. The target group of the training were local farmers from Shenako, as well as regional and national experts to disseminate the methods to other areas. The training was a combination of theoretical content and practical exercises in the field. The fences were set up without GIZ's support in 2018 and 2019 by local people to continue the rehabilitation of the degraded slope.

Outlook

The experience showed that there are two basic options, which define the applicability of rotational grazing practices in Shenako:

- ✓ Option 1: If farmers are interested in enhancing milk production per cow, rotational grazing could definitely contribute to reach this goal. Beneficial rotational grazing is dependent on a set of favourable conditions, for example, productivity (good forage, productive breeds), location (vicinity to farmstead) and accessibility (steepness of slopes). This means rotational grazing is mostly effective for dairy cows on good sites near the village. Instead of Site 1, it is recommended to look for a more suitable site, which could be the area north-east of Shenako settlement. As a consequence, Site 1 should only be managed for the purpose of erosion control as described below.

- ✓ Option 2: If farmers are interested erosion control more than enhancing milk production, rotational grazing must/could only partly be practised, e.g. in order to keep the calves for fattening. As rotational grazing is very time-consuming, it would be more useful and efficient to reduce grazing time, number of animals on the area and/or to fence out vulnerable areas (like Site 1), allowing grazing for certain periods of time (e.g. after ripeness of plants, as animal can help to trample the seeds into the soil in order to germinate more easily).

4.3. Showcase 3: Pasture passports

Description

The project area comprises the Tusheti Protected Areas on the northern slopes of the Greater Caucasus. This group of protected areas consists of a strict nature reserve, a national park and a protected landscape with about 40 villages and settlements. Together they form a total protected area of approx. 114,000ha.

Agriculture, and first of all livestock grazing is the predominant economic activity in the Tusheti region, although the importance of tourism has increased significantly during the last decade. The Tusheti region has a long tradition in transhumant pasture systems. The presently applied pasture systems comprise three different approaches:

- Far distance transhumant pasture system (summer pasture in Tusheti, winter pastures in the area of Dedoplistskaro municipality, 250km distance in one direction)
- Short distance transhumant pasture system (summer pasture in Tusheti, winter pastures in Akhmeta lowlands, 80-110km distance in one direction)
- Permanent farmers located in Tusheti (wintering livestock in Tusheti)

Each winter, the larger herds move to the Dedoplistskaro municipality, while the smaller flocks stay in Akhmeta municipality in winter. Only few farmers stay in Tusheti for the whole winter.

Overgrazing, but locally also undergrazing, resulted in soil erosion and biodiversity loss. Especially the intensive and unsustainable use of summer pastures in Tusheti during the Soviet period led to a severe deterioration of the mountain slopes. So far, there are no standards or guidelines in Georgia for the elaboration of sustainable pasture management plans. Pasture passports, as a first step towards a sustainable pasture management, document the actual grazing capacity for each pasture unit and serve as a guiding document for shepherds and local stakeholders.

WHERE

- Full territory of Tusheti Protected Areas (114,000ha)

WHY – Erosion phenomena & causes

- Overgrazing leads locally to increase of erosion
- No current information on pasture qualities and carrying capacities are available
- No standards for leasing contracts are available

WHAT – Implemented pilot measures

- Assessment of available grasslands, fodder biomass and erosion risk
- Digitisation of old pasture units
- Separation of village areas from potential lease areas
- Integration and alignment of the protected area categories and zonation
- Preparation of maps and tables for each pasture unit in a standardised format ("pasture passports")

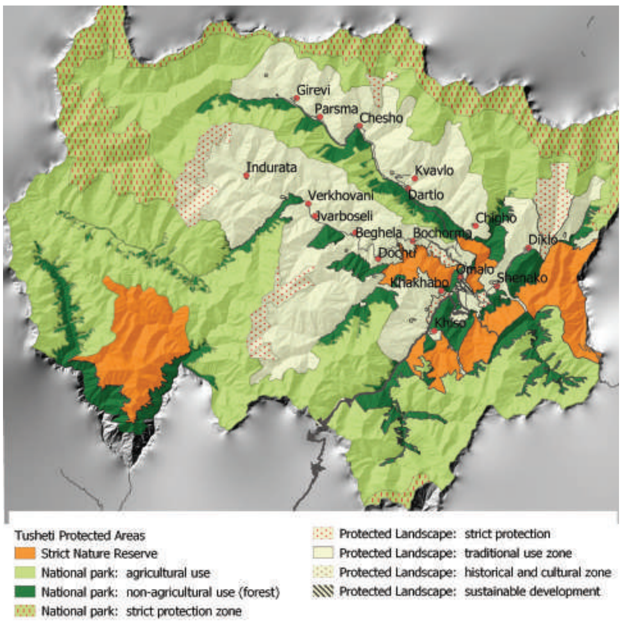


***Figure 40:** Tusheti Protected Areas (project area)*

WHO – Main stakeholders involved

- Administrations of Akhmeta Municipality and Tusheti Protected Landscape
- Tusheti National Park management and APA
- Local staff and experts from FATPA – Friends Association of Tusheti Protected Areas
- National GIS, remote sensing experts from GIS-LAB
- Spatial planners and GIS experts from Geographic
- National ecologists from Universities and NACRES
- GIZ IEC/IBiS program staff & international experts

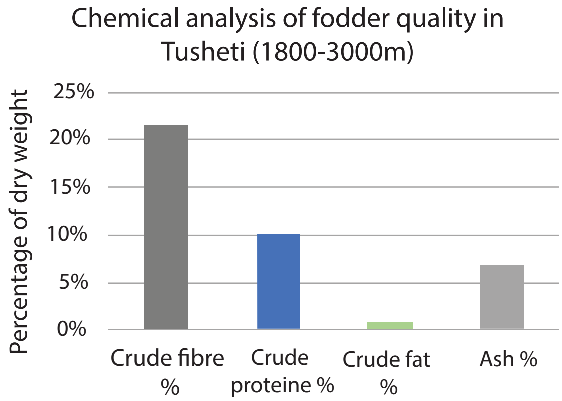


Figure 41: *Chemical analyses of fodder quality*

Methodology

As a prerequisite for the development of pasture passports, the following catalogues were prepared at the beginning of the planning process: number of shepherds/herds located in Tusheti; number of grazing cattle/sheep/goats/horses; areas used; productivity of different types of vegetation (pastures); areas at high risk of erosion due to overgrazing.

The generation of the pasture passports was structured in several phases. In the first phase, the remote sensing and the field surveys were conducted. The data from the remote sensing and field surveys are stored in a GIS system and database. The project team used raster datasets for the land cover types, biomass and inclination (slope). Erosion risk and the pasture units were also converted to a raster dataset to improve performance. All raster sets were combined into one (all information comprised in the raster attribute value) with a raster size of 10x10m. In GIS, the maps of each of the 168 pasture units were created using a map book or map atlas functionality. The reports (pasture passports) were exported as pdf files.

Figure 42: *Map shows Tusheti PAs territory's division by river basins to identify location of farm camps (green dots). The size of the dots indicates the number of livestock per farm (largest dot = 500 cows/3000 sheep, smallest dot = 50 cows/300 sheep).*

Quality and quantity of fodder biomass

A chemical analysis was conducted from 23 biomass samples to describe the average fodder quality by raw protein, fibre, fat and ash content. The chemical analysis shows similar quality of fodder biomass as in other mountain pastures (e.g. in the Alps).

Assessment of farms and livestock numbers and pasture units

From 2016-2018, all gorges were assessed by field experts, and interviews were conducted with shepherds. According to the survey results, 66 shepherds keep livestock Tusheti. In total, they breed around 62,000 sheep, 4,200 cattle and 700 horses. Most farmers were found in the Pirikiti and Gometsari gorge, as well as in the western parts of Chanchakhovani and Chaghma gorge. In contrast, grazing is hardly practised in the western part of Tusheti. The collected data show the location of the shepherd summer camps ("farms") and the number of livestock bred by them .

At the time of the assessment, one third of the former Soviet pasture units were in use. From these units ("numbers"), several parts were excluded which were neither to be grazed nor used for leases:

- All strictly protected areas and zones: the strict nature reserve, the strict protection zones of the national park and the protected landscape;
- All areas covered by forest
- All areas classified as highly erosion-prone by remote sensing (steep slopes with low vegetation cover) and
- Village areas and parts that had previously been used for other agricultural activities (e.g. ploughing) were removed from the grazable area.

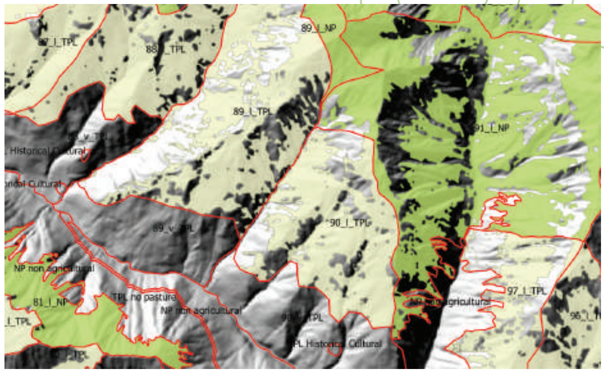


Figure 43: Example of lease areas from the pasture passport map. Yellow areas are lease areas within the Protected Landscapes, green areas are located in the National Park

Remote Sensing

For the assessment of land cover, erosion risk and pasture biomass, remote sensing tools were used in combination with data collected in the field for calibration. Satellite images from SENTINEL 2 were used to derive land cover and fodder biomass.

In order to evaluate sites with high erosion risk, precipitation data were derived from the CHELSEA project website (1x1km grid of monthly mean precipitation). The digital elevation model was derived from the old Soviet topographic map and soil data from the soil map 1:200,000 was used.

The remote sensing results were verified from more than 200 field samples. The pasture quality approach from Etzold (2013) was used for ground truthing. The evaluation results showed a statistically significant correlation between field data and remote sensing results.

While the field sample provides more detailed information on each sample plot (e.g. number of plant species), the advantage of the remote sensing approach is that it covers the entire area of the Tusheti PAs and provides statistically sound figures for the available fodder biomass.

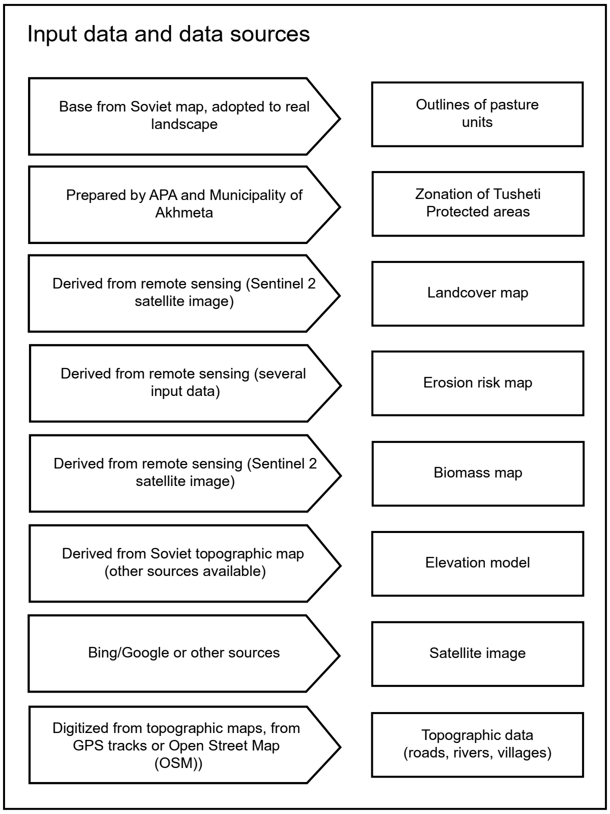


Figure 44: Input and data sources

The old Soviet map of pasture units with Soviet numbers was digitised and corrected using topographical information from NACRES – Centre for Biodiversity Conservation & Research. The boundaries of the map were aligned with the natural boundaries, such as rivers or ridges, and the boundaries of the protected areas.

As part of the spatial planning process of the municipality of Akhmeta, an assessment of the village areas was carried out. The purpose of this planning process was to separate pasture lands that can be leased to shepherds from those are used as hay meadows, arable lands or village pastures. The resulting map showed lands which cannot be leased and should be available to the village.

The Pasture Passports

Every pasture unit is described in the pasture passport on four pages. The content consists of:

- The header line with the pasture unit (code) and the total area
- An overview map of the pasture units on a satellite image
- A map of the land cover types ***(Figure 45)***
- A map of the results of the erosion risk model (***Figure 46)***
- A map of the biomass of the grassland, available biomass and carrying capacity for pastureland ***(Figure 47)***
- The name of farmers / shepherds and their livestock numbers using the pasture unit

Table 16 shows the total biomass for each of the 100m altitudinal belts. Not all of the biomass is available for the livestock. Grazing areas with an inclination less than 20° A practical as accessible for cows and sheep. Areas with inclination of 20-30° are classified as accessible only for sheep. Areas steeper than 30° are not classified as regular grazing areas.

Livestock requires a daily amount of fodder equivalent to 4% of its living weight. The average weight of a Tushetian sheep is estimated with 50kg, the weight of an average cow is 300kg. The grazing period is about 4 months (June, July, August, September; 120 days). This gives an average need of 240kg of fodder for a sheep and 1,440kg fodder for a cow for one season. All fodder volumes are calculated as dry biomass (1kg of dry biomass is equivalent to 2.8kg fresh biomass).

The available fodder biomass in the pasture unit divided by the needed kg of fodder for cows or sheep (live weight times 0.04) gave the maximum number of cows or sheep that can be sustainably fed with this pasture unit. The number of cows and sheep cannot be added. For each cow grazed inside the pasture unit, the number of maximum sheep carrying capacity had to be reduced by 6 (one cow unit = 6 sheep units).

Pasture unit: 1_I_NP lease area Total area (ha): 299

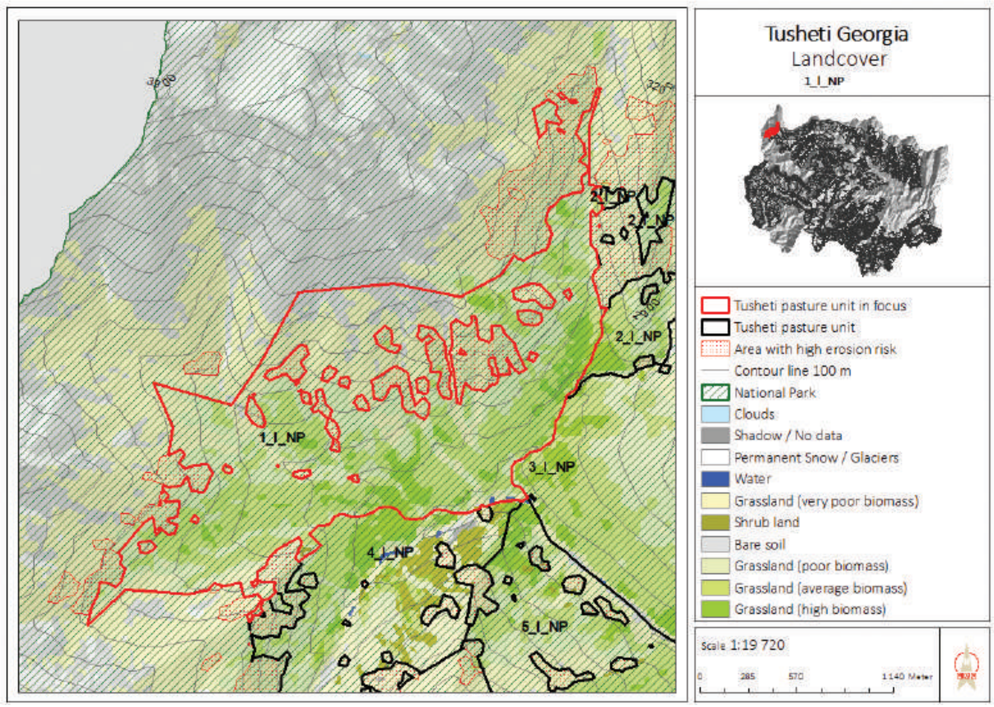


Figure 45: *Land Cover Types*

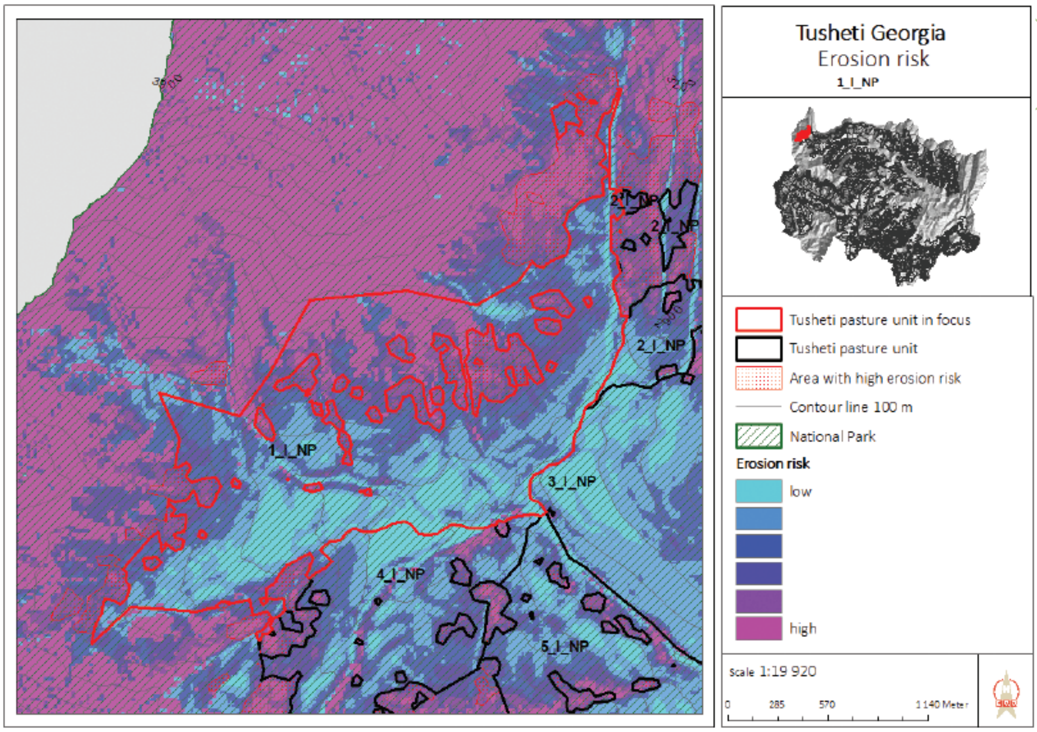


Figure 46: Soil Erosion Risk Model

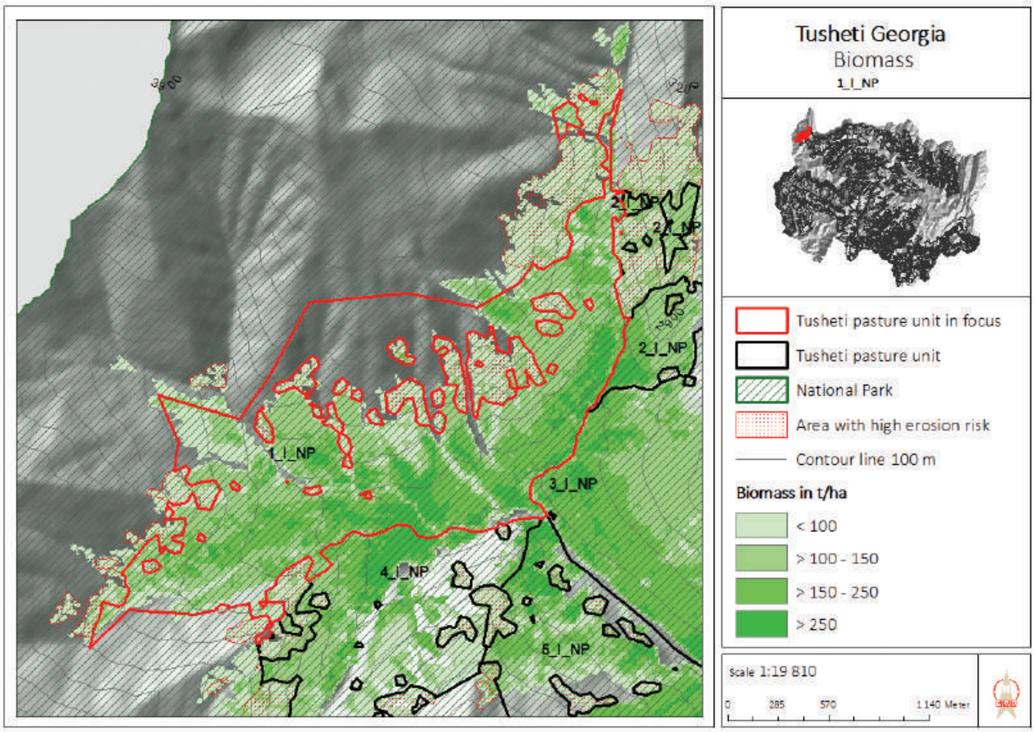


Figure 47: Biomass of the grassland, available biomass and carrying capacities of pastureland

Available biomass:

Elevation:	ha:	biomass total:	available for cows:	available for sheep:
2500	6.0	9 t	6 t	9 t
2600	31.6	75 t	56 t	74 t
2700	45.5	89 t	50 t	85 t
2800	64.1	85 t	54 t	83 t
2900	60.2	65 t	40 t	64 t
3000	46.1	32 t	15 t	31 t
3100	31.1	14 t	7 t	14 t
3200	14.5	0 t	0 t	0 t
Total	**299**	**368.8 t**	**227.6 t**	**360 t**
		maximum number:	of cattle **158**	of sheep: **1 501**
tons of biomass needed for 120 days grazing:			1 cattle (adult) 1.44	1 sheep: 0.24

Table 16: *Available biomass for grazing*

In the pasture passports, the name of farmers/shepherds were given, and the number of livestock was listed in the table. In some cases, the farmers/shepherds are using two pasture units. If a shepherd was using two pasture units, the percentage from total on this pasture unit would be 50% which means, that the total number of livestock of this farmer/shepherd is twice as much as indicated in the table but was split into two pasture units.

The table of farmers was followed by a map showing the results of the Soil Erosion Risk Model ***(Figure 46).*** The colours in the map are indicating varying sensitivity of the land to surface erosion by water runoff. Areas with a high risk of surface erosion (more than 20t of potential soil loss per hectare and year) were removed from the lease map and should not be grazed. The biomass on these high erosion sites was excluded from the calculation of the available biomass and carrying capacities.

Figure 48 shows the pasture unit on a satellite image to indicate the boundaries on the landscape. The boundaries of the relevant protected areas categories were shown on the map as well.

Outlook

In total, about 440 workdays were spent for this pilot project. For replication, the field assessment could be reduced to biomass sampling (4 samples = 1 day) and the evaluation survey will not be needed for follow up studies (as the method is validated). Thus, 250-300 expert days might be sufficient for a study area of 100,000ha. If applied to larger areas, even more, efficient sampling designs would reduce the needed resource per ha.

All information from the pasture passports was used in a participatory way together with all relevant stakeholders, including shepherds, herd owners, representatives of the four Tushetian gorges, Tusheti PAs administrations (protected landscape and national park/nature reserve), Akhmeta municipality, local NGOs, and other projects, to develop a detailed sustainable pasture management plan for Tusheti PAs (in progress). The pasture passports themselves contribute to the development of a strategic pasture management concept in Tusheti PAs and can also be used to draw up new lease contracts with shepherds.

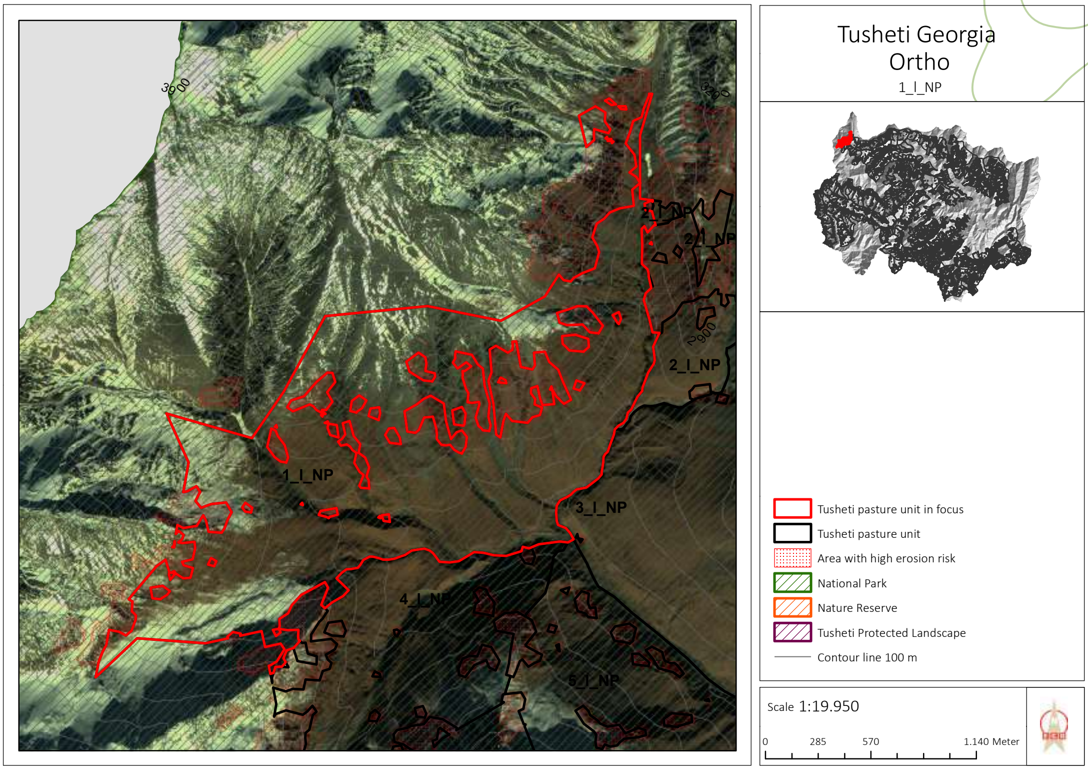


Figure 48: *Orthophoto overview inside the pasture unit 1_I_NP*

The passport precisely describes the size and location of the lease area, as well as the quality of the pastureland and the maximum carrying capacity of the unit. Areas which must not be grazed (forest areas, eroded areas, strictly protected zones) are indicated in the maps which help both shepherds and rangers to verify that the area used complies with the roles and regulations of the lease.

Besides the information on each pasture unit, the compilation of the data gives a comprehensive overview of the available grazing biomass, the current situation on erosion risk in Tusheti, detailed location of the farm camps, and the current number of livestock. Comparing the current land use with the zoning of the Tusheti National Park and the Tusheti Protected Landscape can help to develop appropriate management regimes to avoid conflicts between protection of the habitats of wild animals (e.g. East-Caucasian Tur or Bezoar goat) and maintenance of the traditional Tushetian land use in a sustainable way.

5. RECOMMENDATIONS FOR UPSCALING

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

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

- → Horizontal scaling up ("replication", "scaling-out") refers to applying experiences in similar or comparable contexts. Horizontal scaling up "asks": what changes incomparable "local systems" will be triggered by the particular experience?
- → Vertical scaling up looks at influencing the policy environment (developing and changing policies, laws and regulations). Vertical scaling-up "asks": what changes in the larger (political-administrative) system will be triggered by the "local" experience?

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".

- → Functional scaling up refers to the transfer of successful approaches to another context or service. This can include horizontal as well as vertical upscaling approaches. Functional scaling up "asks": what changes that proved to be successful under specific conditions can be adapted to the conditions in another country or in another sector?

GIZ projects follow a multi-level approach worldwide, which relates to horizontal as well as vertical upscaling ***(Figure 49).*** In case of the IBiS project, horizontal upscaling would include the extension of erosion control measures to the same pilot communities as well as to other communities with similar conditions. Vertical upscaling is envisaged through constant policy dialogue with political partners at the municipality and at the national levels. In this context, the goal is to have successful pilot projects being taken up by the Georgian government, incorporated into policy guidelines or regulations and then being applied at a larger scale. Examples of successful upscaling include the remote sensing technology as a monitoring method for LDN, which has been introduced at national level, and the pasture passports that will be considered by the APA in other PA. Functional upscaling is also observed in the frame of the IBiS programme. Since IBiS is a regional programme working in the three South Caucasian countries, successful measures and approaches are shared and adapted to specific circumstances, e.g. application of bioengineering measures in Georgia and Armenia.

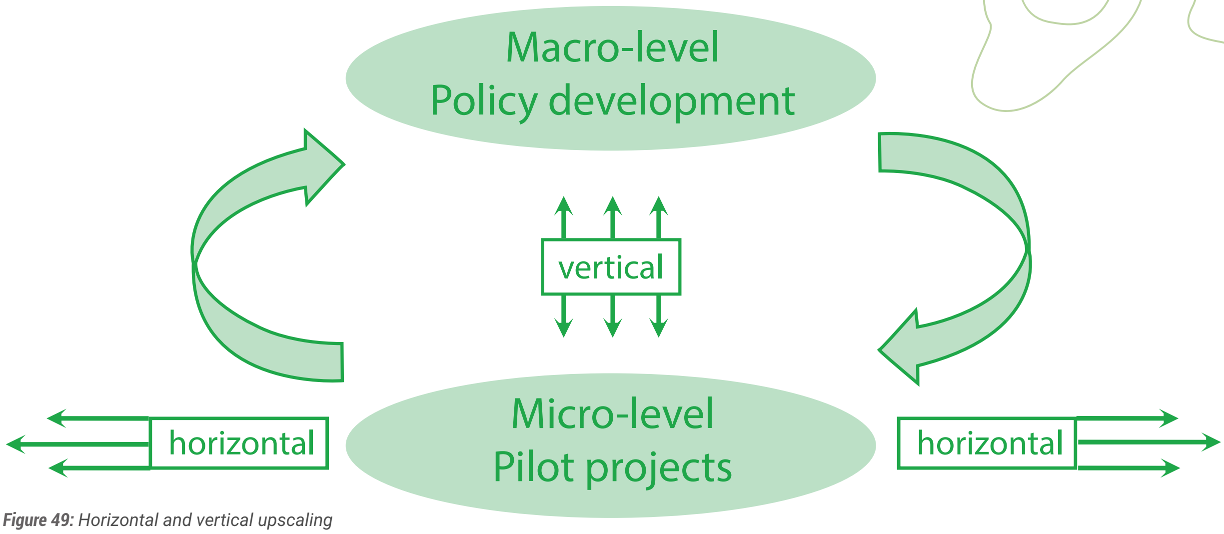


***Figure 49:** Horizontal and vertical upscaling*

5.1. Tool for assessing the upscaling potential of a pilot measure

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

5.1.1 Assessment grid: upscaling potential of a pilot measure

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

NO.	CRITERIA	SCORE (1-7)
1	How relevant is the pilot measure for local users?	
2	Following a simple cost-benefit analysis of the pilot measure: are there financial benefits for the local user?	
3	Check carefully the technical dimension of the pilot measure: is the measure easy, persuasive, convincing, adjustable? Does it provide different options?	
4	Check carefully the social dimensions of the pilot measures Is the pilot measure affordable for its intended users? Does it have a market potential?	
5	Check the effectiveness of the pilot measure: does it give good results in a short time?	
6	Check, if equal access (e.g., gender sensitivity and gender equality) is assured, and if pilot measures are not discriminatory e.g., against minorities.	
7	Check, if the pilot measure ensures ownership by its intended users, as well by relevant stakeholders such as multipliers and decision-makers.	

***Table 17:** Advantages and disadvantages of different fence types*

5.2. Spider diagram

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

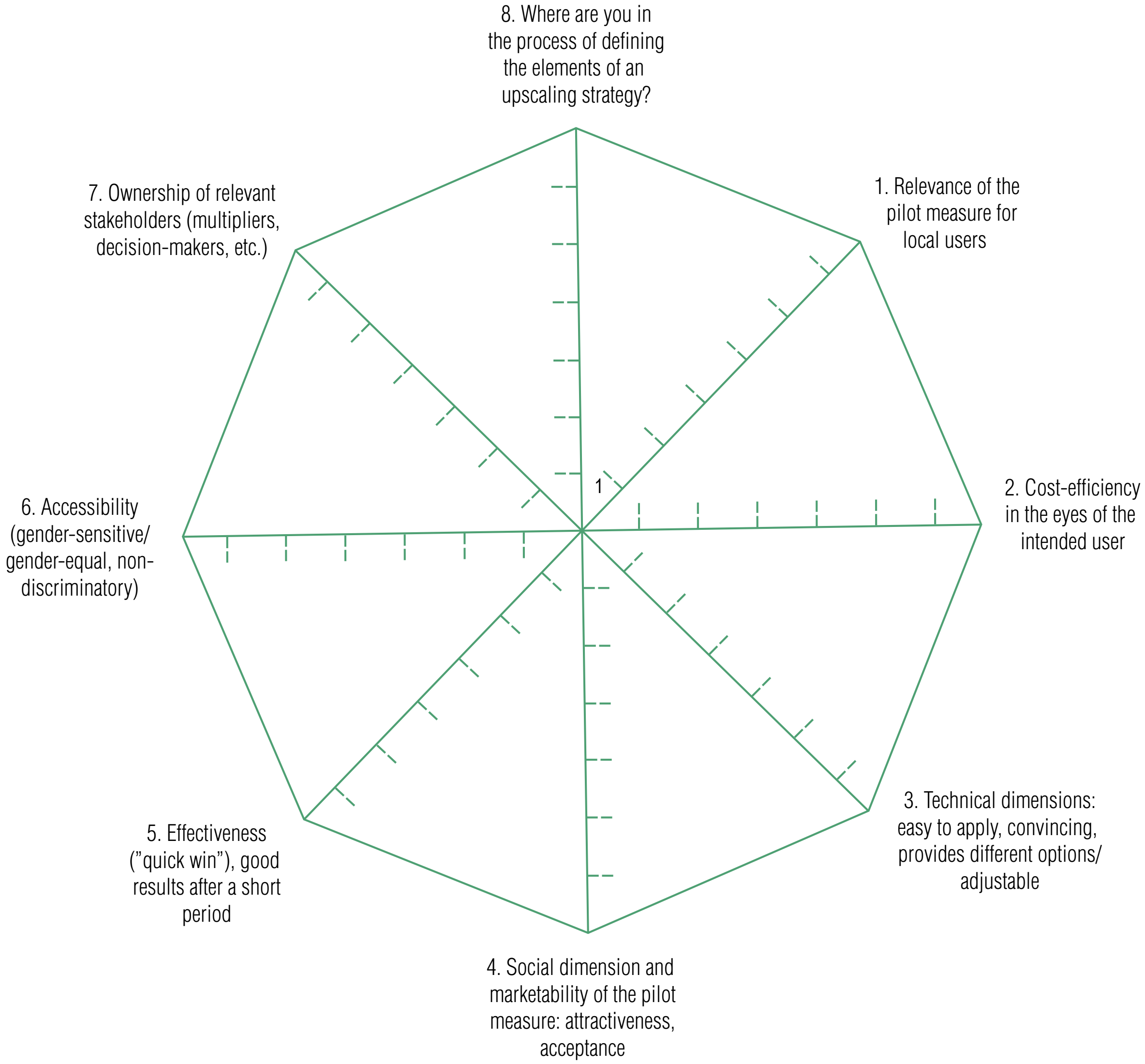


Figure 50: *Upscaling potential of particular pilot measures*

6. ANNEXES

6.1. Annex 1: Glossary of terms

NO.	ENGLISH	EXPLANATION
1	Afforestation	Afforestation is the establishment of forest cultures through planting or seeding on previously non-forested forest land and also on other purpose lands.
2	Deforestation	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	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	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	An ecosystem is a community of all living organisms in a given area (habitat).
6	Ecosystem services	Ecosystem services are the diverse benefits that are derived from the natural environment
7	Forest	Land with tree crown cover (or equivalent stocking level) of more than 10% and area of more than 0,5ha. The trees should be able to reach a minimum height of 5m at maturity in situ (FAO).
8	Grazing capacity	Grazing capacity is the carrying capacity of a pasture or area of the range usually expressed as the number of animals (cattle, sheep) that it will support for a specified length of time or indefinitely.
9	Gully	A gully is a ravine formed by the action of water and through which water often runs after rains.
10	Land degradation	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	Mulch/mulching	A protective covering (e.g. sawdust, grass, straw) which is spread or left on the ground to reduce evaporation, maintain even soil temperature, prevent erosion, control weeds, enrich the soil, etc.
12	Natural succession	Natural succession or “ecological succession” is the observed process of change in the species structure of an ecological community over time.
13	Planting scheme	The planting scheme describes the number of seedlings per ha and their spatial distribution, e.g. line planting, chess pattern or group planting schemes.
14	Planting technique	The planting technique describes how the seedling is planted, e.g. in trenches or in plant holes.
15	Prevention	Prevention implies the use of conservation measures that maintain natural resources and their environmental and productive functions.
16	Reforestation	“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.
17	Remote Sensing	“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.
18	Seedling	A seedling is a young plant that grows from a seed. Bare rooted seedlings are grown in tree nurseries on fields. Containerized seedlings are produced in special growing containers, usually in nurseries equipped with greenhouses and irrigation systems.

NO.	ENGLISH	EXPLANATION
19	Soil bioengineering	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.
20	Soil erosion	Soil erosion refers to soil losses in terms of topsoil and nutrients. It is a natural process in mountainous areas but is often made much worse by poor management practices. Rainfall, and the surface runoff which may result from rainfall produces four main types of soil erosion: splash erosion, sheet erosion, rill erosion, and gully erosion. Splash erosion is generally seen as the first and least severe stage in the soil erosion process, which is followed by sheet erosion, then rill erosion and finally gully erosion (the most severe of the four).
21	Upscaling/ scaling up	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.

6.2. Annex 2: List of planted tree and shrub species

NO.	SCIENTIFIC NAME (LATIN)	ENGLISH NAME
1	*Salix caprea*	Goat Willow
2	*Sorbus aucuparia*	Rowan (mountainous ash)
3	*Betula litwinowii*	Birch
4	*Rubus idaeus*	Raspberry
5	*Pinus sylvestris var. kochiana* *[syn. Pinus sosnowsyi]*	Scots Pine
6	*Rosa sp. L. (native varieties)*	Rosehip

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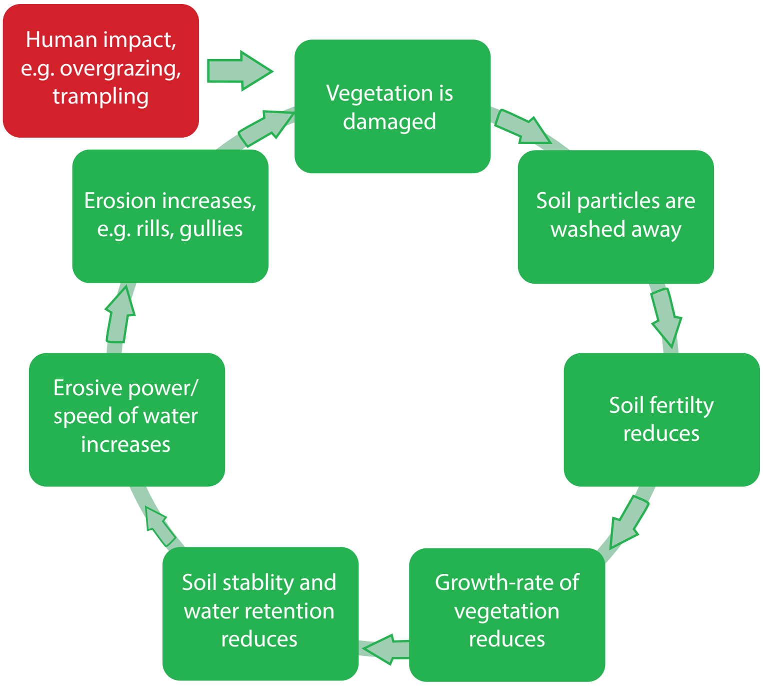
6.4. Annex 4: Fact sheets

Factsheet 1: Erosion assessment

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 lost, it is of uppermost importance to avoid soil loss by erosion whenever possible. The earlier the problem is observed, the easier are the preventive or erosion control measures. In case of inaction, erosion processes will accelerate.

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



The self-accelerating process of erosion underlines the importance of an early intervention

Factors that influence soil erosion

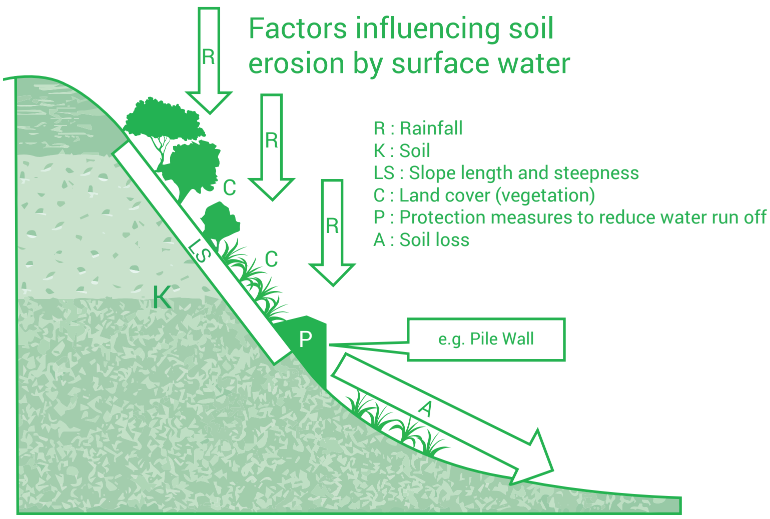
Natural factors

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

Effects of human activities

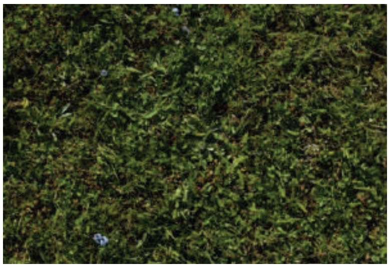
Disturbance of vegetation cover & soil stability through, e.g.

- Trampling of livestock
- Overgrazing
- Heavy vehicles



Factors influencing soil erosion caused by rain and surface runoff

Erosion assessment in the field

EROSION PHENOMENA	VISUAL ASSESSMENT	APPROPRIATE MEASURES
No erosion > 90% vegetation cover		No immediate action required Regular observation, if site has a natural high risk of erosion (e.g. steep slope, heavy rainfalls)
Beginning sheet erosion 70-90% vegetation cover		Temporary fencing (1-2 years) and vegetation will recover Reduce grazing intensity Using pasture rotation or lower livestock numbers
Medium/strong sheet erosion < 70% vegetation cover		Temporary fencing, mulching, sowing of grass, manure application Slope > 10°: Horizontal pile walls Slope > 30°: change of land use (hay meadow, forest, no use)
Rill erosion: rills up to 0.3m deep		Reduce grazing pressure Temporary fencing, pasture rotation or reduced livestock numbers Horizontal pile walls Mulching, sowing of grass, manure application
Gully erosion: rills deeper than 0.3m		Temporary fencing, mulching, sowing of grass, manure application Horizontal pile walls Check dams (if settlements or infrastructure are endangered)

Factsheet 2: Tree planting

General information

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

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

Needed materials & resources

Materials with the following specification are needed:

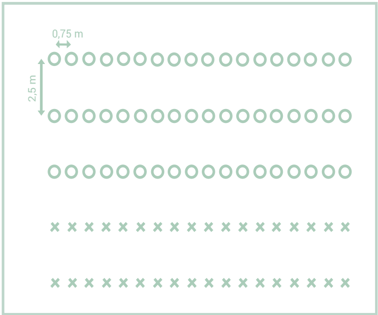
- → Tree seedlings: preferably local species adapted to site conditions.
- → Hole driller of spades: hole driller is recommended for larger afforestation activities as it substantially reduces working time.
- → Means of transportation for seedlings and irrigation water.
- → Water: 5-10l per seedling.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

Resources for 1ha afforestation:

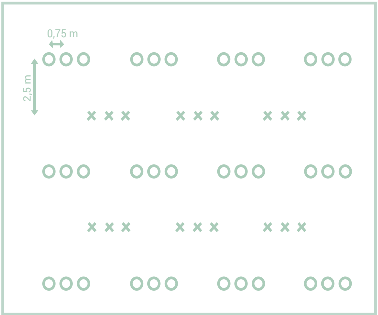
- 2,000-5,000 seedlings
- 10-50t water (for initial irrigation)
- 40 - 100 working days
- Shuffles or soil driller
- Means of transport

Planting scheme

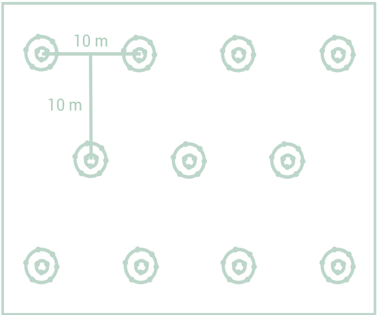
For afforestation of larger areas, select a planting scheme according to the specific site conditions:



Line planting scheme



Chess pattern planting scheme



Group planting scheme

Site preparation

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

Planting

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

Maintenance

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

Factsheet 3: Pile wall construction

General information

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

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

Needed materials & resources

Pile walls are established by using a combination of technical and vegetative construction materials. The technical requirements and workload are relatively low.

Materials with the following specification are needed:

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

Resources for 1 pile wall:

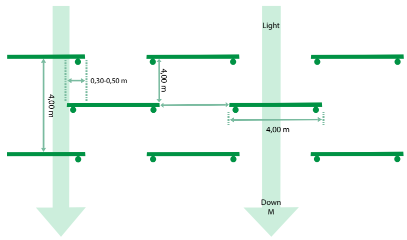
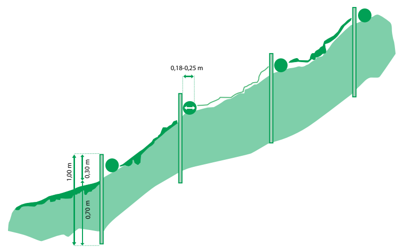
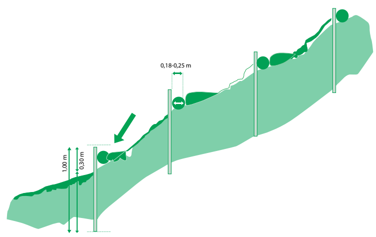
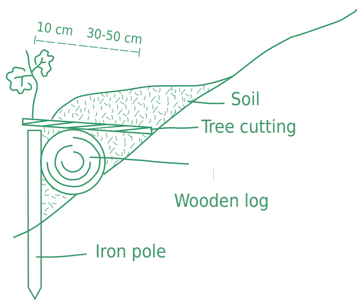
- 2 iron piles + a hammer
- 1 wooden log (or a bundle of branches)
- 10-20 tree cuttings (for a 2-4m long pile wall)

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

Preparation of the site

The establishment of a fence is important for protecting the area from trampling and grazing and enhancing the rehabilitation of the vegetation cover. The fence can be either a permanent (barbed or mesh-wire) or a temporary construction (electric fence). However, the fence should remain until sprouts from the tree cuttings grow up to 1.3m high to withstand the pressure caused by grazing.

Construction

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

Optional measures

→ Apply hay mulch on the terraces to cover the bare soil and to support vegetation growth (300-500g/m²).

→ Plant tree seedlings on the terraces (see Factsheet 2).

Factsheet 4: Gully plugging

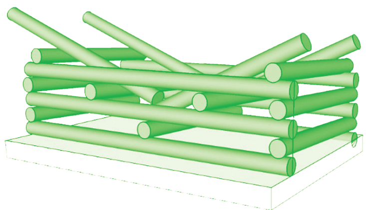
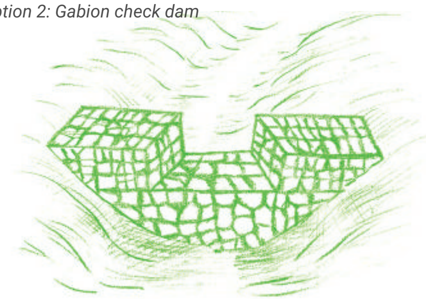
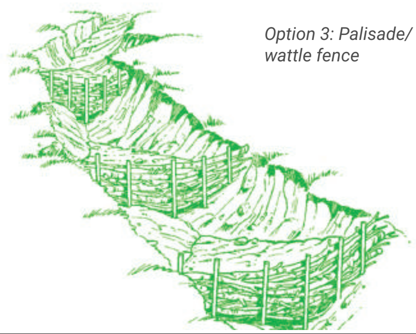
General information

Down streaming water has a strong erosive power and can form erosion gullies or channels. Especially steep slopes with scarce vegetation have a weak water retention capacity and are very susceptible to that kind of erosion phenomena.

Check dams are structures built across a gully or channel to prevent it from deepening further. In case of small gullies (less than 1.5m deep and 5m wide) the water velocity can be reduced significantly with relatively little efforts. Depending on the available materials, the dam for plugging the gully can be constructed either from wooden logs, branches or rocks or from a combination of different materials. Combined with the planting of tree and shrub cuttings or seedlings, such dams show immediate effects: they slow down the vertical water movement, increase water infiltration, and enhance the settlement of sediments.

Different construction types & needed materials

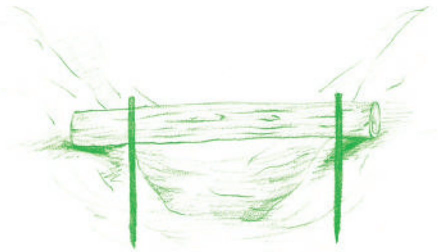
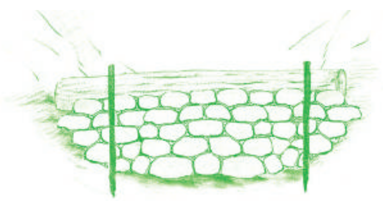
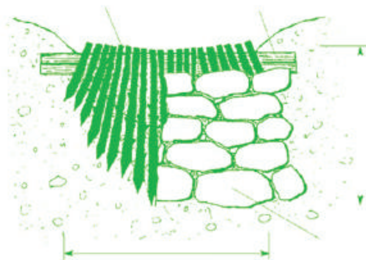
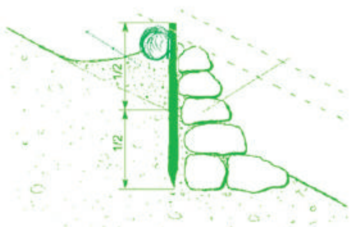
Depending on the topography of the eroded site (e.g., the depth and the width of the gully) and the available materials, check dams can be constructed in different ways. Three examples are presented below. Keep in mind that each situation may require its own improvised approach!

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

Construction of a palisade check dam

Materials for 1 unit:

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

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

Optional measures

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

Construction of a wooden check dam

WORKING STEPS	DESCRIPTION
Prepare the basement	• Ensure appropriate position of the basement according to the slope balance of the gully of blocking the complete gully width • Dig check dam basement; width and depth depending on the local situation • The excavated material should deposited above the basement to make a refillment of the structure easier 
Build the check dam	• Place first 2 logs across the gully • Place alternating layers of transverse and crossing logs • Connect crossing and transversal logs with nails • Fill the check dam with small and large rocks, existing soil (from the excavation)  
Build a discharge section	• Place wooden logs on the side of the structure to concentrate the flow in the centre of the checkdam 
Filling and plantation of the check dam	• Fill the check dam with small and large rocks, existing soil • Cover the top with flat rocks • Use hay to cover the bare soil areas • Place cuttings in between the check dam and on the sides 

Optional and maintenance measures

→ Flatten the adjacent gully shoulders to support revegetation.
→ Consider side “gabions” if water is damaging sides.
→ Plant and replant cuttings and shrubs for further stabilization.
→ Improve bottom section if damaged by floods.

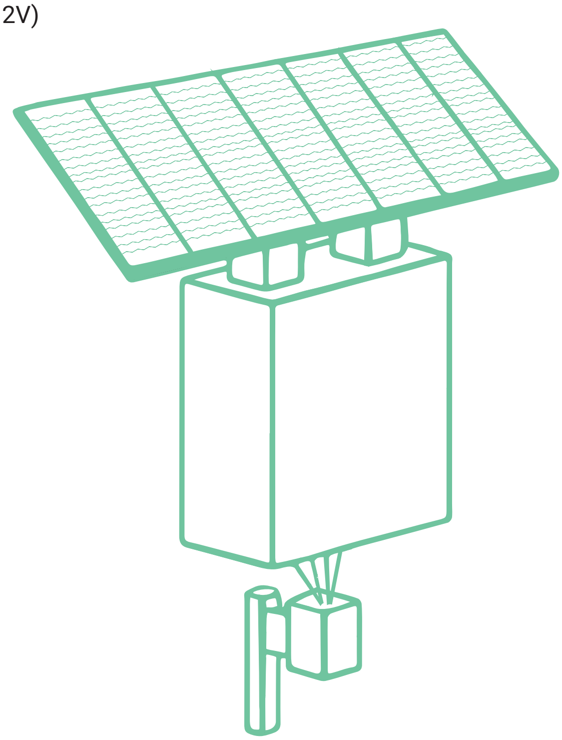
Factsheet 5: Electric fencing

General information

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

Needed materials

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



Solar panel and box containing energizer and battery

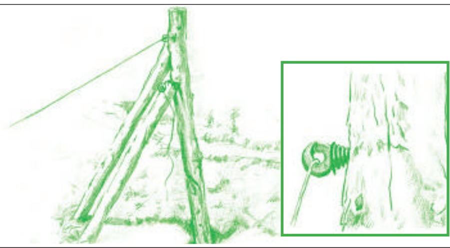
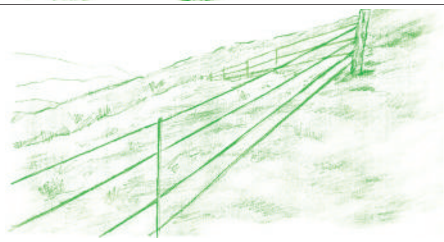
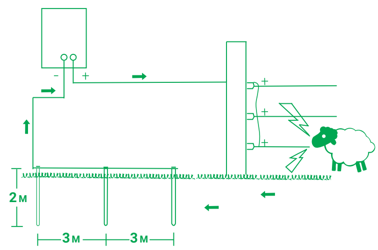
Selection of the appropriate system

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

Number and height of fence wires for different livestock:

Sheep: 4 wires, heights: 20, 40, 65, 90 cm above the ground.
Sheep and cattle: 3 wires, heights: 25, 55, 90cm.
Cattle: 3 wires, heights: 30, 60, 90cm or 2 wires, heights: 45, 90cm.

Set-up of an electric fence

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

Final check

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

Maintenance

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

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Integrated Biodiversity Management, South Caucasus (IBiS)
GIZ c/o Ministry of Environmental Protection and Agriculture
6, Gulua St., 0114 Tbilisi, Georgia
T +995 2 2201829-111
I www.giz.de;
www.biodivers-southcaucasus.org

Authors
Hanns Kirchmeir, Michael Huber, Anneliese Fuchs, Caroline Wegner, Johann Peter Rauch, Natia Kobakhidze

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Idea Design Group LLC

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Vahagn Mkrtchyan

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