Watershed Management and Landscape Restoration Opportunities Assessment for Sioni Reservoir Watershed System in Georgia

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WATERSHED MANAGEMENT AND LANDSCAPE RESTORATION OPPORTUNITIES ASSESSMENT FOR SIONI RESERVOIR WATERSHED SYSTEM IN GEORGIA

October 2022

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ABBREVIATIONS AND ACRONYMS

AA	Association Agreement
BFP	Biodiversity and Forest Policy
CHIRPS	Climate Hazards Group InfraRed Precipitation with Station Data
DEM	Digital Elevation Model
EEIC	Environmental Education and Information Center
EIA	Environmental Impact Assessment
ENPI East FLEG II	European Neighborhood and Partnership Instrument East Countries Forest Law Enforcement and Governance II Program
EU	European Union
EUWI+4EaP	EU Water Initiative Plus for the Eastern Partnership
FAO	Food and Agriculture Organization (of the United Nations)
FLR	Forest Landscape Restoration
FMNR	Farmer-Managed Natural Regeneration
GIS	Geographic Information System
GIZ	German Corporation for International Cooperation (*Deutsche Gesellschaft für Internationale Zusammenarbeit*)
HPP	Hydropower Plant
GVA	Gross Value Added
IUCN	International Union for the Conservation of Nature
LROA	Landscape Restoration Opportunities Assessment
LS	Length Steepness
LULC	Land Use/Land Cover
MDF	Municipal Development Fund of Georgia
MEPA	Ministry of Environmental Protection and Agriculture
MESD	Ministry of Economy and Sustainable Development
NAMR	National Agency of Mineral Resources
NDC	Nationally Determined Contribution
NDVI	Normalized Difference Vegetation Index
NEA	National Environmental Agency
NFA	National Forestry Agency
PoMs	Programme of Measures
PV	Present Value
RBMP	River Basin Management Plan
RECC	The Regional Environmental Centre for the Caucasus
REDD+	Reducing Emissions from Deforestation and Forest Degradation
ROAM	Restoration Opportunities Assessment Methodology
RUSLE	Revised Universal Soil Loss Equation
SDGs	Sustainable Development Goals

SWMCG	Solid Waste Management Company of Georgia
TOR	Terms of Reference
UNCCD	United Nations Convention to Combat Desertification
USAID	United States Agency for International Development
USLE	Universal Soil Loss Equation
UWSCG	United Water Supply Company of Georgia
WMLROA	Watershed Management and Landscape Restoration Opportunities Assessment
WRI	World Resources Institute
WWF	World Wildlife Fund

ABSTRACT

This assessment report presents the results of a study focused on the Sioni Reservoir watershed, which is subject to seasonal sediment loads affecting the sustainability of water for hydropower generation and irrigation. The study reveals the major causes of landscape degradation within target watershed and sediment loads to the Sioni Reservoir affecting the suitability of water for irrigation and the lifetime of the dam. The study also identifies the main interventions for landscape restoration and provides a brief analysis of the institutional and policy gaps and recommendations that are applicable for other watersheds in the region as well.

EXECUTIVE SUMMARY

The Context

Within the framework of a multi-donor trust fund established to facilitate the implementation of the Nationally Determined Contributions (NDCs) pledged by countries under the Paris Agreement in 2015, the World Bank has been working since 2020 to support certain activities aimed at raising the level of mitigation and adaptation to climate change in Georgia. One of these activities is to increase the climate resilience of irrigation reservoirs in eastern Georgia through landscape restoration and watershed management efforts aimed at regaining ecological functions and enhancing human well-being in degraded landscapes as well as reducing the rate of soil erosion and land degradation.

Purpose and Methodology

The study aimed to prepare a Watershed Management and Landscape Restoration Opportunities Assessment (WMLROA) for the area upstream and downstream of the Sioni irrigation water reservoir. The WMLROA methodology includes the following main steps: mapping and involvement of all stakeholders, identification of major issues causing degradation of watershed ecosystems, identification of priority areas for intervention, and elaboration of measures for landscape restoration. As indicated in recent studies[1] and confirmed by the analysis of the biophysical and socioeconomic environment of the watershed area, intensive sedimentation of the reservoir is one of the main challenges within the Sioni watershed area. Sedimentation of irrigation canals is due to suspended matter carried with the water extracted from Iori River which has high suspended sediment load, as well as with the water received from the Sioni Reservoir which may also be loaded with suspended matter due to sedimentation of intake areas. The study focused on soil erosion within the target watershed to confirm its estimated dynamics and associated risks. A geographic information system (GIS) supported application of the Revised Universal Soil Loss Equation (RUSLE) was used to enhance the accuracy of the assessment of soil erosion risk. The sedimentation study serves as a basis to undertake a Forest Landscape Restoration Assessment and prepare landscape opportunity maps for the target catchment using the Restoration Opportunities Assessment Methodology (ROAM). Identification of the priority areas for landscape restoration led to further steps of working out sets of

[1] http://jeb.co.in/journal_issues/201709_sep17_spl/paper_36.pdf.

potential interventions for landscape restoration followed by cost estimation of the recommended restoration measures. Finally, a program for implementing landscape restoration was formulated, which includes institutional, policy, and technical measures recommended to ensure landscape restoration within the Sioni Reservoir watershed and reduction of water-induced erosion.

Main Results and Recommendations

The baseline study reveals the following major causes of landscape degradation within the Sioni Reservoir watershed:

- Seasonal sediment loads to the Sioni Reservoir affect the suitability of water for irrigation and the lifetime of the dam. The Sioni Reservoir already lost approximately 75 percent of its volume due to the sedimentation process. Consequently, during annual flooding, the river overflows its banks, causing damage to the riverine area and posing potential threats to the population, infrastructure, and environment.
- Reservoir sedimentation is caused by intense soil erosion in the watershed area which, in turn, is a result of deforestation, unsustainable agricultural practices, and overgrazing.
- Extraction of sand and gravel from the Iori riverbed significantly distorts the natural equilibrium of the stream channel. By removing sediment from the active channel bed, in-stream mines interrupt the continuity of sediment transport through the river system, disrupting the sediment mass balance in the river downstream.

Based on restoration opportunity maps (developed using the RUSLE methodology and ROAM), field investigations, and consultations with local stakeholders, four critical interventions for forest landscape restoration (FLR) were recommended:

(a) Agroforestry on cropland in Chekuraantkhevi River valley

(b) Arrangement of a vegetated buffer strip on the left shore of the Sioni Reservoir as a natural barrier for runoff entering the water body

(c) Restocking of degraded forests and installation of sediment capture ponds in the catchments of small ravines on the left bank of the Sioni Reservoir

(d) Recultivation of worked-out and abandoned sand and gravel mines in the Iori riverbed and creation of buffer vegetation around ponds formed in the depressions of former mining sites.

The proposed WMLROA identifies ways to maximize the conservation of rainwater in land and the infiltration of water into the soil, thus reducing surface runoff and the consequent rate of water-induced erosion. Measures included in the assessment enable increased water security, delivery of ecosystem services, and economic growth for all irrigation schemes in the watershed, also estimating costs and suggesting institutional arrangements for the implementation of specific measures. **It is recommended that the proposed restoration options are validated and further refined at the stage of their design through more in-depth research of aspects and continued engagement**

with local stakeholders. Also, for the success of the proposed interventions, it is critically important to specify already outlined maintenance needs and ensure arrangements are in place for meeting them.

Although the study is focused on identifying technical gaps and providing relevant measures for FLR within the Sioni Reservoir watershed area, it also provides brief analyses of the institutional and policy gaps and recommendations that are applicable for other watersheds in the region as well. These are summarized as follows:

- Despite significant international commitments, currently, FLR is not adequately integrated into sectoral strategies and development plans. There is no clear policy for coordinating international processes related to forest restoration. Limited financial resources are available for investment in forest restoration.
- The understanding of the FLR concept is quite limited among the stakeholders, especially at the local level. The FLR concept is not properly integrated in the policies, legal acts, and regulations related to forest restoration. The limited knowledge and capacity of stakeholders regarding the FLR concept is an important constraint for planning and implementing relevant measures.
- **The provision of policy and regulatory basis for FLR integration into sectoral and regional planning and capacity building of related institutions are recommended to facilitate implementation of the proposed landscape restoration measures in the Sioni Reservoir as well as for establishing an enabling environment for FLR at the national level.**

The Sioni Reservoir WMLROA combines a variety of themes, such as water resources management, land degradation, irrigation systems improvement, sustainable forestry and reforestation, agroforestry and sustainable agricultural practices, and mineral extraction. Therefore, implementation of this assessment requires coordination and close cooperation of several governmental bodies at the national and local levels.

Establishment of a coordination council with the participation of key stakeholders, such as the Ministry of Environment Protection and Agriculture represented by the Department of Biodiversity and Forest Policy and the Department of Hydrology and Land Management as well as the National Forestry Agency; Agency for Sustainable Land Management and Land Use Monitoring; Georgian Amelioration LTD; and Tianeti, Sagarejo, and Gardabani Municipalities, is advised as a viable coordination and joint decision-making platform.

Limitations and Further Activities

- There was limited information available with regard to the current state of sedimentation for the Sioni Reservoir and for the head ponds of irrigation canals. Additional information is also required to refine watershed boundaries and stakeholders' objectives and to compare impacts of alternative options/scenarios. Further activities are proposed to fill these information gaps and to refine the proposed landscape restoration measures accordingly.

- Further activities may also include the refinement of some variables over selected watersheds and time frames (for example, land use change, climate and water flow inter and intra annual variability, population growth, mining, water balance, and social forest use), as well as the preparation of the overall seismic assessment and water balance.
- Additional activities may also include the potential use of valuation tools such as SWAT (Soil & Water Assessment Tool)[2] and InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs),[3] to check the validity of the results obtained with the RUSLE approach. The results could also be used to better represent the link between watershed/soil erosion and ROAM and the required stakeholder involvement.
- The above information would also be useful to map all relevant institutions, their current capacity, and the potential areas for improvement (for example, use of technology, new approaches, stakeholder consultation, and public outreach).

[2] https://swat.tamu.edu/.
[3] https://naturalcapitalproject.stanford.edu/software/invest.

1. INTRODUCTION

1.1. Background

Within the framework of a multi-donor trust fund established to facilitate the implementation of the Nationally Determined Contributions (NDCs) pledged by countries under the Paris Agreement in 2015, the World Bank has been working since 2020 to support activities aimed at raising the level of mitigation and adaptation to climate change in Georgia. One of these activities is to increase the climate resilience of irrigation reservoirs in eastern Georgia through landscape restoration and watershed management efforts to regain ecological functions and enhance human well-being in degraded landscapes as well as reduce the rate of soil erosion and land degradation.

The NDC/World Bank project for the *Preparation of Watershed Management and Landscape Restoration Plan for Areas Upstream and Downstream of Sioni Irrigation Water Reservoir* implies the identification and prioritization of landscape degradation hot spots, the selection of landscape restoration activities, and the preparation of the Watershed Management and Landscape Restoration Opportunities Assessment (WMLROA) for areas upstream and downstream of a targeted irrigation reservoir located in eastern Georgia, the Sioni Reservoir. This is a long-operated (1963) multi-purpose reservoir constructed across the Iori River, supplying irrigation water to the Zemo and Kvemo Samgori irrigation schemes and electricity to the national grid.

The Regional Environmental Center for the Caucasus (RECC) was appointed by the World Bank to prepare a watershed management and landscape restoration plan for the area upstream and downstream of the Sioni irrigation reservoir. This task includes the design and execution of soil erosion investigations in the target catchment, to confirm the mechanism of sedimentation processes affecting the reservoir and irrigation infrastructure. The RECC services also include scoping landscape restoration and watershed management activities, to be implemented immediately upstream and downstream of the Sioni Reservoir, that could reduce the rate of soil erosion and land degradation, increase the operational life of the reservoir, and increase the resilience of the irrigation schemes that are directly/indirectly fed from it.

1.2. Objectives and Scope of the Study

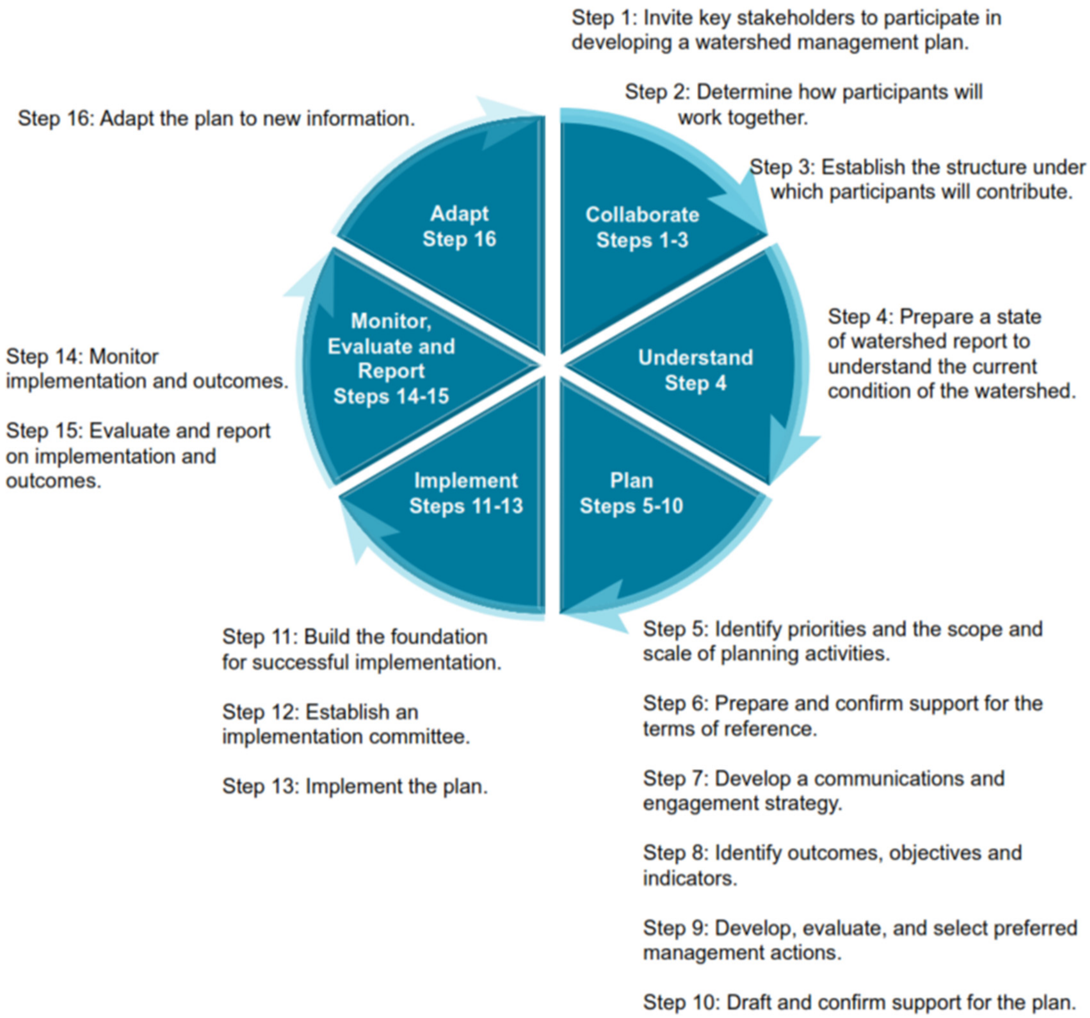
The WMLROA for the targeted catchment, the area upstream and downstream of Sioni Irrigation Water Reservoir, is the main output of the undertaken study. It supports the case for restoring landscapes and managing watersheds of other valuable irrigation schemes throughout eastern Georgia. The results can also help explore intervention opportunities to increase water security in the region and raise the ambition of Georgia's NDC in relation to the country's climate mitigation and adaptation goals. Furthermore, the outcome of the research undertaken toward development of the WMLROA will help in informing national and local government officials; private and public donors; and key stakeholders from the water, agriculture, and energy sectors about the benefits of landscape restoration and watershed management, thus soliciting their support and cooperation.

Preparation of the WMLROA involved three main tasks. **Task 1** consisted of undertaking a desk-based soil erosion assessment in the target catchment, which includes areas upstream and downstream of the Sioni irrigation reservoir, and producing the findings report. The sedimentation study served as a basis to undertake **Task 2,** which consisted of preparing landscape opportunity mapping for the target catchment, using the Restoration Opportunities Assessment Methodology (ROAM). **Task 3** consisted of preparing the WMLROA for the target catchment. The assessment included feasible management measures and physical interventions, using nature-based solutions, integration of gray and green infrastructure, and evaluation of their potential socioeconomic and environmental impacts. Task 3 also included capacity building through webinars and workshops focused on landscape restoration and watershed management practices, involving all relevant stakeholders.

1.3. Methodology

The term 'watershed' is intended, in this study, as a body of land where water from rain or snowmelt drains downhill into a body of water such as a stream, wetland, river, lake, or reservoir. Watershed management planning is a comprehensive process, which requires a dynamic and iterative approach and the use of best available information (Figure 1). Dealing with land use issues is a key prerequisite to the success of a watershed management plan.

Figure 1. Watershed management planning process



Source: Guide to Watershed Management Planning in Alberta, 2015.

Study Area Selection

The study area includes territories upstream and downstream the Sioni Reservoir covering the worked-out mining area and the Lapianiskhevi River valley which are considered two of the main sources of sedimentation of the Iori River (see Figure 3 in Chapter 2).

Stakeholder Identification and Involvement

Watershed management planning is a collaborative effort among agencies and groups who have shared interests in the long-term health and viability of their watershed. Therefore, all stakeholders that are potentially affected or interested in the decision shall be involved in the process. The stakeholders identify the watershed's resources, issues, and concerns and develop and implement a watershed management plan with solutions that are environmentally, socially, and economically sustainable.

To ensure the involvement of all stakeholders in the planning process, several webinars and workshops were conducted to discuss landscape restoration and watershed management practices. Stakeholder feedback was reflected in the WMLROA.

Participants of watershed management planning included the following institutions and groups:

- The Ministry of Environmental Protection and Agriculture (MEPA)
- National Forestry Agency (NFA)
- Georgian Amelioration, LTD
- Tianeti Municipality Assembly and Mayor's Office
- Sagarejo Municipality Assembly and Mayor's Office
- Agriculture extension centers in Tianeti and Sagarejo municipalities
- Agency of Protected Areas
- Georgia Irrigation and Land Market Development Project Implementation Unit within MEPA
- International Union for the Conservation of Nature (IUCN)
- World Bank
- World Resources Institute (WRI)
- German Corporation for International Cooperation (*Deutsche Gesellschaft für Internationale Zusammenarbeit*, GIZ).

The first workshop, held in September 2021, was organized to engage key local stakeholders in the landscape restoration opportunity mapping. It was followed by a series of consultation workshops at the local level and field visits which resulted in the identification of priority areas and suggested measures for landscape restoration within the target area. Identified measures have been presented and discussed on the workshops with local stakeholders in the municipalities located within the Sioni watershed (Tianeti and Sagarejo). A final workshop was held in January 2022 to consult with stakeholders the selected measures for landscape restoration and their financial-economic analyses.

Identification of Major Issues Causing Degradation of Watershed Ecosystems

The watershed assessment is an important step in planning. It describes the state of the watershed and human pressures. Subsequent watershed assessments will identify and report changing trends and conditions in the watershed. The watershed assessments serve as benchmarks by which environmental change can be measured.

Multidisciplinary approaches integrating the fields of geography, hydrology, landscape ecology, forestry, agriculture, social and economic sciences, and environmental engineering have been adopted to collect all available data characterizing the main features of the Sioni Reservoir watershed and revealing the main pressures and root causes, which are described in Chapter 2.

As indicated by the recent studies[4] and confirmed by the analysis of the biophysical and socioeconomic environment of the watershed area, the process of intensive sedimentation of the reservoir is one of the main challenges within the Sioni watershed area. Accordingly, a study focused on soil erosion within the target watershed was conducted at the assessment stage, to confirm estimated soil erosion dynamics and provide inputs for the assessment.

The study consisted of using a geographic information system (GIS) supported application of the Revised Universal Soil Loss Equation (RUSLE), to assess the soil erosion risk through a combination of contributing factors, including Rainfall Erosivity Factor (R), Soil Erodibility (K), Topographic Factor (length steepness [LS]), Crop Management (C), and Conservation Support Practice (P). The findings of the study, presented in Chapter 3 of this assessment, describe the processes through which sedimentation is generated in the reservoir and affects the Iori River and irrigation infrastructure downstream of the reservoir. A detailed description of the RUSLE methodology is presented in the same chapter.

Identification of Priority Areas and Measures for Landscape Restoration

The sedimentation study serves as the basis to undertake an assessment of FLR opportunities using ROAM. A detailed description of the FLR concept and ROAM is presented in Chapter 4 of this WMLROA.

An overview of the steps undertaken to identify the priority areas for FLR is described below.

The first step consisted of a mapping exercise to identify the areas potentially suitable for landscape restoration opportunities assessment (LROA), using a mix of available information and literature, satellite imagery, outputs of the soil erosion RUSLE model, and existing data sets (for example, land use and land cover change, soil loss, and land productivity loss). Altogether, six potential target areas were selected for further analysis (Figure 2):

(a) North and northeast of Tianeti

(b) Around the Sioni Lake (irrigation reservoir)

(c) Iori Reservoir (headwork of the Zemo Samgori irrigation scheme)

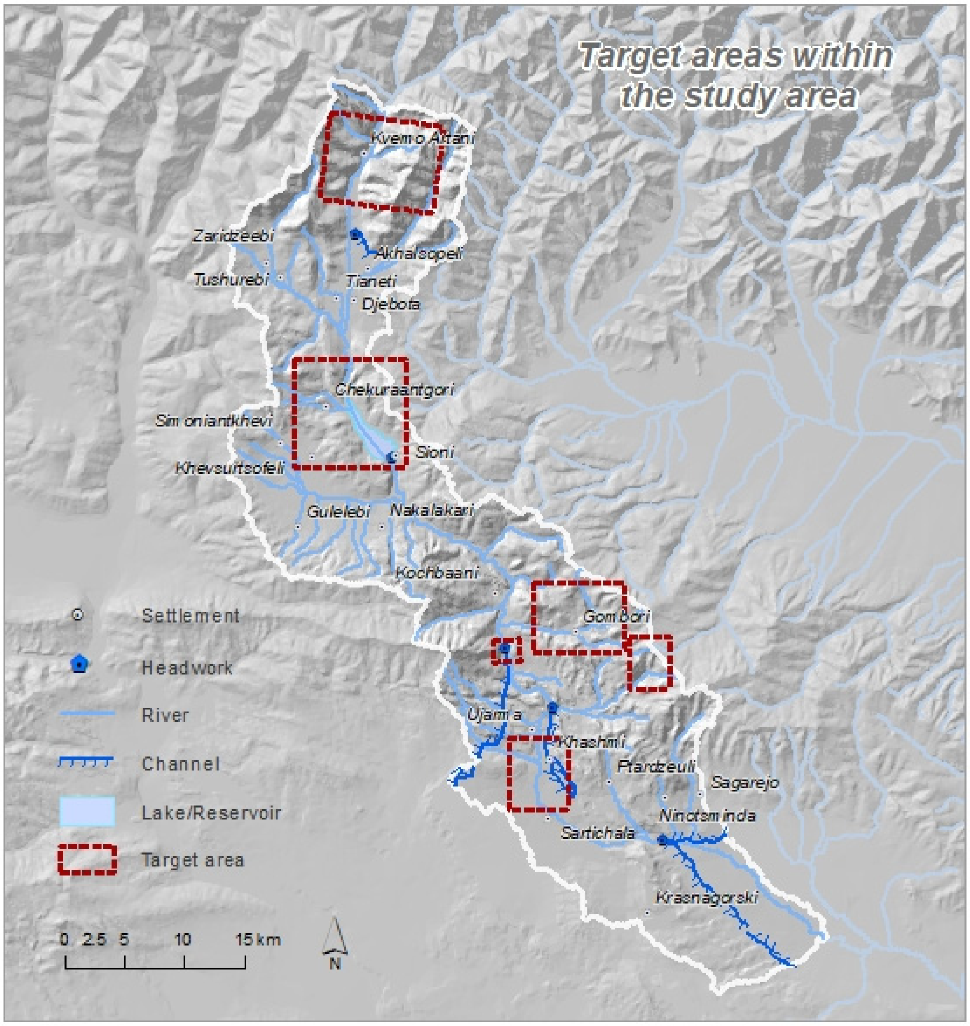
(d) Upstream of Gombori River

(e) Lapianiskhevi River

(f) Sediment quarries at midsection of the Iori River.

[4] http://jeb.co.in/journal_issues/201709_sep17_spl/paper_36.pdf.

Figure 2. Potential target areas for LROA



Source: RECC

The mapping exercise was followed by four field visits to refine the selection of target areas for LROA. The purpose of the field visits was to undertake visual inspection and field verification of preselected sites. Based on workshops and face-to-face consultations with local stakeholders, the list of priority areas was refined to cover places where active landscape restoration interventions are the most needed within the study area. The selection process is described below.

The visual investigation revealed that the area north and northeast of Tianeti does not show real potential for intensive soil erosion and thus sediment contribution to the Iori River and the Sioni Reservoir.

On the other hand, the areas **northeast of Sioni Lake and upstream of Qusno (Tushurebi and Zaridzeebi)** seem more interesting due to intensive agriculture practices and possible soil erosion, with an increased sediment load to the surface water bodies.

The same is true for another right tributary of the Iori and Sioni Reservoir— **the Chekuraantkhevi River**, especially the area upstream, with an intensive agriculture practice, and at the estuary to the Sioni Reservoir, where there is visible evidence of high sediment load into the lake.

The left bank of the Sioni Reservoir seems to have significant sediment load and pollution due to intensive vegetation loss, overgrazing, and deforestation. It is proposed for a possible restoration action, including vegetation management and controlled grazing for the prevention of untreated wastewater pollution and sediment load due to soil erosion.

The Lapiani-Khevi River, a left tributary of the Iori River—this site is characterized by a massive source of sedimentation of a natural character. A vast amount of mudflow is likely to happen anytime, by intense precipitation upstream, possibly exacerbated by landslides. Without a more detailed site survey, it is difficult to imagine any measure that could prevent sediment load in the river, although this would make a significant difference in general and improve the quality of water, both in terms of ecological status and its use as a source for household and irrigation purposes.

Sand and gravel quarry sites along the Iori River—the old mining sites are currently used as fishponds, operated by some private/commercial firms. These do not seem to contribute to sediment load entering the Iori River, although they possibly have a negative impact on its water quality. In this area, there are also several existing sand and gravel extraction sites, operated under the license of the mining agency of the Ministry of Economy and Sustainable Development (MESD), which appear to be significantly contributing to the sediment load entering the Iori River, thus severely affecting water quality. This environmental degradation is noteworthy and immediate measures are required to protect the operation of the irrigation schemes located downstream, the adjacent ecosystems, and the river.

Finally, based on field visits and consultations with local stakeholders, four critical areas for FLR interventions were selected:

(a) Chekuraantkhevi River

(b) The left bank of the Sioni Reservoir

(c) Catchments of small ravines on the left bank of the Sioni Reservoir

(d) Sand and gravel quarry sites at mid-flow of the Iori River.

The above-mentioned process of defining the priority areas for landscape restoration led to further steps for identifying potential landscape restoration measures. This was followed by the cost-benefit analysis of the suggested measures to be implemented in the study area. The results are presented in Chapter 4.

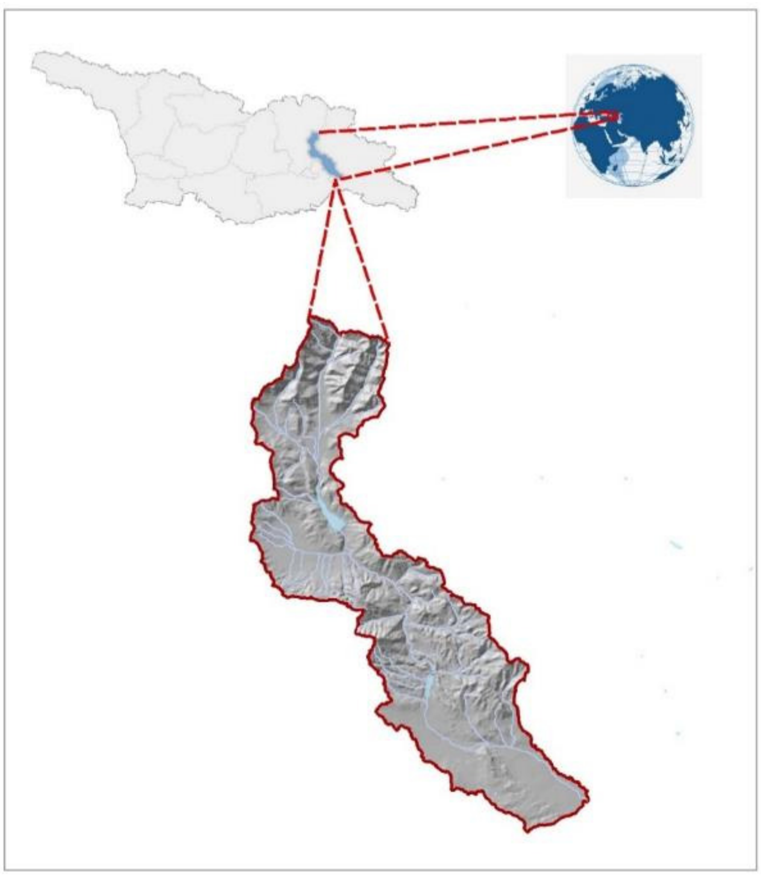
Finally, a program for implementing landscape restoration potential was formulated, including institutional, policy, and technical interventions recommended to ensure landscape restoration within the Sioni Reservoir watershed and reduce water-induced erosion. For ease of identification, the recommended measures are highlighted in ***bold and italic*** in the text.

2. CHARACTERISTICS OF THE STUDY AREA

The study area stretches upstream and downstream of the Sioni irrigation water reservoir (Figure 3). According to the discussions with stakeholders, the upstream area includes the catchment of the Sioni Reservoir, and the downstream area includes the confluence of the Lapiankhevi tributary as well as the nearby area with worked-out mines and the gravel extraction quarry located further downstream, which are considered the root causes of suspended sediments entering the Iori River.

The study area, which includes most of the Tianeti Municipality (Mtskheta-Mtianeti Region), part of Sagarejo Municipality (Kalheti Region), and the area of Sartichala community (Gardabani Municipality), has a total surface of 122,310 ha. The Iori River, which flows through the study area, originates in the Greater Caucasus Mountains in eastern Georgia and continues into Azerbaijan, where it flows into the Mingachevir reservoir. The Sioni Diversion Dam, a multi-purpose water retention structure located on the Iori River, impounds water in the Sioni Reservoir, which can store up to 325 million m^3 of water.

Figure 3. Location map of the study area



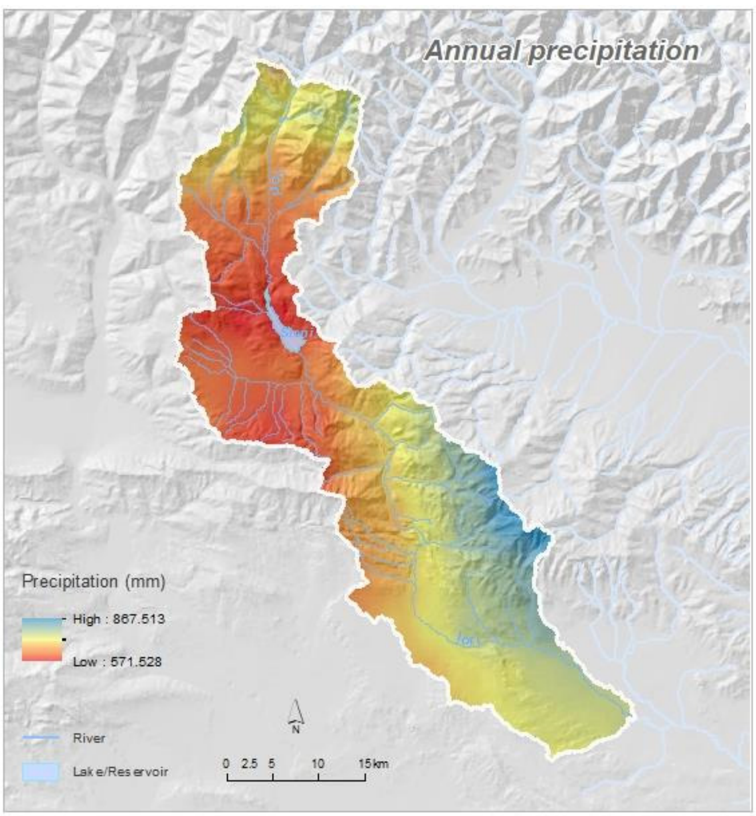
Source: http://orgenergomsheni.ge/en/sionhesi.html.

2.1. Geographic Overview

2.1.1. Climate: Precipitation and Temperature

In the upstream areas of the Iori river basin, the average annual atmospheric precipitation is 1,300–1,400 mm, while at the lower parts of the study area, it is in the order of 600–900 mm (Figure 4). The average maximum air temperature in the lower parts is within the range of +16°C to +19°C, while at highlands, it is within the range of 0°C to +8°C. The January mean temperature in the lower parts varies from −10°C to −2°C, and the July mean temperature is +19°C. In the high-mountainous areas, in January, mean temperature drops to −10°C and below, while in the lower parts, it fluctuates from −1°C to −3°C. The July temperature in the upstream of the river is +8°C to +19°C, while in the downstream, it is +22°C to +27°C. The average minimum air temperature in the lower parts is within the range of +7°C to +9°C. The absolute minimum in the upstream areas is within the range of −40°C and −28°C, and the absolute maximum ranges from +22°C to +36°C. The absolute maximum in the downstream is +39°C, and the absolute minimum is within −16°C and −7°C. Data provided by the meteorological stations operated in the area in different years are included in Annex 1.

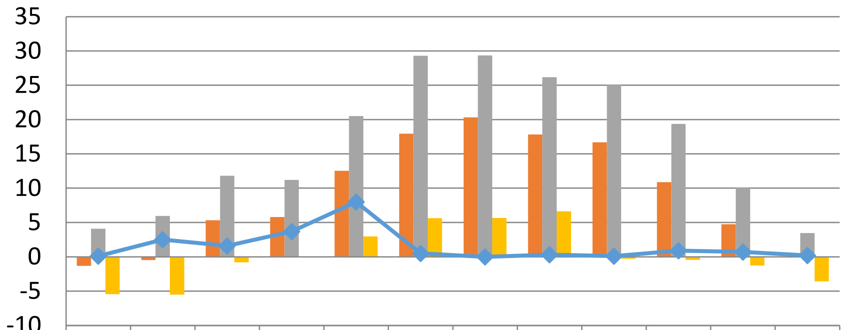
Figure 4. Precipitation map of the study area



Source: RECC

The meteorological station of the Institute of Geography near the Sioni Reservoir has been operating since 2018, providing useful overview of average monthly temperatures and precipitation (Figure 5).

Figure 5. Average monthly temperatures and precipitation for the Sioni Reservoir, 2020



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Temperature °C	-1.32	-0.49	5.32	5.78	12.52	17.94	20.31	17.81	16.67	10.88	4.73	0.54
Mean Maximum Temperature °C	4.08	5.96	11.81	11.21	20.51	29.3	29.34	26.18	25.12	19.37	10.06	3.45
Mean Minimum Temperature °C	-5.46	-5.52	-0.81	-0.07	2.97	5.62	5.64	6.62	-0.3	-0.47	-1.28	-3.59
Precipitation (mm)	0.1	2.5	1.6	3.7	8	0.5	0	0.3	0.1	0.9	0.7	0.2

Source: Institute of Geography.

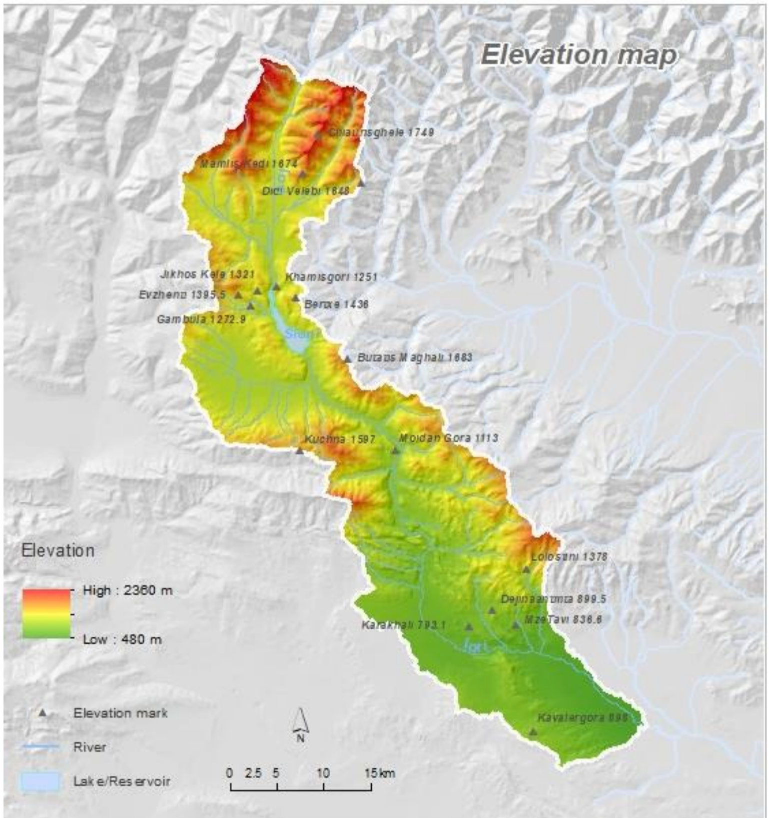
2.1.2. Topography: A Complex Terrain

The Iori River basin within the study area is located on the south slope of the Main Caucasian range. It stretches from northwest to southeast between the Kartli and Kakheti ridges. The river basin is stretched over the middle and low mountains of the southern slopes of the Greater Caucasus. More specifically, the extreme upper reach of the river basin is located on the southern slopes of the central part of the Greater Caucasus and the upper and middle reaches—in the Saguramo-Gombori middle-mountain area, bordered with Kartli and Gombori ridges.

The northern boundary of the study area runs along the Korsavi ridge. The study area is bordered by the Kartli, Zakari Seri, and Ialno ridges from the west and the Kakheti ridge from the east. The study area is characterized by a rather difficult terrain. There are many orographic elements within it (including the Chiauri ridge, Tsiv-Gombori ridge slopes, and Ialno ridge), which are separated by river valleys, ravines, and canyons, that give it a wrinkled look. The outermost southern part of the study area is characterized by less difficult terrain. A series of minor plateaus intersected by deep gorges and natural drains are mainly represented here.

The elevation within the study area ranges from 2,361 m in the highland to around 485 m in the floodplain, and the slopes range from 0 to 59.40 degrees (Figure 6).

Figure 6. Elevation map of the study area



Source: RECC

2.1.3. Geology and Hydrogeology: Two Tectonic and Two Hydrogeologic Zones

Mountainous areas of the Iori Basin belong to the Mestia-Tianeti tectonic zone of late Jurassic and Cretaceous carbonate flysch of the fold-and-thrust structure of the southern slopes of the Greater Caucasus, more specifically to the Djinvali-Gombori tectonic subzone. The flysch is mostly composed of sandstone, marl, limestone, and breccia (sedimentary rocks) mixed with porphyries and conglomerates. Tianeti and Ertso depressions are formed by quaternary sands, clays, and pebbles.

Downstream of the Sioni reservoir, in the middle reaches of the basin, the Mestia-Tianeti tectonic zone turns into the eastern zone of molassic deposits of the Iberian inter-mountainous depression, more specifically, into the Mukhrani-Tiriphoni subzone. This subzone is represented by Alazani sediments composed of thin layers of conglomerates and clays and Dusheti formations.

A small part of the basin in the middle to lower reaches is in the southern zone of the depression, namely in the Sartichala subzone. This subzone is composed of quaternary alluvial-delluvial-proluvial deposits of sedimentary rocks.

According to the hydrogeological zoning (Buachidze 1970) shown in Figure 7, the Iori River basin is part of the following two hydrogeological zones: east part of the Georgian plate Artesian basin zone and the fractured groundwater of the east slope of Javakheti Range (IV) and Artvini-Bolnisi belt groundwater zone (V)

From the east part of the Georgian plate Artesian basin zone:

- III $_{10}$ - Porous, fractured, and fractured/karstic artesian basin of Alazani
- III $_{11}$ - Porous and fractured water artesian basin of Iori-Shiraqi
- III $_{12}$ - Porous and fractured water artesian basin of Marneuli-Gardabani.

From the fractured groundwater of the east slope of Javakheti Range:

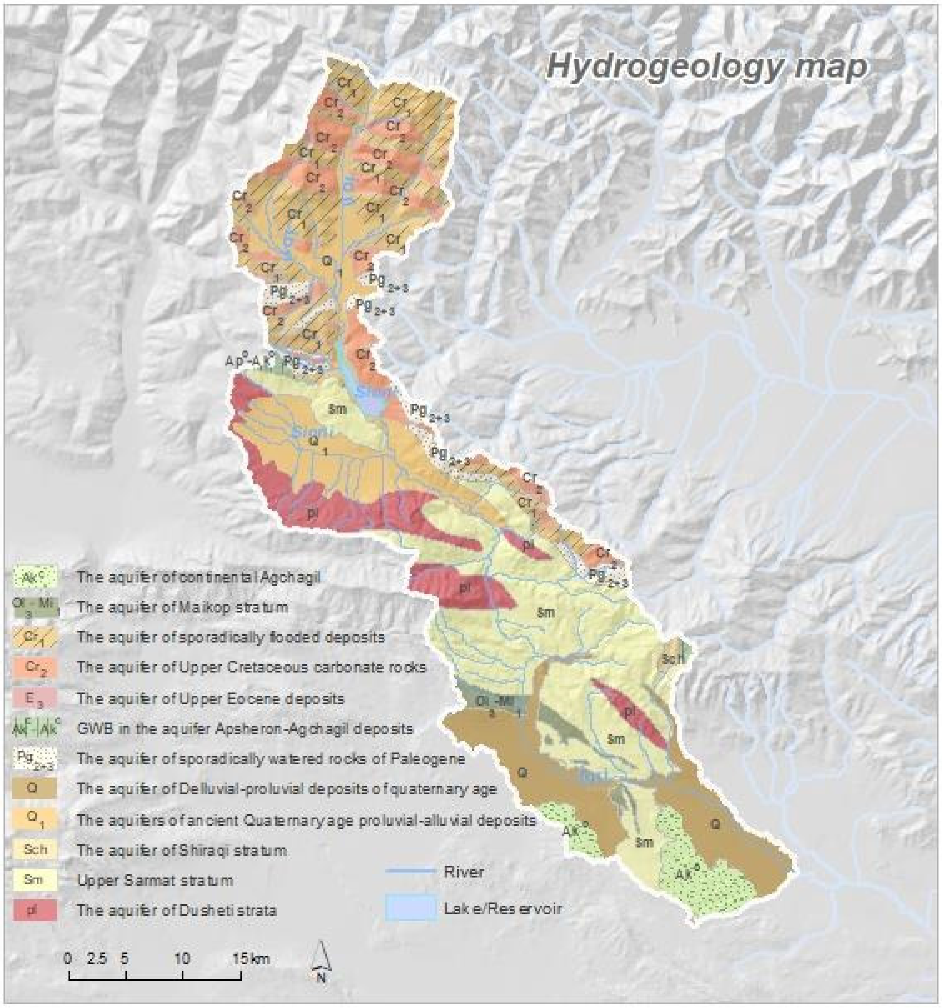
- IV - Pressured water system of Adjara-Trialeti fold mountain zone
- IV $_{3}$ - Fractured and fractured/karstic pressured water system of Tbilisi (Figure 7).

Groundwaters of the Iori Basin are represented by Mestia-Tianeti Basin of pore and fracture water, Iori-Shirak Basin of pore and strata water, and, to a lesser extent, Marneuli-Gardabani basin of pore and strata water and lower Kartli Plain artesian basin. Aquifers of the Greater Caucasus fold zone represented by the Mestia-Tianeti Basin of pore and fracture water are found in the upper reaches of the Iori Basin. These are mostly composed of terrigenous and carbonaceous flysch of the early and late Cretaceous and late Jurassic ages as well as of middle and early Jurassic shale stratum. Due to numerous fractures and karsts, limestone and sandstone are highly permeable and saturated with water. Outcrops of the terrigenous flysch are mostly met in the upper weathered zone (to 20–25 m) and have low flow rates, up to 0.2 L/s in shale formations and up to 6 L/s in sandstone interbeds.

Flow rates of the springs occurring in the limestone mainly exceed 1 L/s, in rare cases reaching 25 L/s. The carbonaceous flysch aquifer of the Late Jurassic period is built with 1,500 m-thick limestone, dolomite, and marl. Water in this aquifer has high flow rate of up to 70 L/s. The shale strata aquifer of the Middle and Early Jurassic age is mainly represented by a thick mass of clayey shale sediments of dislocated and fractured structure. It includes zones of intensive and restricted water circulation. Unconfined fracture groundwater circulates in the upper zone, with spring outputs ranging 0.02–0.1 L/s. In large faults, where the crystalline rocks thrust the shale mass, spring flow rates are much higher, reaching 5 L/s. Intermountain aquifers are represented by groundwaters of Iori-Shirak and Marneuli-Gardabani pore and strata water basins, built with merged river debris cones.

Groundwaters occur at the tops of the cones forming a single unconfined aquifer. In the center and periphery, where clays or clayey matrix occurs, these divide the single aquifer into the unconfined aquifer and several confined ones. An aquifer of the quaternary alluvial-proluvial sediments of 10–500 m thickness is widespread within Tiriponi-Mukhrani, Marneuli-Gardabani, and the Iori tableland.

Figure 7. Hydrogeology map of the study area

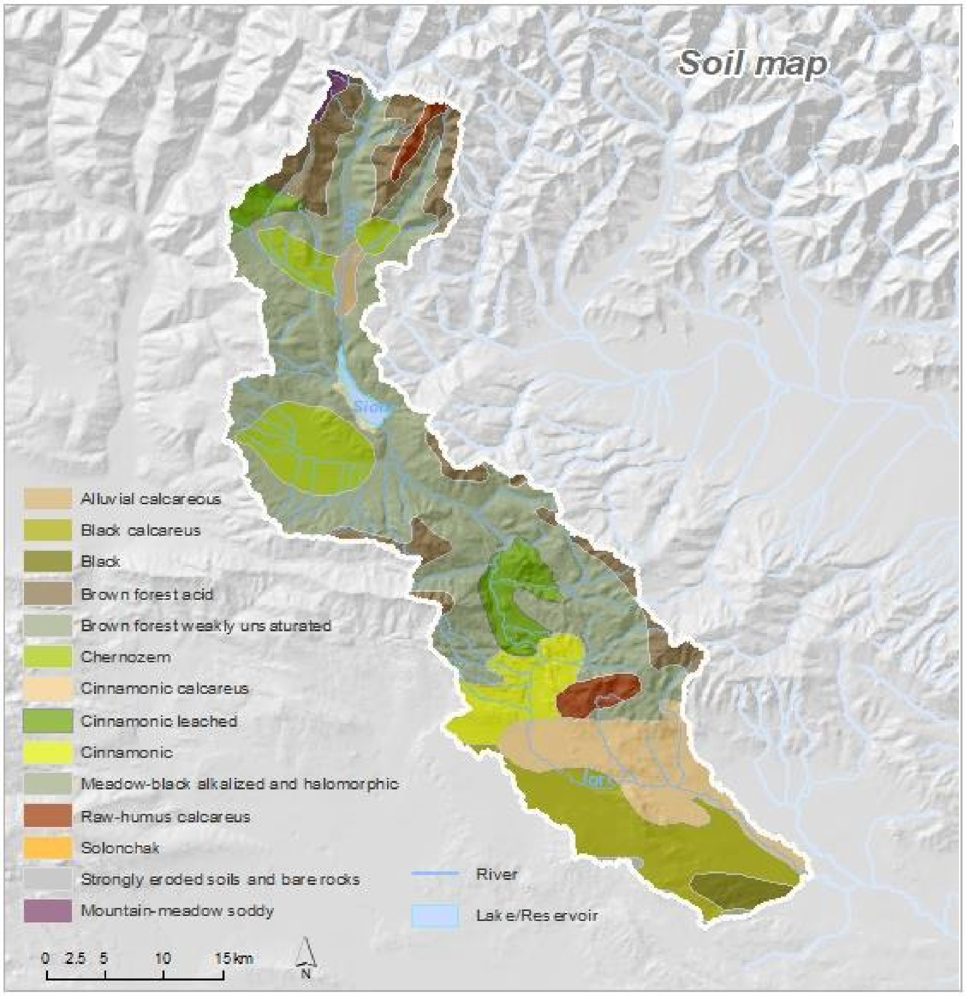


Source: RECC

2.1.4. Soils: Diversity of Eleven Types

Due to the complex climatic and biological conditions of the Iori River basin, soils in the target areas are diverse and represented by the following types (Figure 8): mountain-meadow soddy (andic cambisols), brown forest acid (umbric cambisols), brown forest weakly unsaturated (eutric cambisols); chernozem (aplic chernozem), alluvial calcareous (calcaric fluvisoils), cinnamonic (cnromic cambisols), cinnamonic calcareus, cinnamonic leached raw-humus calcareous (calcaric rendizians), black (vertisols), black calcareous, and strongly eroded soils and bare rocks (dystric or eutric lithosols).

Figure 8. Soil map of the study area



Source: RECC

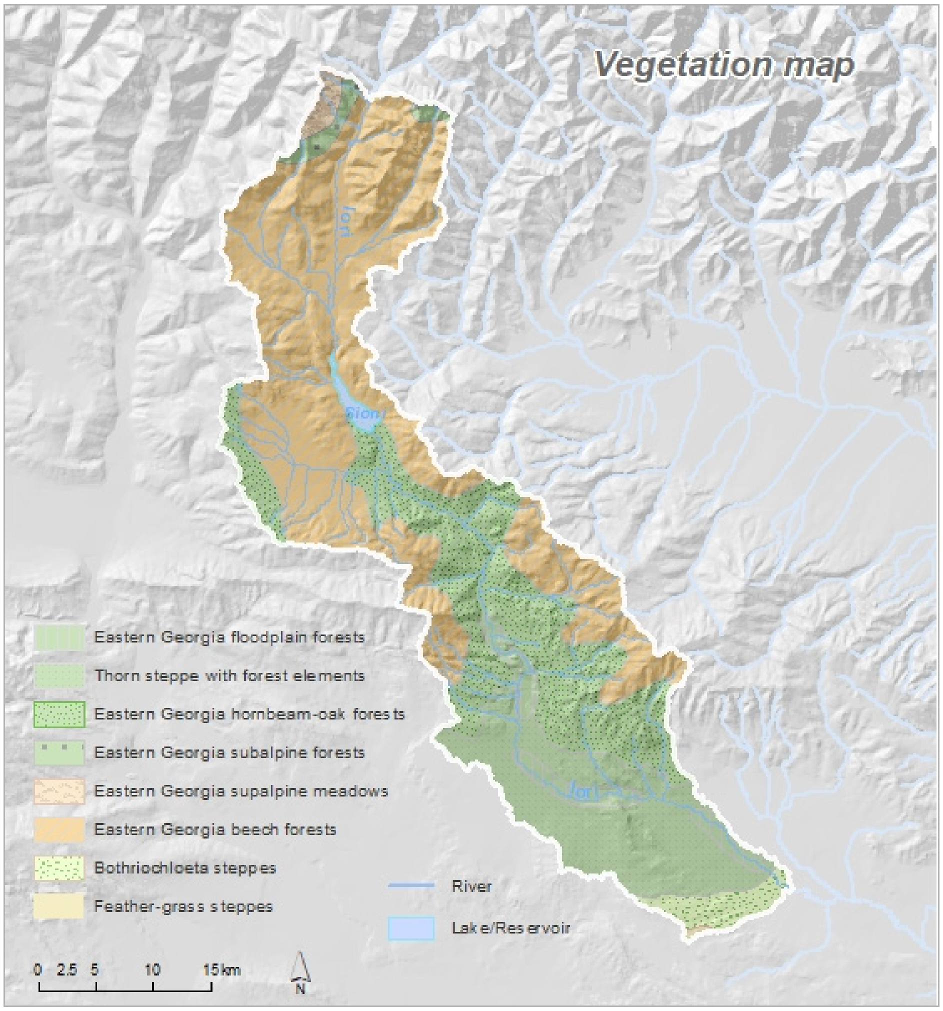
2.1.5. Landscapes: Hills and Mountains

The study area is predominantly hilly and mountainous, represented by five types of landscapes: (a) sub-Mediterranean semi-humid, hilly, erosion-accumulative, with oak and hornbeam derivates; (b) low-mountainous moderately warm, erosion-denudative, with hornbeam and oak forests; (c) mid-mountainous moderately warm, erosion-denudative, with beech forests; (d) upper-mountainous, cold, erosion-denudative, with high-mountain subalpine forests; and (e) high-mountainous meadow, denudative, paleoglacial, with subalpine meadows.

2.1.6. Vegetation, Land Use, and Biodiversity

Middle-mountain, low-mountain, and foothill landscapes are represented within the study area with broad-leafed forests of beech hornbeam, oak, ash-tree, elm, and so on at an altitude between 600 m and 1,900 m (Figure 9).

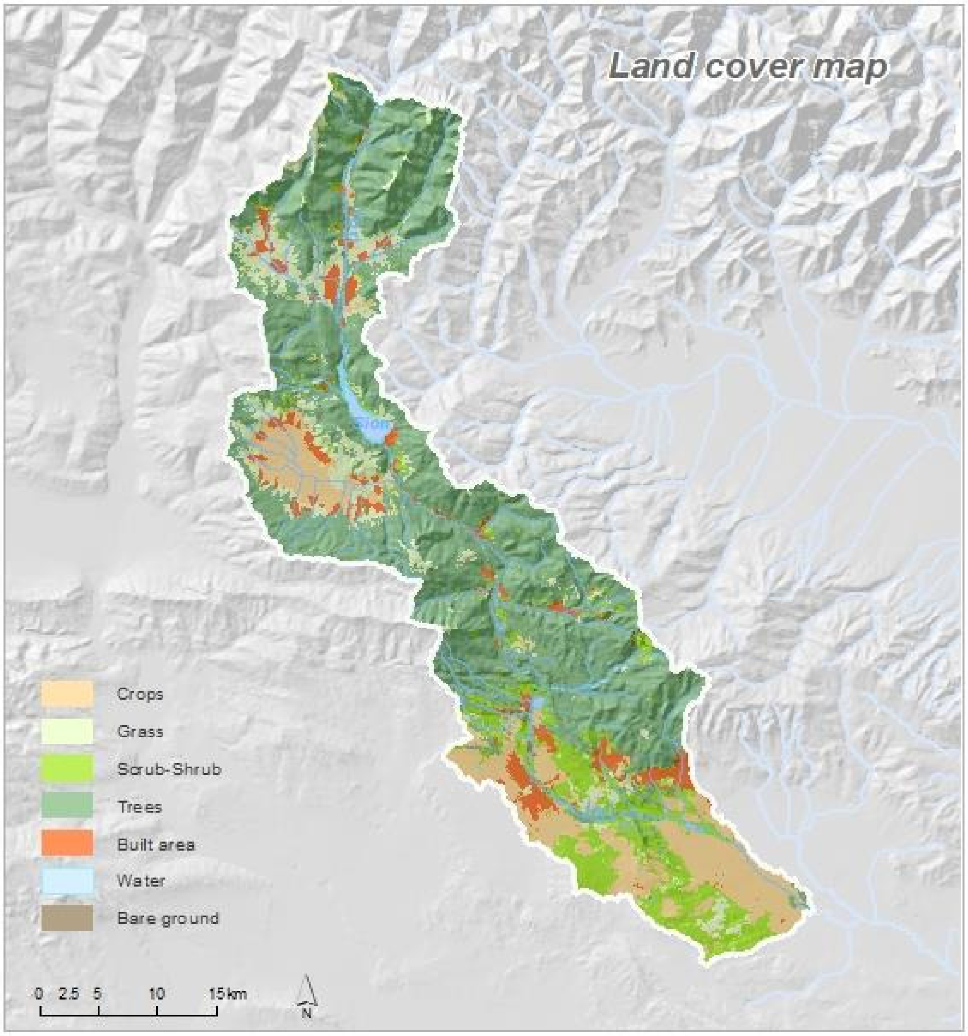
Figure 9. Vegetation map of the study area



Source: RECC

The southern part of the study area, mainly within Sagarejo and Gardabani municipalities, is occupied by arable lands and perennial plants (Figure 10).

Figure 10. Land use map of the study area



Source: RECC

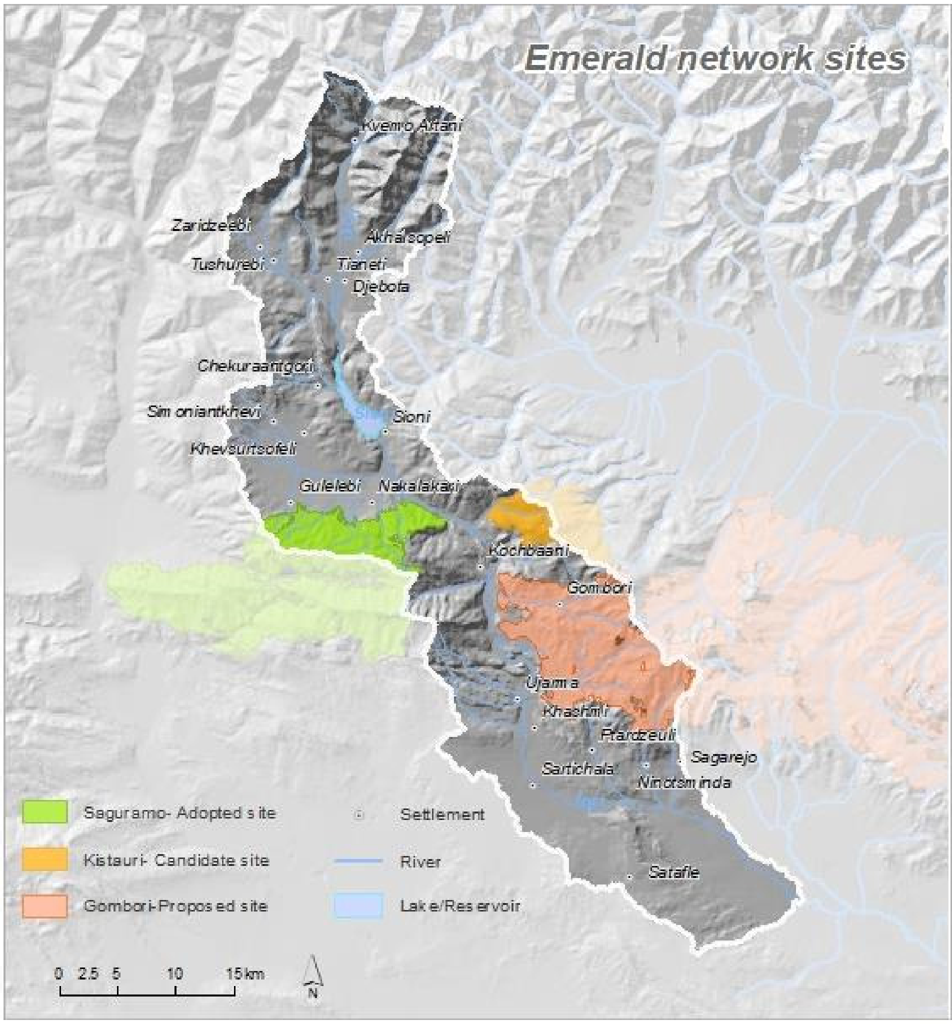
The study area is rich in biodiversity. It has a high diversity of landscape and biological species. Mesophilic mountain forest landscape is the most peculiar and diverse landscape in Georgia, which is part of the study area too. The forest is characterized with a rich diversity of plant and animal species with a high proportion of endemic species.[5]

A part of the Tbilisi National Park (designated protected area) falls in the study area. The park is rich in flora and fauna, including species entered in the Red List of species of Georgia, and endemic and relict species.[6] Eight critically endangered species, nine endangered species, and 37 vulnerable species are believed to be present within 50 km of the study area.[7]

[5]http://biodiversity-georgia.net/index.php?pageid=905.
[6] https://apa.gov.ge/en/biomravalferovneba/tbilisis-erovnuli-parkis-biomravalferovneba.
[7] https://www.ibat-alliance.org/.

Parts of three Emerald Network[8] sites are also located within the study area[9] (Figure 11): Saguramo (site code: GE0000047), approved; Kistauri (site code: GE0000055), candidate; and Gombori (site code: GE0000027), proposed.

Figure 11. Emerald Network sites within the study area



Source: RECC

2.2. Water Resources

2.2.1. Hydrographic Network

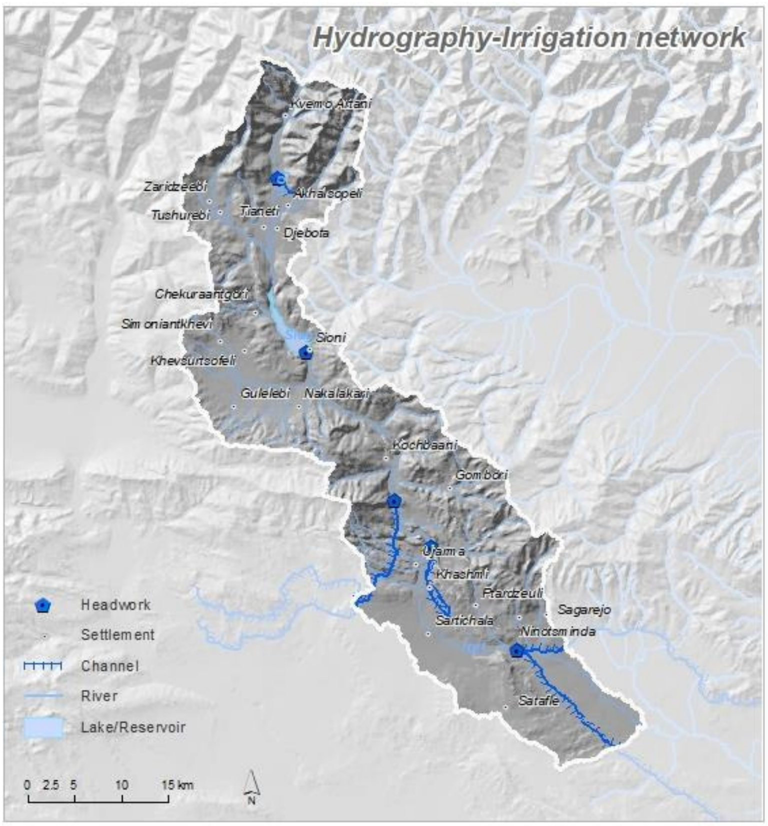
The Iori River starts from the southern slope of the Caucasus range near the confluence of Kakheti and Kartli slopes, at 2,800 m altitude. The river has tributaries only in the upper body. It flows in the narrow gorge, in its middle body crosses the Samgori cave, and enters the Mingechavir Reservoir

[8] The Emerald Network is a European ecological network with the goal to preserve the biodiversity of Europe. Its establishment is one of the requirements of the Convention on the Conservation of European Wildlife and Natural Habitats (known as the Bern Convention, adopted at Bern on 19 September 1979).
[9] Source: https://emerald.eea.europa.eu.

(which in the past was used to join the Alazani River). The Iori River is 320 km long (313 km in Georgia and 7 km in Azerbaijan). About 107 km section of the Iori River is located within the study area, from confluence of the Korsaviskhevi River to the Korugi Managed Reserve.

The following tributaries flow into Iori within the study area: Rivers Soplinura, Gorkhashiskhevi, Artnula, Kuskheura, Sakhevis-Khevi, Skhlovani-Khevi, Bodakheura, Sagami, Sachure, and Kusno flow into the Iori upstream of the Sioni Reservoir, which is located 56 km downstream of the river head. River Chekuraantgorikhevi flows directly into the Sioni Reservoir. Below the Sioni Reservoir, the following tributaries join the river within the study area: Adzedzi, Orvili, Vashliani, Gorana, Gombori, Laphiankhevi, Baghliatkhevi, Kalotkevi, and Tvaltkhevi.

Figure 12. Hydrography-irrigation map of the study area



Source: RECC

2.2.2. Surface Water Resources: Iori River and Its Four Tributaries

Annual flow of the Iori River is 341 million m^3. According to a series of hydrological observations (1934–1993), the multiyear average runoff of the river is 15.1 m^3/s, at 75 percent probability - 12.6 m^3/s, and at 97 percent probability - 9.32 m^3/s; maximum runoff is 838 m^3/s at 1 percent probability, 707 m^3/s at 2 percent probability, 524 m^3/s at 5 percent probability, and 445 m^3/s at 10 percent probability.

In the midstream and downstream parts of the basin, water is scarce. The runoff rate ranges within 5.00–2.80 L/s per km^2.

Iori is fed by snowmelt, rainfall, and groundwater, with the following contribution: groundwaters - 39 percent, rainfall - 33 percent, and snowmelt - 28 percent. Groundwaters have the highest importance in the lower reaches. The flow regime of the river is characterized by the uneven annual distribution of the runoff, with spring floods, summer-fall high waters and flash floods, and winter steady low waters. Over 40 percent of the annual flow occurs in spring, 27–33 percent in summer, 16–17 percent in fall, and 8–14 percent in winter. However, in the wintertime, the flow regime is characterized by instability year after year and in some years equals the summer flow. The minimum flow is observed in winter (December–February) and equals 8–14 percent. High waters during the spring floods, caused by the melting of seasonal snows and rainfalls, usually start in March, in the lower reaches of the river—in the second half of February—and achieve the maximum in May–June. Floods continue till the end of July and are accompanied by low short rain peaks. The summer–fall season floods, provoked by intensive rainfalls, reoccur every year, 3–6 times a season with the duration of 2–10 days. High waters often reach the maximum levels during the spring floods. The winter low-water level is steady, its fluctuation does not exceed 0.1 m, and in separate years, the water level stays on the same mark for 10–30 days. The lowest daily minimums have been observed in January and early February. The highest sediment discharge and concentration have been observed during the spring floods. The maximum sediment load from monthly averages is observed at the river head in April and in low waters in June. The minimal sediment load is observed in winter (January–February). The sediment concentration changes significantly along the river. Ice conditions in downstream waters are noticed rarely. According to the survey data, on average there are 33 days with ice phenomena. During the low water level, the water in the river is clean, transparent, and good for drinking.

The following is a brief description of the major tributaries of the Iori River within the study area:

The Kusno (Verkhveli) River flows through Tianeti Municipality and is a right tributary of the Iori River. It originates on the eastern slope of the Kartli Range at 1,985 m asl. Its length is 20 km, and the catchment area is 88 km^2. It is fed by rain, snow, and groundwater. Water level is high in spring and low in winter. Heavy rains cause flash floods in summer and autumn. The average annual discharge is 1.3 m^3/sec. The water is used for irrigation.

The Adzedzi River takes its origin from springs situated on the south branch of the Kartli Range, 3 km west from the village Simoniaskhevi at an elevation of 1,198 m. It flows into the Iori River from the left bank, about 259 m from its origin near the village Orkhevi. The length of the river is 16 km, total fall of the river surface is 223 m, average slope is 13.9 percent, the area of the watershed is 162 km^2, its average height is 1,240 m, total length of the tributary network is 134 km, and total density is 0.82 km/km^2. The basin is developed to the right-bank direction; 64.8 percent of the whole basin is located here. The river slightly meanders and is not branched. The width of the river varies from 2 m to 4 m, mostly around 3 m. The depth varies from 0.1 m up to 0.24 m, mostly 0.2 m. The velocity of the river changes from 0.6 m/s up to 1.2 m/s. Annual flow of the river is characterized by high water level and floods in spring and low water level in summer and winter. The flooding period starts in March and reaches its maximum in the middle of May. In this period, the water level is 1–1.2 m, and in some years, the water level increases to 1.6–1.8 m. The high-water-level period ends at the end of June. After the high-water-level period, summer starts, with an uneven low-water period. During the summer, a rapid increase of the water level in the river and flooding can be observed because of heavy rains.

The Lapiankhevi River is a torrential river in Sagarejo Municipality, a left tributary of the Iori, originating on the western slope of the Gombori Range at 1,620 m. Its length is 11.5 km, and the catchment area is 51 km^2. It is fed by rain, snow, and groundwater. The water level is high in spring and low in summer and winter, and floods are common in autumn. The average annual discharge is 0.5 m^3/s.

The Gombori River flows down the southwest slope of the Gombori Range, originating close to the Gombori Mountain pass at 1,550 m asl and joining the Iori from the right at the village Otaraantkari. The river length is 13 km. It is fed by rain, snow, and groundwater. The water level is high in spring and low in winter.

2.2.3. Irrigation Network: Reservoir, Headworks, and Canals

Above the Sioni Reservoir, in the opposite direction of the river stream, near the village of Mamadaani, Tianeti Municipality, there is the **Chabana-Gojiani irrigation canal** that was used in the past to supply irrigation water to the homestead plots of Chabano, Duluzauri, Akhalsopeli, and Gojiani communities of Tianeti Municipality through the pipeline and, if necessary, mobile pumping units. At present, this irrigation canal is dysfunctional and needs rehabilitation.

The multi-purpose Sioni Reservoir, operated since 1963, is supported by an earth dam designed as 84.8 m high and 780 m long structure. Its purpose is to regulate the Iori River runoff, irrigate 68,400 ha of agricultural land in the Kakheti and Kvemo Kartli Regions, fill the Tbilisi Sea,[10] and operate five hydropower plants (HPPs)[11] on the Sioni-Paldo–Tbilisi Sea tract. The useful volume of the reservoir is 315 million m^3, and the dead volume is 10.0 million m^3. The normal flood level of the reservoir is 1,068.3 m, while the level of forced flooding is 1,070.3 m. There are two discharge gates in the Sioni Reservoir: one discharges water for hydropower generation and the other discharges water for irrigation. Both have a calculated flow rate of 25 m^3/s. The estimated discharge of the emergency runoff canal of the dam is 600 m^3/s. The calculated spill from the emergency runoff canal of this dam is 600 m^3/s.

Operation of the Sioni Reservoir during the irrigation season responds to the water demand in the service areas, while outside the irrigation season, it depends on the volume of accumulated water in

[10] A freshwater artificial reservoir termed as 'sea'.
[11] Sioni HPP with installed capacity 9 MW, Satskhenisi HPP with installed capacity 14 MW, Martkopi HPP with installed capacity 3.9 MW, Tetrikhevi HPP with installed capacity 12.4 MW, and Tbilisi Sea HPP with installed capacity 0.4 MW. https://esco.ge/ka/kvalifitsiuri-satsarmoebi/small-power-plants.

the Sioni Reservoir. In recent years, in the context of global climate change, due to the sharp decline in precipitation in eastern Georgia, the Sioni Reservoir is not being filled up to its capacity. Hence, water is mainly released only during the irrigation season.

Another major reason that affects the sufficiency of water for irrigation is the seasonal sediment load to the Sioni Reservoir. Sedimentation shortens the lifetime of the reservoir and damages the dam, as confirmed by the latest bathymetric survey of 2016. The Sioni Reservoir has already lost approximately 75 percent of its volume. A recent study[12] indicates that the territory adjacent to the Sioni Reservoir is under risk. The sediment accumulation above the reservoir raised the riverbed by 3–5 m. Since 2015, during annual floods and freshets, the river overflows its banks, causing damage to the riverine area and posing threats to the population, infrastructure, and environment. It is forecasted that, in the short term, the silting prism and riverbed parameters will change by 15–20 percent, posing a significant risk to the neighboring settlements. Due to excessive siltation, floods of the magnitude usually occurring in every two decades have become a serious threat with potentially disastrous consequences.

The Iori River runoff, regulated by the Sioni Reservoir, is distributed by the **Paldo Headworks** between the Upper and Lower Samgori Irrigation Systems.

The water running in the lower stream of the Paldo Headworks feeds the **Khashmi Irrigation System,** whose carrying capacity does not exceed 1 m^3/s. It serves 200 ha of agricultural land in the village of Khashmi, Sagarejo Municipality.

In the lower part of the study area, there is a headwork of the Kvemo Samgori Irrigation System, which supplies water to the left and right main canals. The Kvemo Samgori Irrigation System, with the capacity of 21.0 m^3/s on the left main canal and 9 m^3/s on the right, serves 21,259 ha of agricultural land in Sagarejo, Gurjaani, and Sighnaghi Municipalities.

2.3. Human Activities and Water Use

2.3.1. Population: Three Towns and 104 Villages

The study area covers parts of two municipalities: Tianeti (Mtskheta-Mtianeti Region) and Sagarejo (Kakheti Region) Municipalities. Area of Sartichala community (Gardabani Municipality, Kvemo Karti Region) is also located within the study area.

There is one urban settlement (town Sagarejo), two small towns (Tianeti and Sioni), and 104 villages within the study area. Out of the 104 villages, 84 are in Tianeti Municipality, 18 villages are in Sagarejo Municipality, and 2 villages are in Gardabani Municipality.

According to the 2014 General Population Census, the population of the study area numbered 38,662, of which 37 percent lived in urban settlements and 63 percent lived in rural areas.

[12] http://jeb.co.in/journal_issues/201709_sep17_spl/paper_36.pdf.

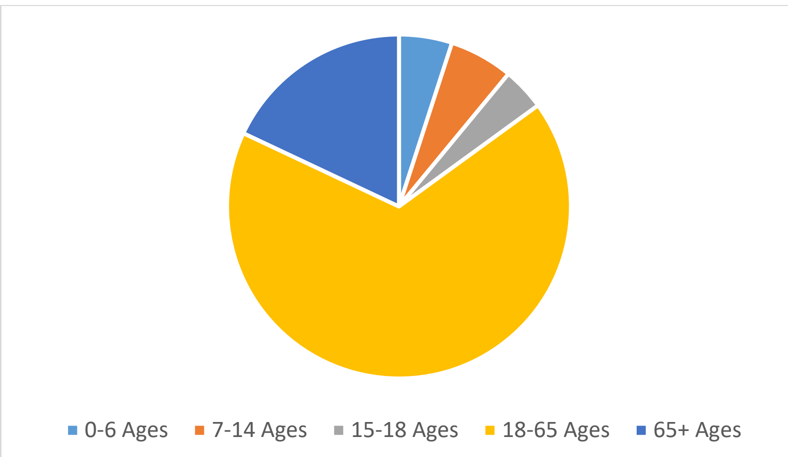
Most of the population within the study area is ethnic Georgian, except Sartichala community within the Gardabani Municipality with a considerable portion of ethnic Azerbaijani residents.

According to the National Statistics Office of Georgia (Geostat), by January 1, 2021, the estimated resident population of **Tianeti Municipality** was 10,300. Over the last seven years, the population of Tianeti Municipality has been characterized by growth, with a 6 percent increase since 2015. The distribution between rural and urban population has remained relatively stable since 2015. Tianeti is not a densely populated area. By 2021, the population density was 11.36 persons per km^2.

According to the data provided by the **Tianeti Municipality** (December 2021), total population is 13,775 people, including 7,216 men and 6,559 women.[13]

Figure 13 shows the distribution of the population by age in Tianeti Municipality.

Figure 13. *Age composition of Tianeti Municipality population*



Source: Tianeti Municipality Mayor Office.

By January 1, 2021, the estimated resident population of **Sagarejo Municipality** was 52,300. Over the last seven years, the population of the municipality has been remaining relatively stable varying between 519,000 and 53,200. Notably, 80 percent of the population lives in rural areas (41,800). The density of the population in Sagarejo Municipality is higher than in Tianeti Municipality—by January 2021, it was 35 persons per km^2.

As mentioned earlier, the study area covers only part of the Sagarejo Municipality, including town Sagarejo and 18 villages. According to the data provided by the **Sagarejo Municipality** (January 2022), the total population of the settlements located within the study area is 21,464. The population under the age of 18 is 18 percent.

[13] The National Statistics Office does not publish/process information at the communities/villages level (except for the 2014 census results). Local governments usually do not have complete statistical information about the local demographic and socioeconomic picture. Therefore, the information provided by the National Statistics Office and the local governments is often different. This report includes information provided by both sources.

Population growth is also observed in Sartichala community since 2014. According to the data provided by the Gardabani Municipality Mayor Office, its population is 14,244, out of which 8,200 are in the village of Sartichala and 6,044 are in the village of Mughanlo.

More detailed information on the distribution of the population by administrative territorial units and gender as well as the main demographic characteristics of Tianeti and Sagarejo Municipalities is provided in Annex 2.

2.3.2. Economic Activity: Local Share in Regional Gross Value Added

Tianeti

The estimated total Gross Value Added (GVA) produced within the Tianeti Municipality in 2019 was GEL 115.23 million at current prices (US$40.87 million),[14] amounting to 11 percent of the regional GVA of Mtskheta-Mtianeti. Over the last years, the GVA produced within the municipality has consistently been increasing. Growth has been especially rapid in the energy, manufacturing, and real estate sectors.

Sagarejo

The estimated GVA produced in Sagarejo Municipality during 2019 is GEL 337.20 million (US$119.61 million) at current prices. This represents 15 percent of the regional GVA of Kakheti. Notably, the GVA produced within the municipality has been increasing over the last years (for which data are available). Agriculture is the largest contributor in the GVA produced in the municipality.

The tables provided in Annex 3 summarize the economic activities contributing to the GVA of the municipalities over recent years for which data are available.

2.3.3. Land Use and Agriculture: Animal Farming, Viticulture, and Cereals

The terrain is much more modified for agricultural purposes in the southeastern part of the study area, within the municipality of Sagarejo, than in the upper reaches of the Iori River, within the municipality of Tianeti, where the area is mostly covered by forests and meadows.

Tianeti

According to Geostat, the total area of Tianeti Municipality is 906.3 km^2, which represents 15 percent of the territory of the region (and 1.3 percent of the country's territory). Most of the territory within the municipality is mountainous and covered by forests, while only 34 percent of the territory is put to agricultural use.

[14] To calculate the equivalent amount in US dollars, the weighted average exchange rate of Georgian lari for US dollar in 2019 was taken (US$1 =GEL 2.8192).

The last agricultural census, conducted in 2014 by Geostat, provides a comprehensive overview of the land use in the municipality.

According to the 2014 Agricultural Census data, a total of 4,130 agricultural holdings were registered in Tianeti Municipality (13 percent of the agricultural holdings registered in the region). Looking at the gender distribution, 68 percent (2,819 holdings) were owned by males and 32 percent (1,311 holdings) by females.

Most agricultural holdings were cultivating the land plots that were under their ownership. In total, 4,988 ha of land were cultivated, 92 percent by the owners (5,585 ha) and the remaining 8 percent by tenant farmers (403 ha).

Despite the high number of people involved in agriculture, many of the holdings were producing mainly for their own consumption. About 3,721 agricultural holdings (90 percent of those in the municipality) produced primarily for their own consumption. Only for 290 holdings, the primary purpose of operation was marketing of their produce (7 percent of holdings in the municipality). Notably, 119 agricultural holdings were out of production in 2014.

Based on the 2014 Agricultural Census data from Geostat, the total agricultural land in Tianeti Municipality operated by agricultural holdings amounted only to 4,788 ha, out of which 1,725 ha were arable, 46 ha were under perennial crops, and 3,017 ha were natural meadows and pasturelands. The main crops cultivated in Tianeti Municipality are wheat, maize, and potato.

Animal husbandry represents a significant share of the agricultural activity in Tianeti Municipality. Table 1 summarizes the statistics concerning different livestock in the municipality.

Table 1. Number of livestock, Tianeti

Livestock type	Units in Mtsketa-Mtianeti Region	Units in Tianeti Municipality as of 2014 (Agricultural Census, Geostat)	Units in Tianeti Municipality as of 2021, (Tianeti Municipality Mayor's Office)
Cattle	36,460	7,797	11,875
Sheep	22,729	3,649	11,640

Sagarejo

According to the Geostat data, the total area of Sagarejo Municipality is 1,491 km^2, which represents 13 percent of the territory of Kakheti Region (and 2.1 percent of the country's territory). Moreover, 31 percent of the municipality is occupied by forest.

According to the 2014 Agricultural Census data from Geostat, 13,639 agricultural holdings were registered in Sagarejo Municipality (14 percent of the agricultural holdings registered in the region). The total area of agricultural land comprised 63,445 ha, out of which 19,450 ha were arable, 3,229 ha were under perennial crops, and 40,766 ha were natural meadows and pasturelands. From the perspective of gender dimensions, 9,756 of the holdings (72 percent) were owned/managed by males and the remaining 28 percent by females. The total number employed in agricultural holdings amounted to 53,039 persons.

In 2019, the total area operated by agricultural holdings in Sagarejo Municipality was 64,866 ha. About 70 percent of those land plots (45,395 ha) were under the ownership of holdings, while the remaining 30 percent (19,471 ha) were rented.

In terms of purposes of agricultural production, like in Tianeti Municipality, many agricultural holdings in Sagarejo Municipality are into subsistence farming. According to the 2014 data, 77 percent of the holdings were producing mainly for their own use, 21 percent were producing mainly for sale, and only 2 percent of the holdings did not operate in 2014.

More than 50 percent of the cropland was occupied by wheat, maize, and vineyards. Moreover, Sagarejo Municipality is one of the largest producers of these three types of crops in Kakheti Region, producing 27.33 percent, 19.82 percent, and 18.65 percent of wheat, maize, and grapes of the regional production, respectively. Among the permanent crops, peach, nectarine trees, and apples were the most widespread in the municipality. The following grape varieties are spread: Rkatsiteli, Saperavi, and Manavi Green. Especially noteworthy is Khashmi village zone famous for Saperavi grape. Among the perennial crops besides the vineyard, almonds and pistachio orchards have been actively cultivated in recent years.[15]

The largest part of the agricultural land in Sagarejo Municipality is occupied by natural meadows and pastures. Accordingly, animal husbandry is an important contributor to agricultural production of the municipality together with crop production. Table 2 summarizes the statistics concerning different livestock in the municipality.

Table 2. Number of livestock, Sagarejo

Livestock type	Units in Kakheti Region	Units in Sagarejo Municipality as of 2014 (Agricultural Census, Geostat)	Units in Sagarejo Municipality as of 2021 (Sagarejo Municipality Mayor's Office)
Cattle	125,394	40,094	9,385
Sheep	620,298	388,938	32,455

As for the Sartichala community, the data provided by Gardabani Municipality Mayor's Office (December 2021) suggest that some 6,475 ha are used for agricultural purposes, out of which 4,114 ha are arable and 2,361 ha are under natural meadows and pastures. The community keeps 1,920 heads of cattle and 2,240 heads of sheep.

The Kakheti Regional Development Strategy 2014–2021 notes that farmers do not follow good soil management practices and do not apply enough mineral or organic fertilizers. Weed management

[15] Local Economic Development Plan, Sagarejo Municipality, 2019

practices are also substandard. Overgrazing leads to desertification, especially in Sagarejo Municipality. Most agricultural lands are affected by wind and water erosion.

Unsustainable agricultural practices applied within the study area as well as overgrazing of pastures cause water and wind erosion of agricultural lands that increases sediment load to the surface water bodies. Recent studies[16] indicate that certain pasture degradation hot spot areas in Sagarejo and Tianeti are affected with heavy erosion. High sediment loads to the Sioni Reservoir originating from agricultural lands, especially on the right bank of the Sioni Reservoir, have been observed during the field visits.

2.3.4. Forestry: Ample Resource and Challenges of Sustainable Use

The Law of Georgia on the Forest Code of Georgia (2020) states that forest ownership is inseparable from the ownership of the land under it and that three types of forest ownership are allowed: state, municipal, and private. However, there are no formally recognized privately owned forests in the country so far because the transition from the former forest legislation to the substantially new order brought about by the 2020 Code is still ongoing. In this process, the status of 'forest' has been given to all forests formerly included in the State Forest Fund, while granting of 'forest' status to the stands existing on private lands is a laborious process, including fieldwork, and has not advanced yet. NFA under MEPA manages the state forest, and the respective municipalities manage municipal forests of local importance.

Within the study area, forests occupy the slopes and foothills of the Greater Caucasus (Tianeti) and Tsiv-Gombori range (Sagarejo). Forests are one of the main natural resources, providing the population with firewood, building materials, and non-timber forest products. A large part of the mountain forests have erosion prevention, soil protection, climate regulation, water, and biodiversity (including genetic biodiversity) conservation functions.

In Tianeti Municipality, 82 percent of the forests are dominated by beech.

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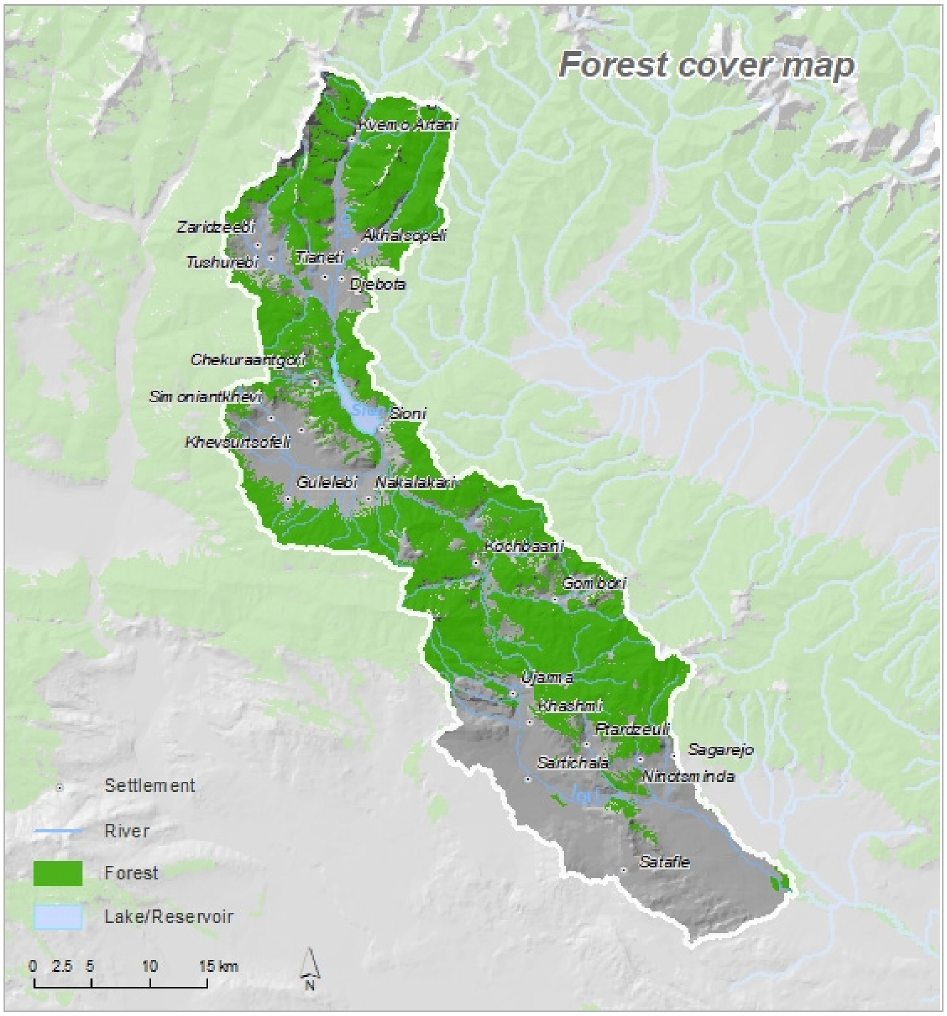
[16] Assessment of Pasture Condition in Sagarejo Municipality, authors(s): ESTOK UG, Bernau, Germany (Ronald Kruwinus, Anja Salzer and Jonathan Etzold), in cooperation with GISLab, Tbilisi, Georgia (Giorgi Mikeladze), GIZ, RECC, October 2019; Assessment of Forest Landscape Restoration Perspectives in Georgia, European Neighborhood and Partnership Instrument East Countries Forest Law Enforcement and Governance II Program (ENPI EAST FLEG II), 2016.

Figure 14. Forest cover map

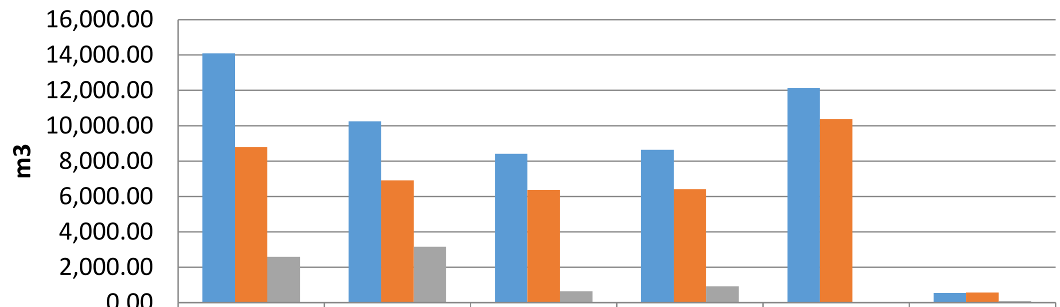


Source: RECC

The area of the state forests within the study area is 59,263 ha (65 percent of the study area), out of which 12,575,7 ha are included in the Emerald Network. Data on the distribution of the forest areas, licenses issued for commercial logging, wood production, and occurrence of forest fires are presented in Annex 4.

According to the NFA, in 2019–2021, 102,276 m^3 of firewood were produced within the study area for social purposes. Additional volume of 27,624 m^3 was produced by the NFA within the same period.

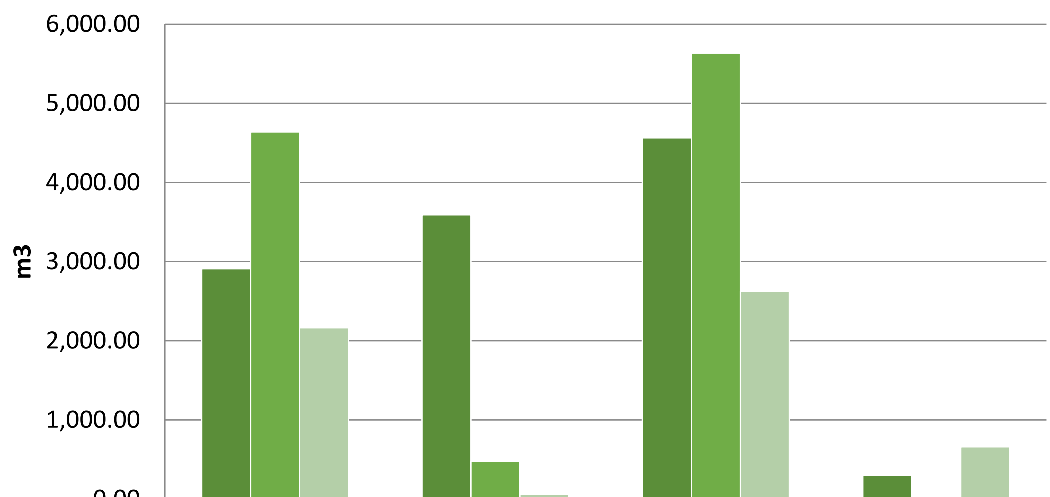
Figure 15. Volume of timber extracted through social cutting



	Akhmeta forest district	Telavi forest district	Sagarejo forest district	Barisakho forest district	Tianeti forest district	Gardabani-Marneuli forest district
2019	14,092.50	10,248.50	8,408.30	8,636.70	12,127.70	539
2020	8,792.30	6,910	6,370.70	6,417.10	10,372.60	569.5
2021	2,583.50	3,155.50	644.3	918	0	81.5

Source: NFA.

Figure 16. Volume of timber extracted by NFA



	Akhmeta forest district	Sagarejo forest district	Tianeti forest district	Barisakho forest district
2019	2,910.36	3,591.30	4,563.50	300
2020	4,637.43	474.87	5,634.36	0
2021	2,163.82	61.93	2,625.94	660

Source: NFA

Following the adoption of the new Forest Code in 2020, significant changes began to take place in the organization of timber production. The code rules phasing out the socially oriented modality of firewood production under which the rural population was allowed to extract wood for household consumption and mandates the NFA to become a sole supplier of firewood harvested in the state-owned forests. Toward this end, the NFA commenced the establishment of the so-called 'business yards' throughout the country, where the extracted trees will be delivered, sorted, processed into hard fuel, and issued to the clients. The process of operationalizing business yards is under way, while social cutting is to be entirely discontinued from 2023 (possibility of deadline extension to 2024 is being considered by the government). This shift in the modality of firewood supply is expected to bring about tangible improvement in forest management, as control over informal operations would strengthen with the shrinking number of individuals authorized to extract trees, and unnecessary damage to forest vegetation would decrease as a limited number of professionals would be allowed to operate instead of a multitude of residents lacking the required skills.

No peaks in the spread of forest pests and diseases have been reported in or around the study area (Tianeti, Sagarejo, and Gardabani Municipalities) in recent years. No forest fires were reported in 2018 and 2021.

In recent decades, the forests within the study area have suffered significant damage from poorly planned and organized logging that led to frequent landslides and mudslides and intensified soil erosion. For example, frequent mudflows were registered in the Lapianis Khevi River watershed, a left tributary of the Iori River, that are attributed to extensive forest harvesting.

The table in Annex 4 shows the data on forest fires recorded within the study area in 2019–2020.

2.3.5. Industry and Mining: Booming Extraction of Sand and Gravel

The study area does not carry large industrial facilities. Tianeti and Sioni are wellness resorts of local importance. There are 4 slaughterhouses and 3 large and 20 small-scale poultry farms in Sagarejo Municipality. The produced meat is provided to approximately 50 percent of the country's market, which distinguishes Sagarejo Municipality from other municipalities in the region. Also, 30 percent of the eggs produced countrywide are produced in Sagarejo. According to the local statistical data, in 2019, there were 760 operating enterprises in the municipality, including 16 large, 36 medium, and 708 small enterprises. A cold storage facility was established under the State program, which serves both the local and capital city markets.[17] Saamo wine factory is in Sagarejo.

In Sartichala community, 19 small and medium enterprises operate, including Chirina LTD. (poultry meat and corn), grain processing enterprises (corn and wheat), and manufacturers of construction materials (sand, gravel, and building blocks).

There are limestone and brick clay deposits within the study area, as well as deposits of groundwater in Artani and mineral water deposits in Sagarejo and Patardzeuli, which are not yet licensed for extraction.

Sand and gravel are extracted from the Iori, Khasmi, and Tvaltskehvi Rivers. Sand and gravel quarries operate in Tianeti, Churchelaurebi, Khashmi, Mughanlo, Sartichala, and Sagarejo. In total, 20 licenses are issued within the study area for the extraction of 4,844,055 m^3 sand/gravel from the Iori riverbed

[17] Local Economic Development Plan, Sagarejo Municipality, 2019.

in total, mainly within 2016–2026 (one license was issued in 2006 and is valid until 2026; the rest were issued in 2016 and are valid until 2026). In addition to the licenses already issued, the National Agency of Mineral Resources (NAMR) is currently considering several new applications for sand/gravel extraction licenses within the study area.

Often, sand/gravel is extracted directly from the watercourse, leading to severe environmental degradation, including deterioration of river water quality.

Limestone is produced in Sartichala (two licenses for extraction of 215,995 tons over the life of the license), and brick clay is produced in Sagarejo (six licenses for extraction of 1,610,350 m^3 over the life of the license).

Mineral springs in Ujarma are operated by Resort Ujarma LTD under a valid license.

2.3.6. Hydropower Generation: Sioni HPP

The Iori River basin is less rich in renewable energy resources than the Alazani River basin. Its estimated technical hydropower potential is 41.5 MW of installed capacity and 237.3 million kWh annual output.[18]

Currently, there is only one HPP operating within the study area—the Sioni HPP in Tianeti Municipality. Arranged at the middle course of the Iori River, the Sioni HPP is owned and operated by JSC Energo-Pro Georgia. The design capacity of the plant is 9 MW. The average annual electricity production is 33 million kWh. About 655,776,000 m^3 of water is used annually for generation, and 570,240 m^3 of water is used for cooling the units. Water supply to the HPP is provided from the Sioni Reservoir with the total volume of 325 m^3, which is supported by an earth dam with an average height of 73 m and maximum height of 84.8 m. In 2007, the reservoir and hydraulic structures were repaired following recommendations developed by the Dam Safety Commission with the funding of the Municipal Development Fund of Georgia (MDF).

2.3.7. Tourism: Growing Visitation and Lagging Infrastructure

In recent years, tourism has been a growing industry in the study area, although it was significantly affected by the COVID-19 pandemic. The number of visitors increased by 30 percent during 2016–2019 in Sagarejo. A cultural heritage monument—the David Gareji Monastery compound—and a balneological resort of Ujarma stimulated the development of touristic facilities in the area. Other drivers of tourism development are vineyards and wineries and an abundance of natural and ethnographic monuments.

Wine tourism is actively on the rise in Sagarejo Municipality. Every year, 1,100 tons of wine are processed in Sagarejo Municipality. Village Khashmi and a few more settlements of Sagarejo

[18] Characteristics of the Alazani and Iori River Basins, Development of River Basin Management Plan (RBMP) for Alazani/Iori River basins in Georgia, EU Water Initiative Plus for the Eastern Partnership (EUWI+4EaP), 2018.

Municipality are included in the so-called *Wine Path*—a well-advertised circuit of wine tourism. In Sagarejo, currently, there are about 20 small, medium, and large commercial wineries and family-owned wine cellars whose products are exported from Georgia.

Hospitality services are provided by six hotels within the town Sagarejo, resort Ujarma, Chateau Khashmi, and small family-run hotels (guesthouses) in villages Khashmi, Patardzeuli, Ujarma, and Kochbaani.

Tianeti is also famous for its cultural heritage sites and natural beauty. There are many important temples and fortresses of the medieval ages. Especially well known are Bochormi Fortress and Church with remarkable architecture and paintings, Tskhrakara Palace, and Jaleti Church. In Tianeti, there is a House-Museum of the Georgian poet Mirza Gelovani. The Historical Museum of Tianeti carries artefacts from the early Bronze to the late Medieval ages, including objects reflecting everyday life, features of churches, biblical manuscripts and printed editions, fabrics (for example, fourteenth-century carpets of the highland of eastern Georgia, Khevsurian folk costumes, and accessories), and medieval ceramic vessels.

Within Tianeti settlement, there is a center for leisure and entertainment, called Kujana Garden. Every year, it hosts a local festival *Tianetoba*.

The Sioni settlement is a health and wellness resort where tourist camps, vacation houses, and sports facilities host thousands of holiday makers all year round. Nowadays, many vacationers, especially from Tbilisi, Tianeti, Telavi, and Akhmeta, choose Sioni for the summer season, mostly due to its proximity; the mild climate; and the combination of the lake, mountains, and the forest landscape.

Within the study area, there are two existing landfills in Tianeti and Sagarejo operated by the Solid Waste Management Company of Georgia (SWMCG). One unregulated dumpsite in Sioni, with an area of 4,078 m^2, was closed by the SWMCG after the establishment of two new formal landfills. The area of the Tianeti landfill is 6,279 m^2. It receives 198 m^3 of solid waste per month on average. The Sagarejo landfill is located near the village Ninotsminda. Its area is 19,037 m^2, and it receives about 2,400 m^3 of solid waste per month. The municipalities are responsible for organizing municipal waste management services within their respective areas, and waste is removed from both urban and rural settlements on a regular basis. Both municipalities have an approved Municipal Waste Management Plan for 2018–2022. At present, the European Bank for Reconstruction and Development and KfW Development Bank (Germany) support the establishment of regional sanitary landfills and waste transfer stations nationwide, including in Shida Kartli and Kakheti administrative regions. Once this infrastructure is provided, the existing landfills in Tianeti and Sagarejo will be closed, and waste from these municipalities will be disposed of to Shida Kartli and Kakheti regional landfills, respectively. Unlike the existing landfills, where no gas and leachate collection and drainage systems are in place, the new regional sanitary landfills will be fully compliant with the European Union (EU) standards. The estimated timing for the operationalization of the regional landfills is 2025–2026.

Waste is not being recycled. The market for recyclables is low, except for a few scrap metal dealers. For other recyclables, the nearest dealers are in Tbilisi and Rustavi. Currently, no treatment of the collected municipal waste is undertaken. Nevertheless, due to numerous agricultural activities, it is assumed that there is a market potential for compost to be used as a soil conditioner.

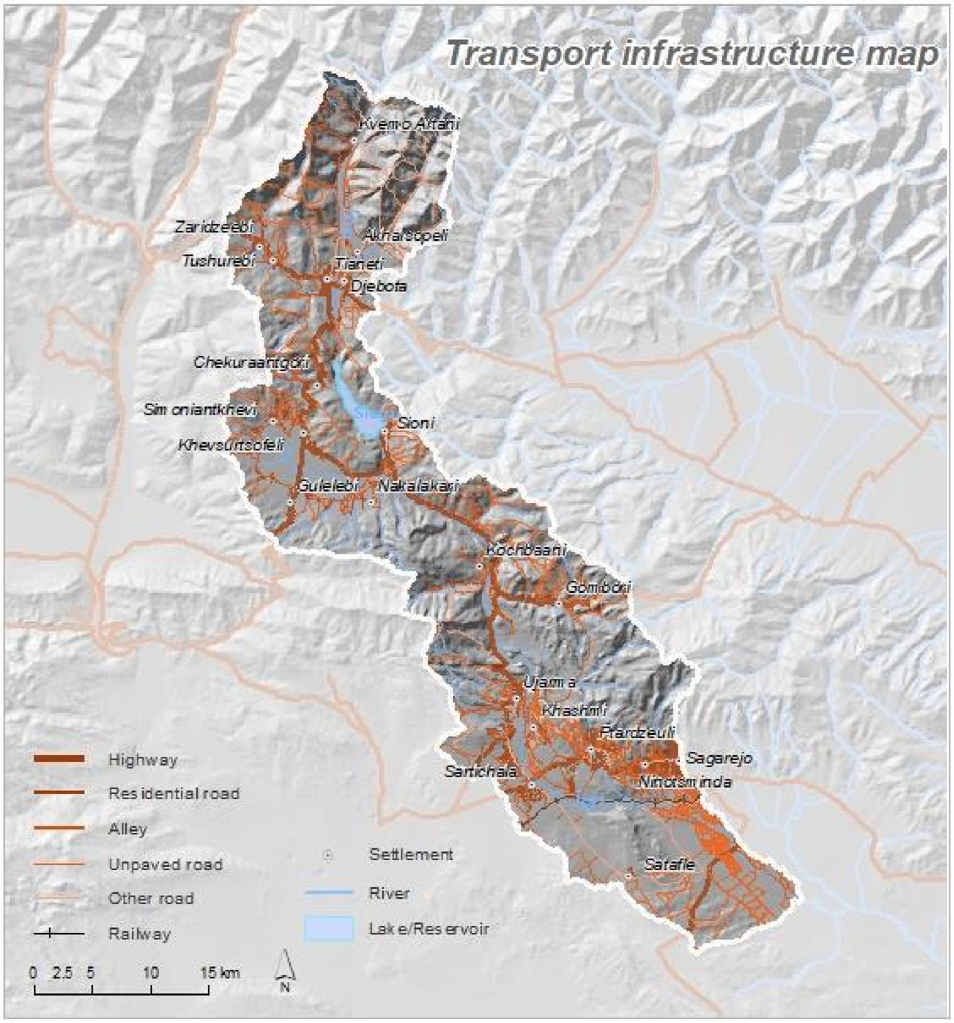
Public awareness and understanding of the need for acquiring good international practices in waste management toward reducing environmental, economic, and social impacts are known to be quite low.

2.3.8. Linear Infrastructure: Pipelines and Roads

The study area is crossed by several gas pipelines operated by the Georgian Gas Transportation Company. For more details and maps, refer to Annex 5.

The study area is characterized by a well-developed road infrastructure (Figure 17). The southern part of the area is crossed by a road of international importance—the Tbilisi–Bakurtsikhe–Lagodekhi road—bordering the Republic of Azerbaijan and connecting the administrative center of Sagarejo Municipality to the capital city of Tbilisi and other municipalities of the Kakheti Region. Sagarejo is situated 50 km (45-minute drive) from Tbilisi and 30 km from Tbilisi International Airport (35-minute drive).

Figure 17. Transport infrastructure within the study area



Source: RECC

The study area is also crossed by several roads of national importance: (a) Tianeti–Zaridzeebi–Zhinvali (21.5 km), (b) Tbilisi (Gldani)–Tianeti (60 km), (c) Tianeti–Akhmeta–Kvareli– Ningori (129.4 km), and (d) Vaziani–Gombori–Telavi (65 km). Through these roads, Tianeti is connected to Tbilisi and its neighboring municipalities, Dusheti, Akhmeta, and Sagarejo. A few years ago, the rehabilitation of the Sasadilo–Skhlovani municipal road was completed, through which the villages located in the Iori River gorge were connected by the shortest route to the Kakheti Region and Tbilisi.

Most local roads are unsurfaced and require seasonal maintenance. Due to the poor condition of the roads in winter, several villages of Tianeti Municipality are difficult to reach, including Sachure, Chiaura, Khaisho, Jervalidzeebi, Tsikvlaantkari, Evjenti, Bokoni, Tsalugelaantkari, Buchkinta, Kvemo Sharakhevi, Zenamkhari, and Lakhato. The roads to Satapleme village and villages of Kochbaani community (Sagarjo Municipality) are also in poor condition and require rehabilitation.

Digital connectivity of the study area is decent: 73.6 percent of households in Kakheti and 77.8 percent in Mtskheta-Mtianeti are provided with internet,[19] but internet access is limited in Tianeti and Sioni. In Tianeti Municipality, mobile telephone networks have a good coverage. Television broadcasting is limited for the remote villages. The existing mobile communication system covers the entire territory of Sagarejo. Internet services are undersupplied and available only for residents of Sagarejo town and of several villages within the study area (Khashmi, Rusiani, Ujarma, Kochbaani, and Patardzeuli). Internet connection is available in Sartichala community of the Gardabani Municipality.

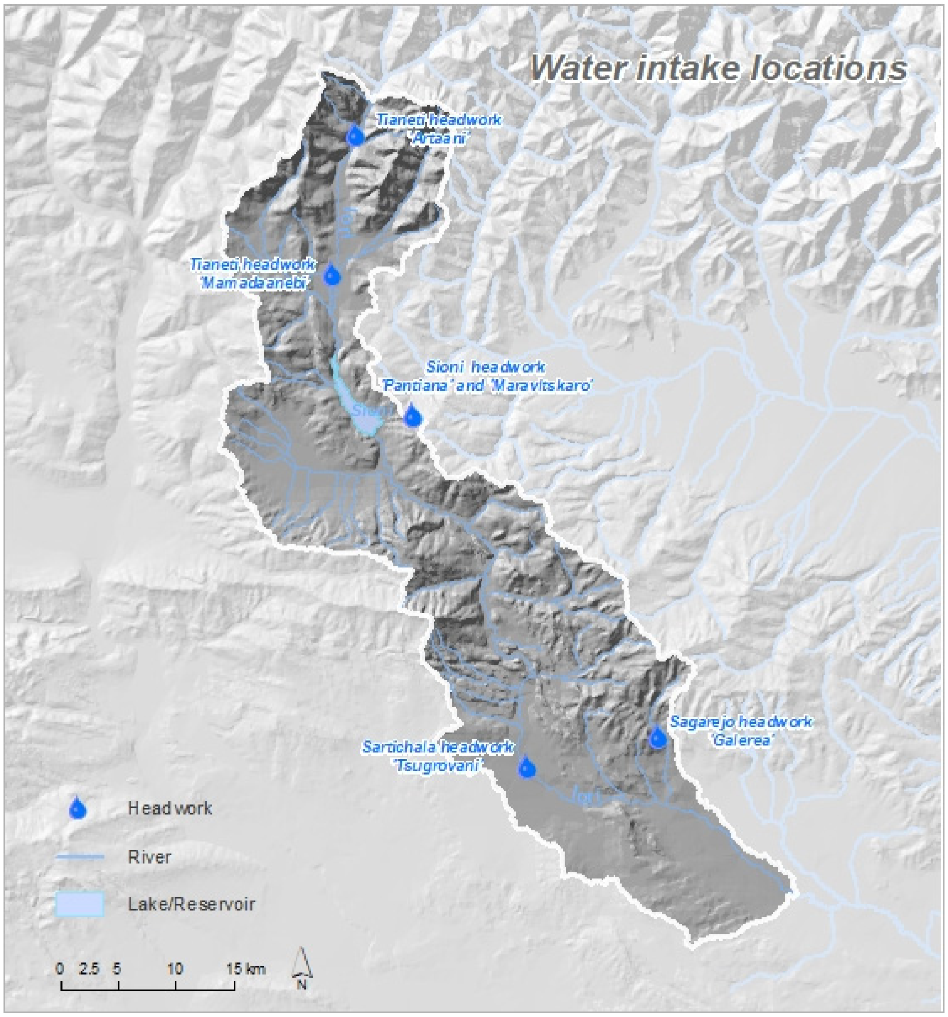
With regard to energy, all people within the study area have access to uninterrupted power supply.

In Sagarejo Municipality and Sartichala community of the Gardabani Municipality, most households are connected to natural gas supply (except villages Gombori, Askilauri, Vashliani, Verona, Rusiani, Gorana, Ikvlivgorana, Kochbaani, Botko, Otaraani, Khinchebi, and Sataple of Sagarejo Municipality). In Tianeti Municipality, natural gas is supplied only to several settlements, including Sioni and Tioni. Socially vulnerable households cannot afford payment for gas supply and predominantly use firewood for heating and cooking.

Within the study area, the town of Sagarejo and the settlements of Tianeti, Sioni, and Sartichala village have centralized water supply managed by the United Water Supply Company of Georgia (UWSCG). Only a few residential districts of Sioni—especially those newly built up with summerhouses—are not covered with municipal water supply services. However, provision of water supply infrastructure to these districts is expected in the short to medium term as part of the plan for a large-scale urban overhaul of Sioni. Construction works for new water supply systems are under way in the villages of Patardzeuli, Ninotsminda, Tskarostavi (Sagarejo Municipality) and Mughanlo (Gardabani Municipality). Construction of water supply systems is planned in several villages of Sagarejo Municipality (including Ujarma, Gombori, Khashmi, Otaraani, Verona, Vashliani, Rusiani, Askilauri, Sasadilo, and Kochbaani) and Sioni townlet. Figure 18 shows the location of the main water intakes while Table 3 provides information on the volume of water supplied from these structures.

[19] National Statistics Office of Georgia, 2021.

Figure 18. Location of existing water intake structures (headworks)



Source: RECC/UWSCG.

Table 3. Water intake by the UWSCG

Name of headwork	Average water volume (m^3/year)	Type of headwork
Galerea (Sagarejo)	1,600,000	Underground/gallery
Tsugrovani (Sartichala)	1,500,000	Underground/drainage
Pantiana and Maravltskaro (Sioni)	120,000	Underground/capture
Artaani (Tianeti)	550,000	Underground/capture
Mamadaanebi (Tianeti)	460,000	Underground/drainage

Source: UWSCG, December 2021.

Villages without centralized water supply systems take water from gravity flow sources and artesian wells. Within Tianeti Municipality, water supply to such villages is managed by the non-profit legal entity *Tianetis Tskali* established by Tianeti Municipality. The amount of water supplied to the rural population mainly depends on meteorological conditions, as most headworks are located on reservoirs filled with surface water runoff. Potable water reservoirs of Tianeti Municipality are supplied from 12 wells, and 5 more are to be arranged later this year.[20]

Except for the town of Sagarejo (where sewerage collection and treatment are undertaken by the UWSCG), there are no sewerage treatment facilities neither within the study area nor in the town of Sioni, which is a larger and more urbanized settlement as compared to the villages of the municipality. Collected sewage is directly discharged into creeks, streams, storm water drainage canals, and so on from where it finds its way to the tributaries of the Iori River and Iori itself. Rural areas do not have centralized sewerage collection systems at all, and many use pit toilets.

Further development of municipal infrastructure is a prerequisite for the economic development of Sagarejo Municipality, and this was made a priority in the planning for 2019–2021. Investments were made into the improvement of drinking water supply and rehabilitation of sewage systems, construction and rehabilitation of road infrastructure, improvement of recreational parks, and rehabilitation or installation of outdoor illumination.[21] These works were financed either from the municipal budget or from the national budget by channeling resources through the MDF.

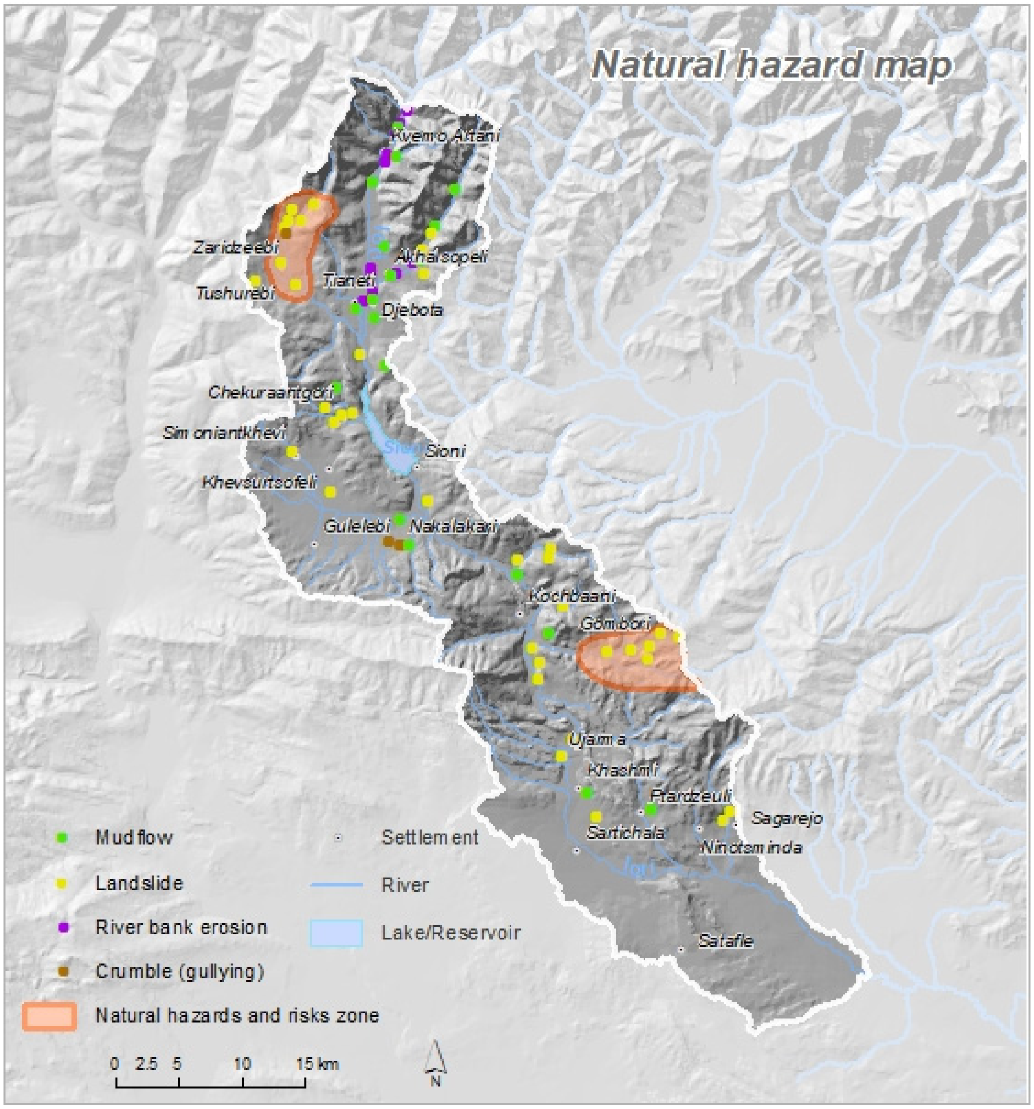
2.4. Natural Hazards and Extreme Weather Events

2.4.1. Floods, Mudflows, and Landslides

Tianeti Municipality is one of Georgia's most high-risk areas in terms of geological activity. Flashfloods, mudflows, and landslides are frequent in the entire municipality, including the part covered by the present study (Figure 19). Occurrence of extreme precipitation, which causes flooding and triggers landslides, has been increasing recently because of climate change.

[20] Letter of the 'Tianetis Tskali', #48, 08. 11. 2021.
[21] Local Economic Development Plan, Sagarejo Municipality, 2019.

Figure 19. Natural hazard map



Source: RECC

Such vulnerability to geological hazards is caused by the complex landscape and geological features of the area, impacts of climate change, and the large amount of sediment and debris accumulated on the slopes of river valleys.

According to the bulletin on the *Results of the Development of Natural Geological Processes in Georgia in 2020 and Forecast for 2021*, published by the Department of Geology of the National Environmental Agency (NEA) in 2021, numerous locations in Georgia are prone to landslides. The high-risk area includes sections of the Tianeti–Akhmeta road and the Sagami River gorge between the villages of Chabano and Chiauri (Figure 20).

Figure 20. Active landslide on the right slope of the Sagami River valley[22]

As a result of these geological processes, several farmlands, homestead plots, houses, and roads are damaged in the villages of Chekuraantgori, Khevsursopeli, Evjhenta, Djebota, Kvemo Artani, and Chabano.

Increased occurrence of torrential flashfloods is recorded on the right tributaries of the Iori River, which poses a risk to the roads, settlements, and agricultural lands, especially in the village of Bodakheva.

On the territory of the village Jijeti, ravines have developed, where both deep and lateral erosion is occurring, and fresh collapses are observed on each bank (Figure 21).

[22] Source of the pictures used in this chapter is the bulletin on the *Results of the Development of Natural Geological Processes in Georgia in 2020 and Forecast for 2021*, Department of Geology, NEA.

Figure 21. Ravines formed in the village Jijeti

The mountainous part of Sagarejo Municipality is in a landslide hazard zone. Landslides threaten homes and public infrastructure (mainly roads and bridges). Floods from the villages within the study area pose a threat to the village of Patardzeuli. Flooding of the riverbanks damages the arable lands along the Iori River. Active landslides are observed in the areas of Gombori, Ujarma, and Askilauri villages. Mudslides are occurring in the riverbeds of Antoki, Tvaltkhevu, and Tokhliauri Rivers.

The formation of low-density and water-saturated mudslides is expected on the Tsiv-Gombori ridge that may affect almost all valleys and ravines beneath. The largest settlement within the risk zone that falls into the present study area is the town of Sagarejo.

Due to the accumulation of large amounts of sediment, there is a high risk of floods in the riverbeds of Tokhliauri, Antokiskhevi, and Tvaltkhevi.

2.4.2. Erosion

According to the 2020 bulletin on the *Results of the Development of Natural Geological Processes in Georgia in 2020 and Forecast for 2021* of the NEA, the total length of riverbanks being washed away in Tianeti Municipality is 1,120 m. This process poses a threat to roads as well as agricultural lands. Table 4 shows a few examples of intense erosion of riverbanks.

Table 4. Examples of intense erosion of riverbanks

	Sagami riverbank erosion (3–10 m wide) along the road between the villages of Chabano and Chiaura posing a risk for the road, agricultural lands, and the power line.
	Iori riverbank erosion near the village of Zemo Artaani on a 400-m-long earth embankment berm on the right bank.
	Erosion in the village of Tetrauli, on the right tributary of the Iori River, affecting 90 m of the bank.

2.4.3. Extreme Weather Events

The risk of disasters caused by natural hazards is exacerbated in the study area by extreme weather events, especially heavy rains (more than 30 mm of precipitation per day), which contribute to the intensification of floods and mudslides. Table 5 is an example of the records on heavy precipitation (rains) in Sagarejo Municipality during 2020.

Table 5. Heavy rains during 2020, Sagarejo

Precipitation (mm)	Date
85.1	August 22
39.0	April 22
34.9	July 10
34.0	July 16
33.8	May 2

Source: NEA, Department of Geology, Bulletin: Results of the Natural Geological Processes in Georgia in 2020 and Forecast for 2021.

2.5. Policy and Institutional Arrangements

2.5.1. Policy Framework and Planning

Natural Resource Management Governance

Several agencies of the Government of Georgia are mandated to manage the natural capital of the country. MEPA works out the policy of natural resource management. It also regulates the use of water and forest resources through permitting water intake from surface water bodies and forest use. Since 2020, the National Agency for Sustainable Land Management and Land Use Monitoring operates under MEPA. The functions of this agency, among others, include assigning the category of agricultural use to land parcels and taking decisions pertaining to the change of this category, taking part in planning and undertaking measures against desertification, and taking part in planning and undertaking measures for the restoration and maintenance of land fertility. The Agency of Protected Areas under MEPA manages designated natural protected areas and habitats, flora, and fauna within the boundaries of these areas. The National Wildlife Agency under MEPA manages wildlife outside the boundaries of the designated protected areas. NAMR, under the Ministry of Economy and Sustainable Development (MESD), issues licenses for the extraction of mineral resources, including groundwater. The State Agency for Regulation of Oils and Gas Resources under MESD issues licenses for the extraction of oil and gas in the territory of Georgia. The rules of issuing resource use licenses require the presence of positive conclusion of MEPA on the Environmental Impact Assessment (EIA) report produced by the project proponent in case the given activity is subject to EIA according to the Law of Georgia on the Environmental Assessment Code of Georgia.

Planning and Management at the Watershed Level

At present, the national legislation of Georgia does not require spatial planning at the level of watersheds.

The spatial planning system is established by the Code of Spatial Planning, Architectural, and Construction Activities of Georgia, according to which spatial plans should be prepared at the national level, for the autonomous republics of Georgia, and for individual municipalities.

The Draft Law on Water Resources Management, developed to align the legislation of Georgia with the EU directives as required by the EU-Georgia Association Agreement, envisages introduction of the river basin management system in Georgia. Before the adoption of the draft law, management plans for several river basins were prepared to facilitate the transition to the river basin management system. The Alazani-Iori RBMP was among those. It was developed within the EUWI+4EaP[23] program, in line with the EU Water Framework Directive. The plan is based on the analysis of baseline information on the subject watershed, delineation of water bodies within it, mapping of natural protected areas and other sensitive receptors within the study area, identification of natural and anthropogenic impacts on water resources, development of management measures and actions, and economic analysis. The RBMP includes the Programme of Measures (PoMs) aimed at managing water-induced erosion and reducing agricultural runoff. This is to be achieved by rehabilitating the main canals and drainage systems of irrigation schemes, setting buffer strips and hedges (establishment of a 3 m buffer strip along the selected water bodies), using modern irrigation technologies for more efficient water use, setting up sanitary zones around potable water reservoirs to protect its quality, improving regulations on material extraction and sediment removal, enhancing and diversifying river bank retention and other hydraulic structures, and conserving riparian and aquatic habitats. However, according to the PoMs, most of the basic measures are focused on the needs of Alazani River sub-basin. Within the Iori River sub-basin, only one basic measure—rehabilitation of the Kvemo Samgori left main canal—is included in the PoMs. Overarching measures like the implementation of the water resources monitoring program and the strengthening of the hydrological monitoring system are also part of the PoMs.

The introduction and implementation of watershed management at the national level requires the creation of a strong legal and institutional basis. This would include the adoption of the new Law of Water Resources Management as well as the passing of several bylaws and regulations. **Landscape restoration, as an important element for the improved watershed management, should be integrated into the watershed management plans rather than appearing as self-standing documents without a formal status. At a higher level, landscape restoration should be mainstreamed into the relevant national and sectoral strategies, regional and municipal development plans, and programs as an activity contributing to the enhanced provision of a variety of ecosystem services for communities, long-term sustainability of water resource use for multiple needs, and climate mitigation and adaptation.**

Forest Landscape Restoration

According to Article 233 of the EU-Georgia Association Agreement (AA), Georgia recognizes the importance of the conservation and sustainable management of forests and acknowledges the role of forests in attaining the economic, environmental, and social objectives of the parties to the AA. By

[23] The EUWI+4EaP project addresses the existing challenges in both development and implementation of efficient management of water resources. More specifically, it supports the Eastern Partnership countries to move toward the approximation to EU acquis in the field of water management with a focus on trans-boundary river basin management as identified by the EU Water Framework Directive.

signing this agreement, the parties committed to "cooperating at the regional and the global levels with the aim of promoting the conservation of forest cover and the sustainable management of all types of forests."

Georgia's international commitments in the forest sector are also shaped by the Sustainable Development Goals (SDGs). Specifically, target 15.2 set under SDG 15 *Life on Land* is to promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests, and substantially increase afforestation and reforestation. Georgia, as a party of the international community, undertook a conditional responsibility to implement sustainable forest management practices and restore/afforest degraded areas by 2030.[24]

In addition to the above international commitments, Georgia is involved in the Pan-European political process for sustainable management of the continent's forests. Georgia is also a party to the Convention on Biological Diversity, and the intentions for improved forest management are reflected in the National Biodiversity Strategy and Action Plan (2014–2020) developed in accordance with the requirements of this convention.

Forests are a powerful carbon sink and have an important role in the mitigation of climate change. Georgia's Updated NDC submitted on May 5, 2021, to the United Nations Framework Convention on Climate Change carries a commitment for 10 percent increase in the carbon sequestration capacity of the forest sector by 2030 as compared to the capacity registered in 2015.

Georgia, as a party to the United Nations Convention to Combat Desertification (UNCCD), joined the global program to support National Voluntary Target Setting for Land Degradation Neutrality and committed to the following national targets for 2030:

- About 1,500 ha of degraded forest will be afforested, about 7,500 ha will be reforested, and 60 percent of forests will be managed sustainably.
- Degraded land will be rehabilitated.
- Irrigation and drainage system will be improved.

In 2018, under the Bonn Challenge, Armenia, Georgia, Kazakhstan, the Kyrgyz Republic, Tajikistan, and Uzbekistan pledged to restore over 2.5 million ha of forest landscape by 2030, followed by Azerbaijan joining with the pledge of 270,000 ha and Scotland with a pledge of 170,000 ha.

Several national strategies set out objectives and activities that are in line with FLR objectives.

The importance of multi-purpose forest use, which will create additional ecological, economic, and social benefits, is emphasized in the program of the Government of Georgia for 2021–2024.

[24] Third National Environmental Action Programme of Georgia (2017–2021).

Development of a national plan for the restoration of degraded forest areas and the restoration of identified priority areas is envisaged by the Third National Environmental Action Programme of Georgia (2017–2021).

The Law of Georgia on the Forest Code of Georgia, passed in 2020, includes provisions of reforestation and afforestation (chapter XVII). The aim of the reforestation is to protect soils from wind, water, and other erosion processes, as well as to improve the biodiversity and productivity of forests stands with low density and yielding capacity located on land not covered by forest and to improve the land protection and other useful functions of forest. Reforestation measures shall be planned annually by a forest management body, based on a forest management plan or an annual action plan.

Despite significant international commitments, FLR is not sufficiently integrated into sectoral strategies and development plans. Also, there is no clear context for coordinating various international commitments implying FLR undertaken by Georgia under various agreements and treaties. Limited financial resources are available for investment into forest restoration. The understanding of the FLR concept is quite limited among the stakeholders, especially at the local level. FLR concept is not properly integrated in the policies, legal acts, and regulations related to forest restoration. The limited knowledge and capacity of the stakeholders regarding the FLR concept is an important constraint for the planning and implementation of relevant measures.

To create the basis for wider application of FLR in the country, an assessment was carried out for Armenia and Georgia in 2018 as part of measures complementary to the ENPI East FLEG II, on the proceeds of the Austrian Development Cooperation administered by the World Bank in partnership with the IUCN and the World Wildlife Fund (WWF). The assessment utilized the principles of the IUCN Guide to the ROAM. The objective of this endeavor was to assess the opportunities for FLR in the selected four regions of Georgia—Akhaltsikhe, Akhalkalaki, Chokhatauri, and Tianeti. Village Sakdrioni (community of Khevsurtsopeli), located in the municipality of Tianeti, Mtskheta-Mtianeti Region, had been selected for a detailed FLR analysis. The area identified for possible restoration had been forested in the past and is currently degraded and used as a pasture. It is affected by erosion. The assessment suggested to arrange a windbreak and create a protective forest stand on the 36.9 ha area identified for an intervention to arrest erosion and protect the soil from degradation. This area, located on the right bank of Iori River, is about 6 km south of the village Chekuraantkhevi, where agroforestry interventions are suggested by the present WMLROA (Chapter 4: restoration option 1: Agroforestry on Cropland). ***It is recommended to undertake joint planning and coordinated implementation of FLR measures in Chekuraantkhevi and Sakdrioni villages to enhance effectiveness of investment.***

There are no general policy and legal requirements regarding the application of FLR and agroforestry measures on agricultural lands in Georgia. One piece of legislation that creates an enabling environment for sustaining productive landscapes is the Law of Georgia on Windbreaks adopted in 2021 that regulates the restoration and management of windbreaks to reduce wind erosion in agricultural lands and prevent land degradation. Arrangement of windbreaks had been included into the Sagarejo Municipality Economic Development Plan before the adoption of this law. The plan was prepared under the auspices of the EU-supported initiative called *Mayors for Economic Growth* to boost socioeconomic development and improve the welfare of communities of Sagarejo. It covered 2019–2022. The strategic vision for local economic growth is based on the integrated development of agriculture and tourism. More specifically, the plan envisaged infrastructure improvements, stimulation of winemaking, and cultural tourism and agrotourism as well as improved access to finance for local businesses. The plan did not refer to combating erosion as a means for increasing agricultural productivity and supporting agrotourism. Restoring windbreaks and fighting desertification were included as activities in support of agriculture. However, traditional, monofunctional windbreaks are becoming less effective in adapting to climate change and long-term sustainability. ***It is recommended to develop policies and relevant legislative changes to facilitate the transformation of windbreaks into multifunctional agroforestry ecosystems, considering the principles of FLR***.

Extraction of Natural Construction Materials

Research undertaken for developing the present WMLROA revealed that the extraction of sand and gravel from the Iori riverbed is the main cause of landscape degradation in the lower part of the Iori River watershed. According to the Law of Georgia on the Environmental Assessment Code of Georgia (2017), EIA is mandatory for quarries and open-cast mining where the surface of the mining site exceeds 25 ha. For a smaller area, extraction of mineral resources is not subject to either screening or EIA, regardless of the location and the type of ecosystem within which this activity is planned. Knowing that conduct of the EIA and obtaining of a positive conclusion of environmental expert review are not required for material extraction from areas below 25 ha, most applications for extraction license are made for the areas below this threshold. This pattern fully applies to the extraction of sand and gravel from the Iori riverbed.

The Environmental Assessment Code requires cumulative impact assessment to be part of the EIA, but individual project proponents are not in a position to undertake an in-depth analysis of impacts of all active and worked-out mining sites along the given river, nor are they pushed for that upon submission of EIA reports.

Environmental conclusion issued on sand and gravel mining EIAs carry environmental conditions under which the mine may be operated. Conditions usually include the implementation of the site reinstatement plan which shall be included in the EIA report. The level of detail and the quality of the reinstatement plans is not uniform, and the enforcement of their implementation is weak. The greatest problem related to the mining sites' reinstatement is that it is not happening gradually, as certain parts of the mining site are worked out, and operation proceeds to a fresh part. Operators claim that the location is not actually exhausted, and extraction will continue. Given that mining licenses may be valid for years, site reinstatement is significantly delayed, affecting water quality, riverbed structure, and aquatic life. Once the license term is over, an operator can quickly walk away with practically no reinstatement. At this stage, fining is the only tool to be used against a noncompliant operator. For most operators, fines are quite affordable and not an effective measure for changing their behavioral pattern. Furthermore, resources levied through fining of mine operators are not earmarked for site reinstatement, and worked-out mines remain abandoned without due harmonization with the landscape. ***Regulatory improvements are recommended to better protect landscapes, spare aquatic and terrestrial habitats, and prevent riverbed degradation in the course of material extraction. This would include more in-depth analysis of cumulative impacts from multiple individual mining sites, prohibition of material extraction from the watercourse, clear and time-bound requirement of gradual reinstatement of worked-out sites, and strengthening of remedial actions of the state regulatory bodies.***

2.5.2. Institutional Framework

The Sioni WMLROA combines a variety of themes, such as water and land resource management, irrigation systems improvement, sustainable forestry and reforestation, agroforestry and sustainable agricultural practices, and mineral extraction. Therefore, implementation of the measures proposed in this assessment requires coordination and close cooperation of several governmental bodies at the national and local levels.

The main stakeholder of WMLROA is MEPA, whose functions include the preparation and implementation of strategic documents in the field of environment and agriculture; the development and implementation of state policies in the fields of water, land, and forest resources management, climate change, mitigation of environmental risks, and impacts; and ensuring of protection and sustainable use of the nation's natural capital.

WMLROA is primarily aimed at FLR to be undertaken for reducing soil erosion within the Sioni Reservoir watershed. This would have a significant positive impact on the operation of the Sioni irrigation reservoir which is prone to siltation that causes reduction of its installed capacity and impedes irrigation water supply to the Zemo and Kvemo Samgori irrigation schemes. Issues caused by erosion in the Sioni Reservoir watershed fall in the spheres of activity of several public institutions, and actions to be taken for addressing these issues are also part of several institutions' mandates.

Institutional authority over the organization and implementation of landscape restoration investments recommended for the Sioni Reservoir watershed is held by two units of MEPA:

- Department of Biodiversity and Forest Policy (BFP, responsible for policy formulation, implementation, and progress monitoring in the forest sector; undertaking of sectoral reforms; and drafting of the regulatory framework in the respective field)
- Department of Hydrology and Land Management (HLM, responsible for policy formulation, implementation, and progress monitoring in the fields of land resource management and hydro amelioration, as well as drafting of the respective regulatory framework).

The following agencies subordinated by MEPA also exercise functions relevant for the implementation of the measures proposed in this WMLROA:

- NFA (Legal Entity of Public Law), responsible for managing the state forest, including conduct of forest inventory, development and implementation of forest management plans, extraction of timber and firewood, organization of commercial use of state forest by the private sector, forest protection from pests and diseases, and forest restoration and afforestation
- Georgia Amelioration (state-owned limited liability company), responsible for the management of public irrigation infrastructure, including the Sioni Reservoir and Zemo and Kvemo Samgori irrigation schemes
- National Agency for Sustainable Land Management and Land Use Monitoring (Legal Entity of Public Law), responsible for the development and implementation of programs for targeted use and protection of agricultural land resources; planning and implementation of measures against land degradation, such as restoration and maintenance of windbreaks and restoration of degraded soil; and regulation of access to state-owned pastures.[25]

Given the significant impact of sand and gravel extraction from the Iori River on the watershed landscapes, NAMR (Legal Entity of Public Law under MESD) is also an influential party when it comes to WMLROA implementation, responsible for the development and maintenance of a database of Georgia's mineral resources, issuance of licenses for the extraction of these resources, and exercising control over the adherence to the license conditions.

Local self-government bodies have a crucial role in the implementation of the Sioni Reservoir WMLROA, especially for activities planned on the municipal or privately owned agricultural lands. This mainly refers to agroforestry measures, which are suggested in the Chekuraantkhevi River valley. Also, local governments are involved in issuing sand and gravel extraction licenses. Although, they do not have a strong voice in the decision-making, local government can still influence the exact location and environmental conditions of extraction licenses.

The study area includes the entire Tianeti Municipality and partially includes Sagarejo Municipality. A small part of Gardabani Municipality (Sartichala community) is located within the study area as well.

Table 6. Settlements within the study area

Municipality	City	Settlement (Township)	Communities	Villages
Tianeti		2	10	84
Sagarejo	1	-	7	18

[25] Resolution of the Government of Georgia on Approval of the State Program for Access to State-Owned Pastures, adopted October 6, 2021.

Municipality	City	Settlement (Township)	Communities	Villages
Gardabani			1	2

Sakrebulo Municipality (Council) is a representative body of the municipality, elected for a term of four years. It is entitled to establish/dissolve administrative units, establish the borders, control and assess the activities of the executive authorities of the municipality, approve the municipal budget, approve the rules of management and use of municipal property, and establish the rules of using water and forest resources belonging to the municipality.

The Mayor is the head of the executive power of the municipality, who is elected for the term of four years. He/she is accountable to Sakrebulo. He/she, among others, is responsible for municipal budgeting and spatial-territorial planning, subject to approval by Sakrebulo. He/she also makes decisions on municipal property management and administration.

Buy-in and active engagement of all relevant stakeholders in the implementation of WMLROA is a critical element of success. Furthermore, coordinated action by various stakeholders and their close cooperation and synergy are highly important for efficient implementation of the measures proposed in this assessment and sustaining its results. A Coordination Council set up through the order of the Minister of Environmental Protection and Agriculture may serve as a platform for joint implementation of WMLROA. The Department of BFP of MEPA, in close cooperation with the Department of HLM of MEPA, can provide the administrative, organizational, and analytical support to the Coordination Council. Other stakeholders (NFA; Georgian Amelioration; National Agency for Sustainable Land Management and Land Use Monitoring; NAMR; Mayors' Offices of Tianeti, Sagarejo, and Gardabani Municipalities) should be represented in the council. The council may provide overall supervision and monitoring of WMLROA implementation, initiate relevant legal and policy amendments to support WMLROA implementation, and do fundraising from the state and local budgets and donor organizations. Producing detailed designs of landscape restoration activities, procurement, oversight and monitoring, and technical cooperation with stakeholders at the local and national levels should be the functions of relevant agencies (NFA for the state forest land and National Agency for Sustainable Land Management and Land Use Monitoring for state-owned agricultural land).

2.5.3. Directory of Water Users

Water Intake

According to the MEPA database of general data on water use, there are 17 registered commercial water users in the study area: 6 in Sagarejo, 3 in Tianeti, and 8 in Gardabani. As of 2020, 274.69 million m^3 of water was extracted from natural water bodies in Tianeti and Sagarejo, including 3.52 million m^3 from underground aquifers. The total volume of consumed fresh water was 231.41 million m^3 in Tianeti and Sagarejo. In Tianeti, 60 percent of the consumed fresh water was used by the HPP and 35 percent for irrigation. In Sagarejo, 95 percent of the consumed fresh water was used for irrigation. Table 7 shows the total water consumption by municipalities.

Table 7. Total water consumption by administrative territorial units, million m³, 2020

Municipality	Number of registered water users	Extracted from natural water bodies		Fresh water users					
		Total	Underground sources	Total	Domestic	Industry	Irrigation	HPPs	Fish farms
Tianeti	3	191.87	2.24	164.48	0.94	6.59	57.99	98.89	0.07
Sagarejo	6	82.82	1.28	66.93	0.65	0.14	63.28	—	2.86
Gardabani	8	464.92	0.54	437.03	0.31	314.92	76.13	43.69	—

Wastewater Discharge

According to the database on annual actual water use developed by MEPA, commercial water users discharged 101.87 million m^3 wastewater to surface water bodies of Tianeti and Sagarejo municipalities, out of which only 0.03 million m^3 was untreated (in Tianeti). In Gardabani, the share of the untreated wastewater is greater.

Table 8. Wastewater discharges into surface water bodies, million m³, 2020

Municipality	Number of registered water users	Total discharges	Discharged into surface water bodies		
			Untreated	Clean wastewater[26]	Treated wastewater
Tianeti	3	98.99	0.03	98.96	—
Sagarejo	6	2.88	—	2.86	0.02
Gardabani	8	265.99	64.26	43.67	158.06

JSC Energo-Pro Georgia

The Sioni HPP is operated by JSC Energo-Pro Georgia—one of the largest power companies in the South Caucasus. The Energo-Pro Group was founded in 1994 in the EU member state - Czech Republic, city of Svitavy Czech. The group owns and operates energy facilities in the Czech Republic, Bulgaria, Georgia, Türkiye, and Slovenia. The group entered the Georgian energy market in 2006. The Sioni HPP has a longer history of operation that was initiated in 1964. More detailed information about the Sioni HPP is provided in Chapter 2.3.6.

Georgian Amelioration LTD

Georgian Amelioration LTD, with 100 percent of shares in the state ownership, is an assignee of the former Sioni-M LTD, Mtkvari-M LTD, Alazani-M LTD, and Kolkheti-M LTD, which had been

[26] Wastewater from HPPs which was used without being polluted.

created in 2006, based on the reorganized Department of Amelioration and Water Economy of the Ministry of Agriculture and Food.

Georgian Amelioration LTD manages the following irrigation structures within the study area: the Sioni Reservoir, Paldo Headwork, Kvemo Samgori irrigation systems, and two irrigation canals (for more details, see chapter 2.2.).

From the Sioni irrigation reservoir, water is supplied to the Sioni HPP (operation capacity 9 MW). The mentioned HPP, which was supplied with 129.94 million m^3 of water in 2021 as of October 2021, has an agreement for water supply with the Zemo Samgori Service Center subordinated to the Georgian Amelioration LTD.

The main canal of Zemo Samgori irrigation system, with a design capacity of 12 m^3/s, supplies water to the Satskheni HPP (with an installed capacity of 14 MW), Martkopi HPP (3.9 MW), Tetrikhevi HPP (12.4 MW), Tbilisi Sea HPP (0.42 MW) commissioned in recent years, and Tbilisi Sea. The mentioned HPPs, which were supplied with 53.24 million m^3 of water in 2021 as of October 2021, have a contract for water supply with the Zemo Samgori Service Center subordinated to the Georgian Amelioration LTD.

In the immediate vicinity of the headwaters of the Khashmi irrigation system, water is supplied to a **fish farming pond** arranged in the riverbed through a water intake facility located on the Iori River based on the water supply contract with the Kvemo Samgori Service Center. As of October 2021, contracts for water supply through the Khashmi canal have been signed with 316 water users, including one contract with the mentioned fishpond. By October 221, water users were provided with 6.10 million m^3 of water, including the pond.

In the lower part of the study area, there is a headwork of the Kvemo Samgori irrigation system, which is owned by the Georgian Amelioration LTD. In 2021, a contract for the supply of water through the left main canal was signed with 751 water users, including two contracts for fish farms fed from the left main canal. In 2021, as of October, these water users, including ponds, were supplied with 37.6 million m^3 of water. Contracts for water supply through the Right Canal were signed with 2,351 water users, including two contracts with fishponds. These water users, including ponds, were supplied with 32.3 million m^3 of water in 2021, as of October. The Kvemo Samgori Service Center abstracted 122.6 million m^3 of water from the river in 2021, as of October, of which 69.9 million m^3 was supplied to water users, and 52.7 million m^3 was released in the tailrace of the Kvemo Samgori irrigation system rework on the Iori River.

Georgian Amelioration LTD undertakes water management at the level of the main infrastructure, most of which is currently in a rather bad technical condition and requires major rehabilitation. Because of the poor condition of the systems, water regulation is limited to turning supply on and off and maintaining approximate water level in the canals. The lack of water measuring equipment makes it impossible to regulate water level based on precise data. The lack of the regulation structures on the main canals prevents the regulation of water quantity in the secondary canals. Hence, operators supply excess water, part of which is then discharged into rivers through drainage canals.

Water supply at the local level depends on farmers' demand. Information about the demand is collected from water users by local representatives of Georgian Amelioration LTD and transferred to the central management of this entity. Farmers estimate the quantity of water required for a given crop by eye, and often try to delay irrigation to avoid paying the charges. They prefer to depend on precipitation until irrigation becomes indispensable due to drought. The farmers whose lands were served by tertiary irrigation canals agree on water use with each other. They often repair and clean the canals on their own or ask for assistance from Georgian Amelioration LTD.

At the household level, ineffective border-dike irrigation method is used. There are some sprinkling irrigation systems in eastern Georgia; however, they are sparse because they require high capital investment and are not used in small farms. A small, yet increasing, number of farmers are installing sprinkling irrigation systems in fruit and vegetable gardens, vineyards, and fields. It is expected that once farmers are convinced of the effectiveness of this technology, more of them will switch to sprinkle irrigation. Therefore, this forecast should be built into the medium- and long-term planning of irrigation service delivery.

United Water Supply Company of Georgia

UWSCG is a limited liability company with 100 percent of shares owned by the state, operating under the Ministry of Regional Development and Infrastructure of Georgia. Founded in 2010, the UWSCG provides water supply and wastewater management services to urban settlements countrywide except for Tbilisi, Mtskheta, Rustavi, Gardabani Municipality, and the Autonomous Republic of Adjara. The head office of the UWSCG is in Tbilisi. The company has 10 regional offices and 56 service centers countrywide.

The main activities of the company include water extraction, treatment, and supply as well as design, construction, maintenance, and operation of water supply and wastewater networks.

There is a central water supply system in the municipal centers (Tianeti and Sagarjo), as well as in Sioni and village Sartichala managed by the UWSCG. Sewage system is in place only in the town of Sagarejo and is managed by the UWSCG (for more details refer to Chapter 2.3.8)

Tianetis Tskali (Tianeti Water)

The non-profit (noncommercial) legal entity *Tianetis Tskali* (established by Tianeti Municipality) manages water supply to the Tianeti Municipality villages in the absence of centralized water supply systems (for more details refer to Chapter 2.3.8).

Groundwater Users

A total of 20 licenses for groundwater extraction have been issued within the study area, including 4 licenses in Tianeti, 4 licenses in Gardabani, and 12 licenses in Sagarejo. The extracted groundwater is for industrial use by several companies and individual entrepreneurs.

3. ASSESSMENT OF SOIL EROSION BY RUSLE

The Sioni Reservoir has multiple uses. The livelihood of communities residing in its vicinity, industry, agriculture, tourism, power generation, and other branches of economy depend on the reservoir and the water supplied from it. Intense sedimentation of the reservoir significantly impairs its resilience to climate change, causes floods, and puts at risk the security of the population and infrastructure. Sedimentation is caused by soil erosion which, in turn, is due to unsustainable agricultural practices, overgrazing, and deforestation. Extraction of sand and gravel directly from the riverbed in the lower part of the Sioni Reservoir watershed also contributes to heavy sedimentation of the Iori River. Therefore, soil erosion has been studied to confirm its estimated dynamics and to reveal hot spots for recommending the most effective and feasible watershed management and landscape restoration interventions.

Soil erosion is a natural process in which the upper layers of soil are entrained by water or wind and transported across a given surface. Intensified soil erosion is a growing environmental problem arising from land degradation, unsustainable agriculture, and other anthropogenic factors. It is one of the top pressing environmental issues the world is facing in the twenty-first century.

Erosion is triggered by a combination of factors such as steep slopes, climate and weather patterns (for example, long dry periods followed by heavy rainfall), land use practices, and land cover patterns (Renschler, Mannaerts, and Diekkrüger 1999). Slope gradient is a significant factor for defining runoff mechanism. The steeper the slope, the lesser the infiltration and the greater the runoff. The runoff generated on a slope finds curves in its downward path, leading to erosion of soil as the velocity of the runoff increases. Some intrinsic features of soil can make it more prone to erosion. Modelling can help understand the ongoing erosion process and its trends, as well as undertake scenario analysis.

According to multiple sources, solid particles generated through erosion transport pesticides and nutrients from agricultural fields while entering streams and rivers, thus polluting surface and groundwater bodies (Gallaher and Hawf 1997). The loss of fertile topsoil to erosion reduces farm productivity and crop yields (Renard 1997). Also, erosion facilitates the transfer of greenhouse gases from the soil to the atmosphere, leading to increased emission of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) (Cox and Madramootoo 1998). Erosion occurs when soil is exposed to rain or wind energy. Raindrops and wind hit the soil surface with great energy and easily displace soil particles from the surface. According to Merritt, Letcher, and Jakeman (2003), soil erosion is a three-stage process involving detachment, transport, and deposition. The impact intensifies on sloping land, where oftentimes, more than half of the surface soil is carried away as the water splashes downhill into valleys and waterways. The rate of erosion is influenced by the soil composition, the slope gradient, and the extent of vegetative cover.

3.1. RUSLE modeling in GIS Environment

The history of forecasting erosion started with analyses reported by Renard (1997) aimed at finding the major variables that affect water erosion of soil. RUSLE is a contemporary model that is derived from the Universal Soil Loss Equation (Wischmeier and Smith 1978) and is based on the empirical data inputs. The RUSLE model (R stands for Revised) enables forecasting of an average annual rate of soil erosion for a site of interest for any number of scenarios involving cropping systems, management techniques, and erosion control practices. The RUSLE model is built with consideration of all main factors affecting soil erosion (Renard 1997). The general principle of the RUSLE application methodology is to make quantitative estimation of factors integrated in the model and feed the data into the system. Several techniques for estimating these factors have been developed, including the use of climate data, soil and geological maps, remotely sensed satellite images, empirical formulas, and the digital elevation model (DEM).

The soil erosion models can be linked to spatial data management systems, such as GIS. GIS is a powerful tool in demarcating spatial distribution of soil loss rates. In the application of RUSLE on a GIS environment, soil loss is estimated within the raster/grid GIS. Raster models are cell-based representations of map features, which offer analytical capabilities for continuous data and allow fast processing of map layer overlay operations (Fernández and Vega 2016).

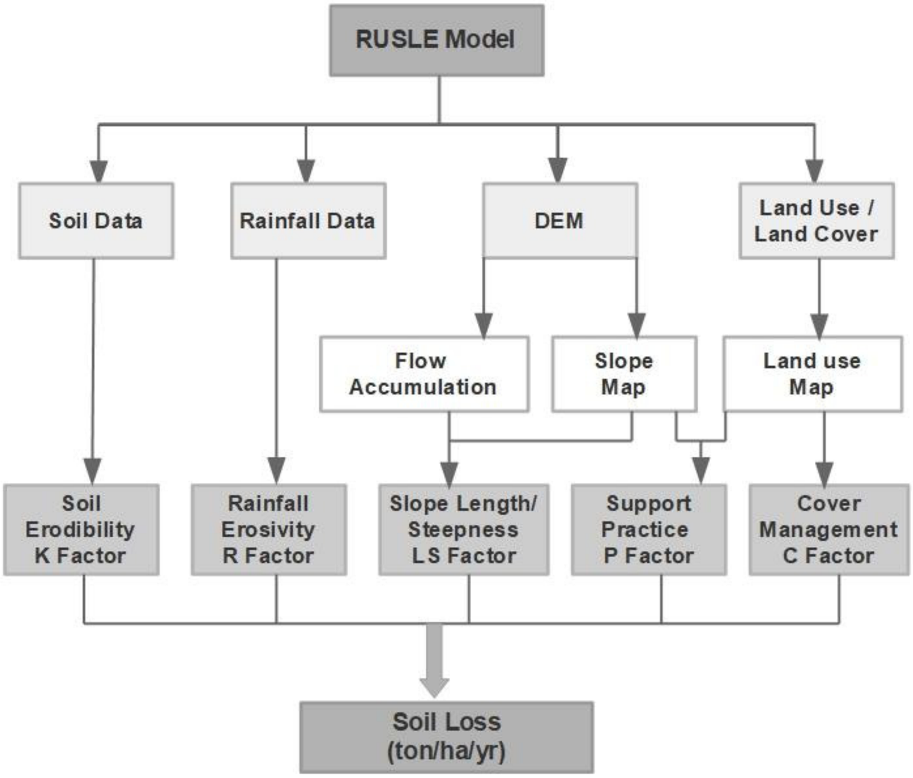
In the present study, for the estimation of soil loss, RUSLE was adopted in a GIS framework. Thus, RUSLE has been used to assess the spatial patterns of erosion risk in the study area. Recent advances in GIS and remote sensing technology have enabled a more accurate estimation of the factors used in the calculation. Five major factors (rainfall pattern, soil type, topography, crop system, and management practices) have been used for computing the expected average annual erosion through the following equation (Renard 1997):

$$A = R \times K \times LS \times C \times P,$$

where A is the computed spatial average soil loss and temporal average soil loss per unit area (t/ha/year); R is the rainfall-runoff erosivity factor (MJ mm ha^{-1} h^{-1} $year^{-1}$); K is the soil erodibility factor (t ha h ha^{-1} MJ^{-1} mm^{-1}); L is the slope length factor; S is the slope steepness factor; C is the cover management factor; and P is the conservation support practice factor. Parameters L, S, C, and P are all dimensionless.

Each factor has been derived separately in raster data format and the erosion calculated using the map algebra functions. Figure 22 shows the conceptual framework diagram for the RUSLE model calculation.

Figure 22. The conceptual framework of soil loss analysis by the RUSLE model



3.2. Rainfall Erosivity Factor (R)

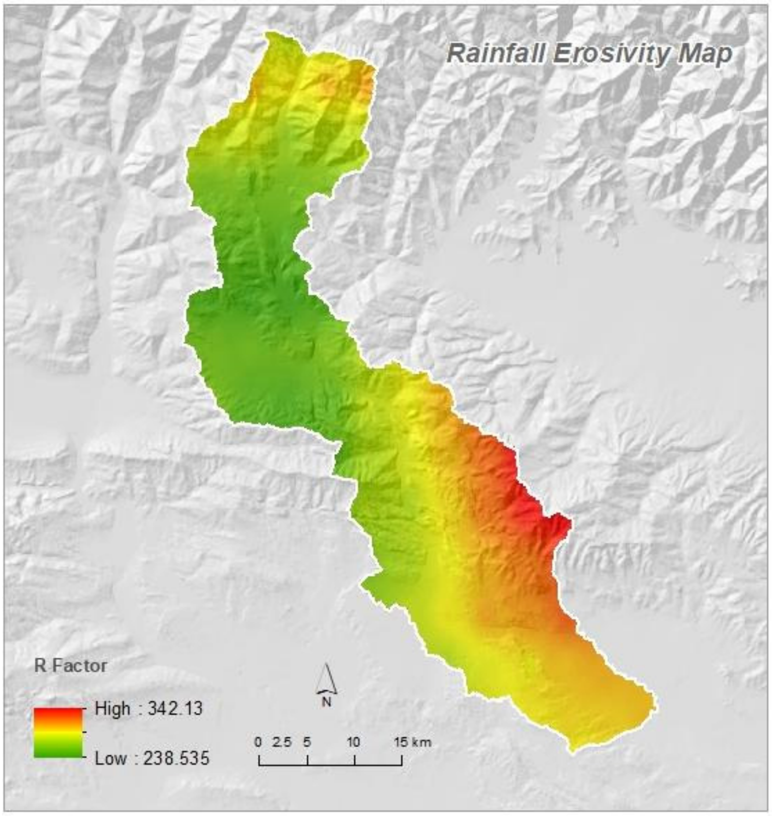
Annual rainfall erosivity is the total rainfall erosivity within a year. The rainfall erosivity factor (R) describes the erosivity of rainfall at a particular location based on the rainfall amount and intensity. This is an important parameter for soil erosion risk assessment under future land use and climate change (Meusburger et al. 2012). The rainfall erosivity factor (R) was calculated using Climate Hazards Group InfraRed Precipitation with Station Data (CHIRPS) precipitation data, and the following equation (Merritt, Letcher, and Jakeman 2003; Tundu, Tumbare, and Kileshye Onema 2018):

$R = 38.5 + 0.35 \times P$,

where R = rainfall erosivity factor and P = annual precipitation (mm)

Figure 23 shows the rainfall erosivity factor map derived for the study area.

Figure 23. Spatial distribution of rainfall erosivity factor (R)



Source: RECC

3.3. Soil Erodibility Factor (K)

Soil erodibility factor (K) is a quantitative description of the inherent erodibility of a particular soil type; it is a measure of the susceptibility of soil particles to detachment and transport by rainfall and runoff (Lane et al. 1992). The main soil properties influencing the K factor are soil texture, organic matter, soil structure, and permeability of the soil profile.

Soil erodibility factor (K) was calculated using the equation by Williams (1995):

$$K_{USLE} = K_W = \int_{csand} \cdot \int_{cl\text{-}si} \cdot \int_{orgc} \cdot \int_{hisand},$$

where $\int_{csand}$ is a factor that lowers the K indicator in soils with high coarse-sand content and increases for soils with little sand; $\int_{cl\text{-}si}$ gives low soil erodibility factors for soils with high clay-to-silt ratios; $\int_{orgc}$ reduces K values in soils with high organic carbon content, while $\int_{hisand}$ lowers K values for soils with extremely high sand content.

All fractions of soil, sand, clay, silt, and organic carbon were represented to the topsoil cover of the watershed because it is affected directly by the raindrop energy. The following formulas have been used to calculate all the above-mentioned fractions:

$$f_{csand} = \left(0.2 + 0.3 \cdot \exp\left[-0.256 \cdot m_s \cdot \left(1 - \frac{m_{silt}}{100}\right)\right]\right),$$

$$f_{cl-si} = \left(\frac{m_{silt}}{m_c + m_{silt}}\right)^{0.3},$$

$$f_{orgc} = \left(1 - \frac{0.25 \cdot orgC}{orgC + \exp[3.72 - 2.95 \cdot orgC]}\right), \text{ and}$$

$$f_{hisand} = \left(1 - \frac{0.7 \cdot \left(1 - \frac{m_s}{100}\right)}{\left(1 - \frac{m_s}{100}\right) + \exp\left[-5.51 + 22.9 \cdot \left(1 - \frac{m_s}{100}\right)\right]}\right),$$

where

m_s = the sand fraction content (0.05–2.00 mm diameter) (percent);

m_{silt} = the silt fraction content (0.002–0.05 mm diameter) (percent);

m_c = the clay fraction content (<0.002 mm diameter) (percent); and

orgC - the Soil Organic Carbon (SOC) content (percent).

Soil data from the Food and Agriculture Organization (FAO) of the United Nations[27] available online were also assessed and used for the study.

To estimate the K factor, the following data from the FAO data set were used:

- Soil unit symbol
- Sand percent topsoil
- Silt percent topsoil
- Clay percent topsoil

[27] http://www.fao.org/geonetwork/srv/en/metadata.show?id=14116.

- OC percent topsoil.

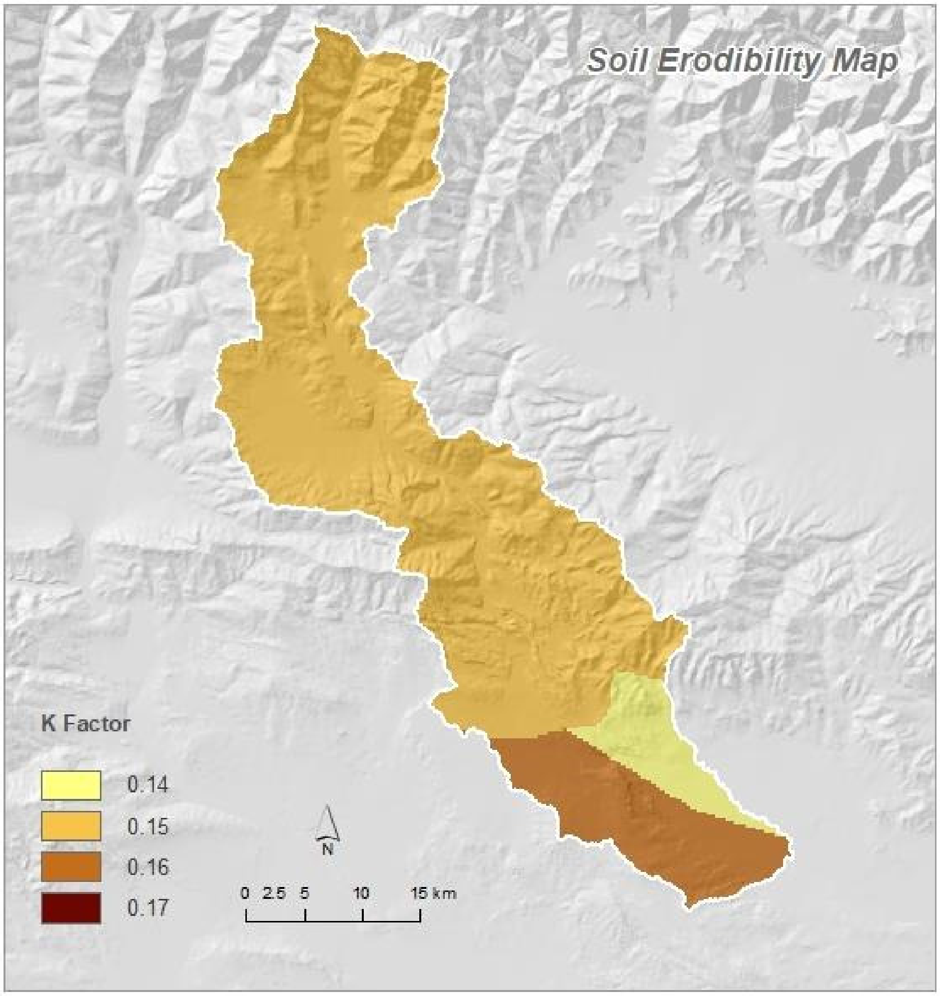
The soil units such as Lithosols (I), Chromic Cambisols (BC), Hapilc Kastanozems (KH), and Luvic Chernozems (CL) are within the study area.

By using the above-mentioned data and formulas, all fractions have been calculated. Afterward, the soil erodibility (K) factor was estimated (Table 9), and based on this, the soil erodibility factor map was created. The map provided in Figure 24 shows the spatial distribution of the soil erodibility factor (K) in the study area.

Table 9. Soil units and the K factor

Soil unit symbol	Sand % topsoil	Silt % topsoil	Clay % topsoil	OC % topsoil	f csand	f cl_si	f orgc	f hisand	K Factor
I	58.9	16.2	24.9	0.97	0.2000001	0.756314	0.992542	0.994235	0.149270
BC	40.1	21.5	38.4	1.44	0.2000950	0.735366	0.981838	0.999886	0.144454
KH	54.5	27.3	18.2	2.16	0.2000120	0.857917	0.975209	0.997659	0.166947
CL	46.3	24.9	28.8	1.27	0.2000410	0.794086	0.985511	0.999576	0.156481

Figure 24. Spatial distribution of the soil erodibility factor (K)



Source: RECC

3.4. Slope Length-Steepness Factor

The slope length and steepness (LS) factor reflects the effect of topography on erosion. Previous studies of soil erosion have demonstrated that increases in slope length and slope steepness can produce higher overland flow velocities and correspondingly more intense erosion (Haan, Barfield, and Hayes 1994; van Remortel, Hamilton, and Hickey 2001). Gross soil loss is considerably more sensitive to changes in slope steepness than to changes in slope length. Thus, soil loss increases proportionately with increase in length and incline of slope (McCool et al. 1987). Slope length has been broadly defined as the distance from the point of origin of overland flow to the point where either the slope gradient decreases so that deposition begins, or the flow enters a defined channel (Wischmeier and Smith 1978). The combined effects of slope length and slope incline give a good estimate of the soil erosion rate.

Rill and inter-rill erosion are the most common types of erosion. The former is a result of surface runoff toward the direction of the slope. The latter is a result of the impact of rain falling on the ground. Inappropriate farming methods cause rill, inter-rill, and gully erosion. RUSLE represents rill and inter-rill erosion and does not differentiate between these two, while gully erosion can be estimated within RUSLE2.[28] The specific effects of topography on soil erosion are estimated by the dimensionless LS factor as the product of the slope length (L) and slope steepness (S) constituents converging onto a point of interest, such as a cell on a GIS raster grid.

The general procedure adopted by several researchers for computing the topographic effect on erosion is to calculate both factors (L and S) together. Nowadays, with GIS technology, many researchers have adopted DEM for generating topography data. The LS factor of the study area has been generated from DEM using the following steps in the GIS environment:

- Filling of sinks of DEM of the study area
- Generation of S factor using filled-in DEM as an input
- Generation of flow direction using filled-in DEM as an input
- Computation of flow accumulation raster using flow direction raster as an input
- Generation of the slope of the study area in degree
- Calculation of the LS factor using flow accumulation slope raster as an input.

There are many formulas for computing topography. Several researchers have adopted the technique as suggested by Moore and Burch (1986). This technique requires measurements of flow accumulation and slope steepness to be entered into the following equation:

$$LS = \text{Power}\left(FA \times \frac{Cel\ size}{22.12}, 0.4 \right) \times \text{Power}\left(\frac{Sin\ (Slope\ 0.01745)}{0.09}, 1.3 \right),$$

where

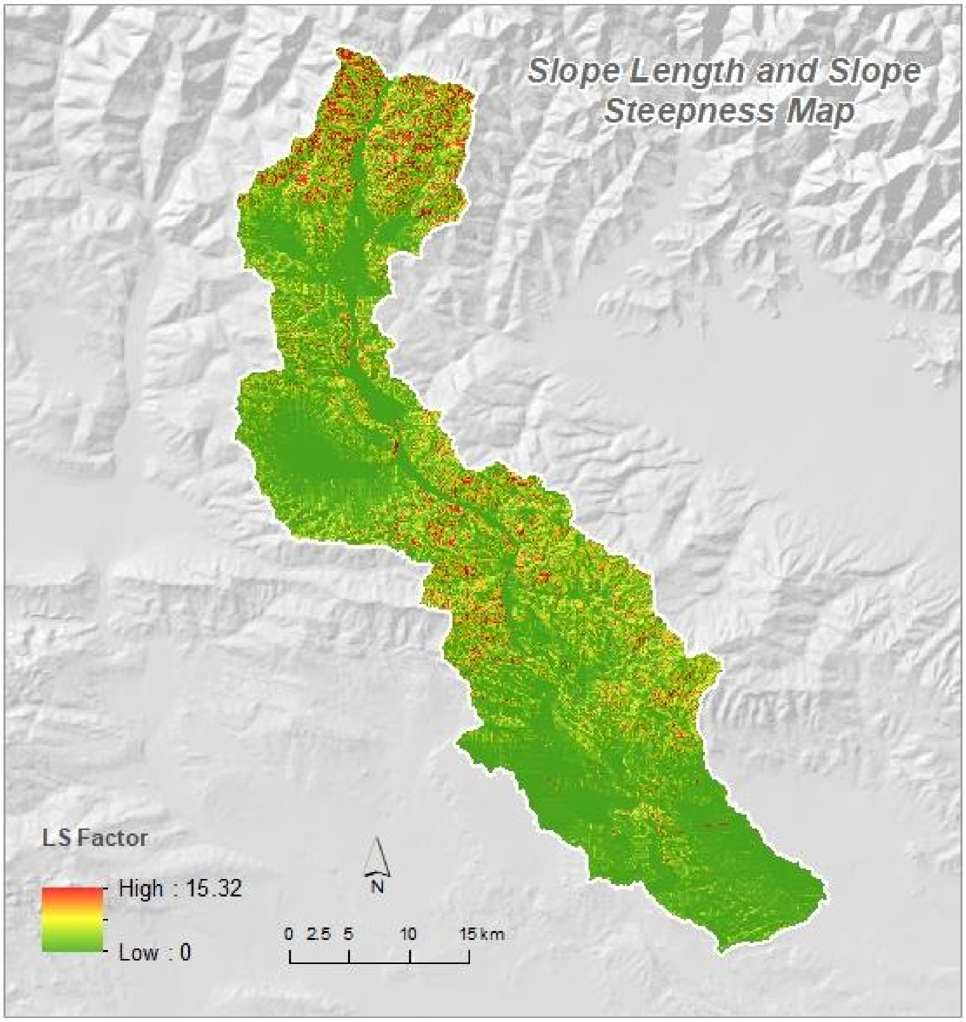
LS = Slope length and steepness factor and

FA = Flow accumulation.

The output LS factor raster map of the study area is shown in Figure 25.

[28] Unadapted version of RUSLE produced in 2003.

Figure 25. Spatial distribution of slope length and slope steepness factor (LS)



Source: RECC

3.5. Support Practice Factor (P)

The support practice factor (P) indicates the rate of soil loss by various types of land cultivation. P reflects the impact of farming practices (such as contour farming, strip cropping, and terracing) on the erosion rate and provides important information for erosion control. Table 10 shows the P value for various methods of land cultivation by various slope gradients (Shin 1999). The P value ranges from 0 to 1, whereby the value 0 indicates a very good conservation practice and the value 1 indicates a very poor conservation practice.

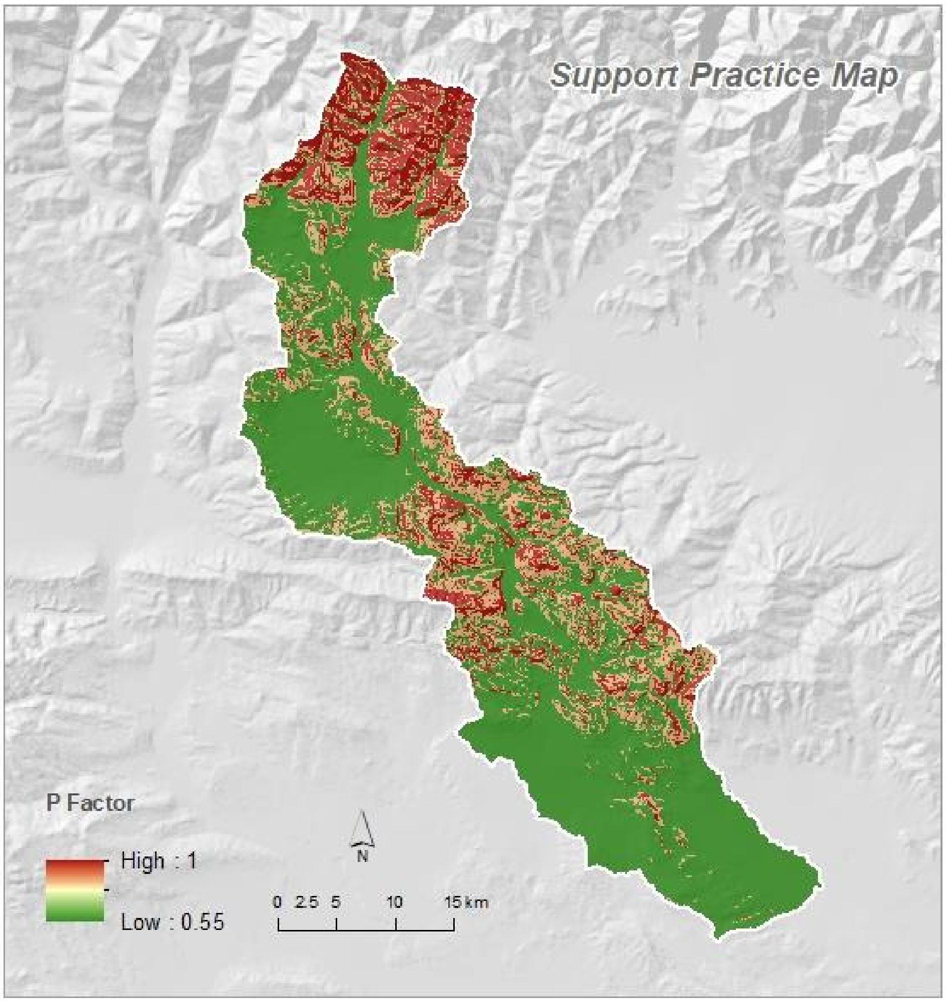
Table 10. Values for different slope gradients

Slope percent	Contouring	Strip cropping	Terracing
0–7	0.55	0.27	0.10
7–11.3	0.60	0.30	0.12
11.3–17.6	0.80	0.40	0.16

Slope percent	Contouring	Strip cropping	Terracing
17.6–26.8	0.90	0.45	0.18
26.8 >	1.00	0.50	0.20

Contour farming has been selected from support practices and used for this study. Afterward, P was estimated and a map of the spatial distribution of P was generated (Figure 26).

Figure 26. Spatial distribution of the support practice factor (P)



Source: RECC

3.6. Cover Management Factor (C)

The Cover Management Factor (C) is used to reflect the effect of cropping and other management practices on erosion rates. Vegetation cover is the second most important factor next to topography controlling soil erosion risk since it is very sensitive to soil loss (van der Knijff et al. 1999). The land cover intercepts rainfall, increases infiltration, and reduces rainfall energy. As the vegetation cover enhances, the soil loss decreases.

It is important to mention that the technique most widely used nowadays for deriving the surface cover factor is by employing remote sensing techniques in producing land use/cover classification from a satellite. This technique has been used in the present study.

To estimate the C value, the Esri 10-meter resolution land use/land cover (LULC) data set[29] was used. Available LULC data give a good understanding of the characteristics of cultivated land, forest, surface water, bare land, and so on, which are essential for the studies of soil erosion or development planning. Table 11 presents the C factor values for different LULC classes within the study area.

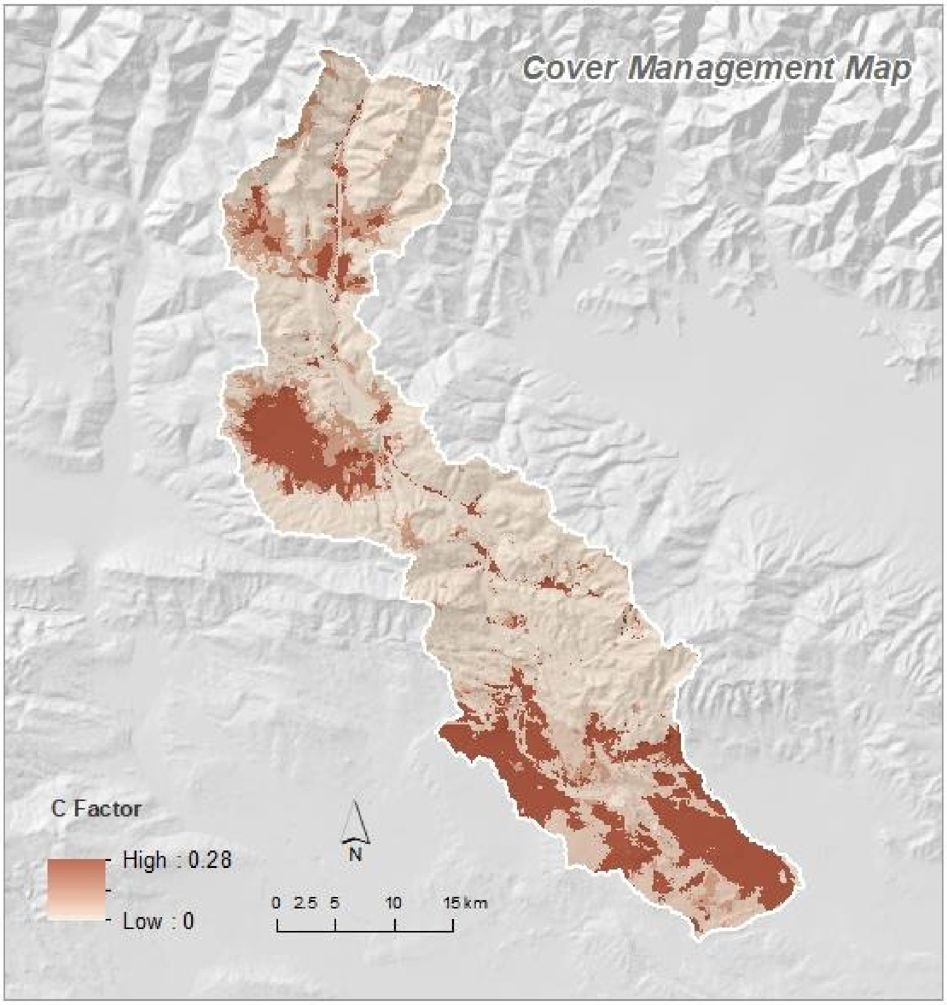
Table 11. Land cover/land use classes and relevant C factor value

Land cover/Land use	C Factor
Cropland	0.280
Urban area	0.090
Bare area	0.180
Forest	0.004
Grassland	0.040
Scrubland/shrubland	0.014
Water body	0.000
Unclassified	0.000

After assigning the C factor values to land cover classes, the cover management factor map was created (Figure 27).

[29] https://www.arcgis.com/home/item.html?id=d6642f8a4f6d4685a24ae2dc0c73d4ac.

Figure 27. Spatial distribution of the cover management factor (C)

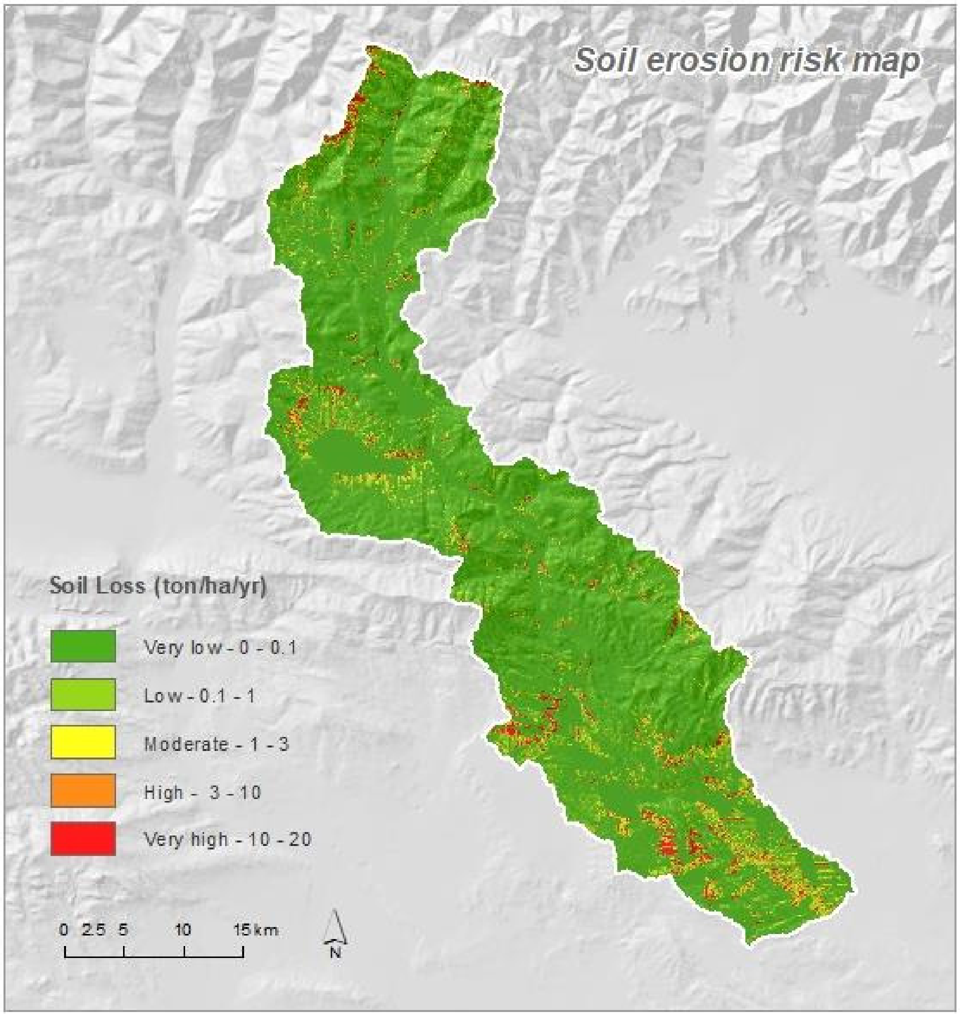


Source: RECC

3.7. Soil Erosion Risk Zones

Implementation of RUSLE in a GIS environment allows to explore and reduce existing soil loss rates in the study area. Thus, a soil erosion risk map has been developed for the study area using RUSLE in conjunction with GIS and remote sensing data. It has been generated by overlaying different factors such as R, K, LS, P, and C. The soil erosion risk zones in the study area have been categorized into five types such as very low, low, moderate, high, and very high. The results are shown in Figure 28.

Figure 28. Soil erosion risk map



Source: RECC

Considering soil loss risk zones, nearly 513.48 ha (0.4 percent) and 53.24 ha (0.04 percent) of the study area are within the moderate and high erosion risk zones, respectively, while only 1.12 ha of the area is within a very high erosion risk zone (Table 12).

Table 12. Soil loss summary of the study area

Numeric range of soil loss (t/ha/year)	Soil erosion risk class	Area (ha)	Area (%)
0–0.1	Very low	108,324.20	88.62
0.1–1	Low	13,346.00	10.92
1–3	Moderate	513.48	0.42
3–10	High	53.24	0.04
10–20	Very high	1.12	0.00

3.8. Current Limitations of the RUSLE Modeling and Future Prospects

Multiple sources of the reviewed literature show that the RUSLE model has been applied extensively and also proven valuable in estimating soil losses as a result of erosion in many parts of the world. Although it is a suitable model for application at the local (small) scale, the combination of RUSLE and GIS techniques has improved the assessment of spatially distributed soil erosion in large catchment scales. Sources show that the five important components of the model can be derived from many sources (DEM, weather data, soil maps, and remote sensing images). Thus, the use of GIS technology allows for a wider study area (large-scale catchment) in soil erosion studies and provides the necessary tools to analyze these to improve the results.

The present study was designed to estimate soil loss and assess the erosion-prone areas within the study area using the RUSLE model in conjunction with GIS and remote sensing data. This study demonstrates that a GIS-based methodology is a valuable tool in developing a spatial assessment of the distribution of erosion risk across the study area. It is observed that the quantity of erosion varies mainly by topography and LULC.

As mentioned earlier, nearly 10.92 percent, 0.42 percent, and 0.04 percent of the area are within the low, moderate, and high erosion risk zones, respectively. Since there are some limitations to the RUSLE mode, its results may lack accuracy in some circumstances. In the risk zones, impacts are manifested by land degradation within them, and also, particulate matter generated here causes negative impacts of sedimentation downstream. This emphasizes the importance of designing and implementing suitable soil conservation/erosion control practices for application in the risk zones. To maximize their effectiveness, erosion control measures should be targeted at the most vulnerable areas, where the impact is likely to be the greatest. But to do this, first, it is necessary to understand the spatial pattern of erosion processes in the study area. By analyzing the impact of the increase in an agricultural area on soil erosion, it appears that as the agricultural area increases, erosion risk also increases due to the inappropriate agricultural practices such as plowing and poorly designed and managed irrigation systems. Field monitoring provides useful information for determining the priority areas for landscape restoration/conservation. The overall impact of intervention is maximized by the application of suitable erosion control measures in the severely affected areas.

Although the methodology used in this study is instrumental for identifying the priority areas for interventions aimed at the reduction of soil erosion, it still has certain limitations and a potential for improvement through more accurate estimation of factors that drive erosion in the RUSLE model, such as rainfall, soil erodibility, and slope length and steepness. In particular,

- Information on precipitation drawn from CHIRPS (a 35+-year quasi-global rainfall data) was used to calculate the rainfall erosion factor. This approach does not capture the distribution of heavy rainfall events, which are known to have a marked impact on soil erosion. The rainfall erosion potential is essentially determined by the total storm energy and maximum 30-minute storm intensity. There are no detailed rainfall data available but, in the future, hourly weather station data could be used to improve the estimates (for example, data from the automated stations recently installed under the EU Water Initiative in the Alazani-Iori basin);

- The combined slope length and slope steepness (LS factor) describes the effect of topography on soil erosion, and accordingly, it has a big influence on soil erosion. Several equations are available for estimating the slope length factor from DEM. This study used the equation that gave a good estimation. The LS factor has been calculated using a high-resolution (20 m) DEM. In general, slope length calculation in the GIS environment results in too long slope length which leads to LS values that are higher than reasonable for the maximum slope length and steepness; and
- Better estimates could be made regarding the soil erodibility factor K if more detailed information is obtained on soil units. As mentioned earlier, the FAO Digital Soil Map of the World has been used to calculate this factor, which does not contain detailed information on soil units (mixtures of different soil types). Accordingly, only four soil units are determined within the study area.

Furthermore, the following recommendations are relevant for future soil erosion studies with the RUSLE model in a GIS framework:

- The widely used remote sensing technique of the Normalized Difference Vegetation Index (NDVI) could be applied for deriving the cover management factor C. This approach can give good results in obtaining C factor surface.
- To improve the result of soil erosion estimation using the RUSLE model, it is worth using the field approach such as erosion pins and the SIBERIA erosion model (Hancock et al. 2008). This approach would lead to better estimation and modeling of soil loss in the study area.
- Results could be calibrated against reality through some sort of ground truthing.
- Fieldwork can be conducted for assessing erosion through the estimation of vegetation cover or by other visible signs of erosion (for example, the occurrence and gravity of rills and gullies).
- RUSLE2 currently is applicable to smaller areas and would require work to define erosivity and other climate properties and to build some generic management. It provides robust estimates of the average annual sheet, rill, and gully erosion from a wide range of land use, soil, and climate conditions. It could have not been used in the present study due to lack of the database it requires.

In conclusion, a soil erosion model such as RUSLE, integrated with GIS, can be applied to estimate soil loss and assess the erosion-prone areas in the study area. Severity of erosion varies mainly by topography and LULC. There is a need to implement suitable soil conservation practices in the areas that come under moderate, high, and very high erosion risk categories.

4. RESTORATION OPPORTUNITY ASSESSMENT MAPPING - ROAM

Watershed management and landscape restoration priorities for the Sioni irrigation water reservoir have been identified at the initial stage of the study, the main objective being the reduction of the amount of sediment being transported to the Sioni Reservoir and the improvement of the irrigation capacity of the reservoir.

4.1. Forest Landscape Restoration Assessment

The concept of FLR was developed about 20 years ago, as an approach for increasing the integrity and capacity of ecosystem service delivery of the degraded forest landscapes, aimed at the improvement of the affected people's livelihood. The impetus for FLR stems from the large degree of forest degradation and loss, which has resulted in global declines in biodiversity and ecosystem services.

FLR interventions are quite diverse because they have to be adjusted to the degree of degradation, current land uses, ecosystem types, and needs of stakeholders. Even for relatively small-scale application of FLR, implementation may be complex because of social factors (for example, governance structures, land tenure and ownership, and stakeholder expectations) and the mechanics of the restoration interventions (for example, planning, training, planting, and monitoring). Each application must be tailored to the specific landscape; however, the types of restoration interventions are usually selected from the conventional menu (for example, ecological restoration, agroforestry, and eco-agriculture). Challenges mount when FLR interventions are scaled up to cover larger landscapes.

Landscape restoration is a long-term process of regaining ecological functionality and enhancing human well-being across cleared or degraded forest landscapes. It is about 'forests' because it involves increasing the number and/or health of trees in an area. It is about 'landscapes' because it involves entire watersheds, jurisdictions, or even countries in which many land uses interact. It is about 'restoration' because it involves bringing back the biological productivity of an area to achieve any number of benefits for the people and the planet. It is 'long-term' because it requires a multiyear vision of the ecological functions and benefits to human well-being that restoration will produce although tangible deliverables such as jobs, income, and carbon sequestration begin to flow right away.

Successful FLR is a forward-looking and dynamic approach, focusing on strengthening the resilience of landscapes and creating future options to adjust and further optimize ecosystem goods and services as societal needs change or new challenges arise.

While FLR sometimes involves the opportunity to restore large contiguous tracts of degraded or fragmented forest land (called wide-scale restoration), particularly in less-populated areas, the majority of restoration opportunities are found on or adjacent to agricultural or pastoral lands. In these situations, restoration must complement and not displace existing land uses. This results in a patchwork or mosaic of different land uses, including for example agriculture, agroforestry systems and improved fallow systems, ecological corridors, discrete areas of forests and woodlands, and river or lakeside plantings to protect waterways.

It is crucial to identify and analyze FLR potential and locate specific areas of opportunity at a national and subnational level. It is the long-term process of regaining ecological functionality and enhancing human well-being across deforested or degraded forest landscapes. FLR is more than just planting trees—it is restoring a whole landscape to meet the present and future needs and to offer multiple benefits and land uses over time.

FLR is undertaken through various activities such as tree planting, managed natural regeneration, agroforestry, and improved land management to accommodate a mosaic of land uses, including agriculture, protected wildlife reserves, managed plantations, riverside plantings, and so on. Furthermore, FLR is a forward-looking and dynamic approach, focusing on strengthening the resilience of landscapes and creating future options to adjust and further optimize ecosystem goods and services as societal needs change or new challenges arise. It integrates the following principles:[30]

- **Focus on landscapes.** FLR takes place within and across entire landscapes, not individual sites, representing mosaics of interacting land uses and management practices under various tenure and governance systems. It is at this scale that ecological, social, and economic priorities can be balanced.
- **Maintain and enhance natural ecosystems within landscapes.** FLR does not lead to the conversion or destruction of natural forests or other ecosystems. It enhances the conservation, recovery, and sustainable management of forests and other ecosystems.
- **Engage stakeholders and support participatory governance.** FLR actively engages stakeholders at different scales, including vulnerable groups, in planning and decision-making regarding land use, restoration goals and strategies, implementation methods, benefit sharing, monitoring, and review processes.
- **Tailor to the local context using a variety of approaches.** FLR uses a variety of approaches that are adapted to the local social; cultural; economic; and ecological values, needs, and landscape history. It draws on the latest science and best practice and traditional and indigenous knowledge and applies that information in the context of local capacities and existing or new governance structures.
- **Restore multiple functions for multiple benefits.** FLR interventions aim to restore multiple ecological, social, and economic functions across a landscape and generate a range of ecosystem goods and services that benefit multiple stakeholder groups.

[30] https://www.iucn.org/theme/forests/our-work/forest-landscape-restoration.

- **Manage adaptively for long-term resilience.** FLR seeks to enhance the resilience of the landscape and its stakeholders over the medium and long terms. Restoration approaches should enhance species and genetic diversity and be adjusted over time to reflect changes in climate and other environmental conditions, knowledge, capacities, stakeholder needs, and societal values. As restoration progresses, information from monitoring activities, research, and stakeholder guidance should be integrated into management plans.

Noteworthily, in less populated areas, a so-called **large-scale restoration** (to restore large contiguous tracts of degraded or fragmented forest land) takes place, while the majority of restoration opportunities on or adjacent to agricultural or pastoral land represent **mosaic restoration**. Because the restoration should not displace existing land uses, various interventions happen on several small patches of land, forming a mosaic of land use types, such as agriculture, agroforestry, forest, woodlands, and rivers.

When applied on larger areas, FLR benefits amplify and generate multiple ecosystem services such as

- Soil formation and regeneration,
- Erosion protection,
- Climate regulation,
- Water regulation,
- Rainfall,
- Food security,
- Energy security, and
- Disaster risk reduction.

4.2. Restoration Opportunities Assessment Methodology

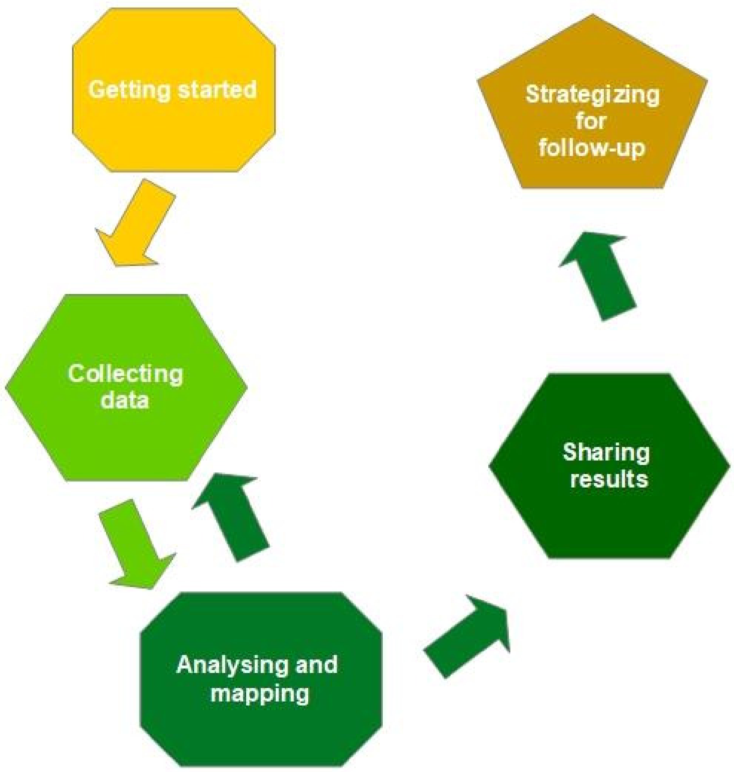
ROAM, produced by the IUCN and the WRI, provides a flexible and affordable framework for rapid identification and assessment of areas that are primed for FLR and for identification of specific priority areas at a national or subnational level. ROAM is designed to provide relevant analytical inputs to national or subnational policy and operational processes, such as the development of programs under national REDD+ (Reducing Emissions from Deforestation and Forest Degradation) strategies, national climate adaptation programs, national biodiversity strategies and action plans, and requests for donor assistance in the related sector of development.

Also, ROAM can provide vital support to countries seeking to accelerate or implement restoration programs and landscape-level strategies. In this regard, ROAM enables countries to define and implement national or subnational contributions to the Bonn Challenge and concurrently allow nations to meet existing international commitments under the Convention on Biological Diversity, UNCCD, and the United Nations Framework Convention on Climate Change.[31]

ROAM is a stepwise and iterative application (Figure 29), which has the following characteristics:

- Involves looking at FLR potential through different lenses, to arrive at the final set of 'best bet' opportunities and
- Uses a powerful combination of stakeholder engagement (best knowledge) and analysis of documented data (best science) to identify and investigate FLR opportunities.

Figure 29. ROAM application - overall process



ROAM is the most comprehensive and responsive framework for FLR. It helps landscape stakeholders to identify FLR opportunities for meeting national and international goals. A ROAM assessment can be undertaken through collaborative engagement with stakeholders and can deliver the following outputs (Gichuki et al. 2019):

- Identified priority areas for restoration

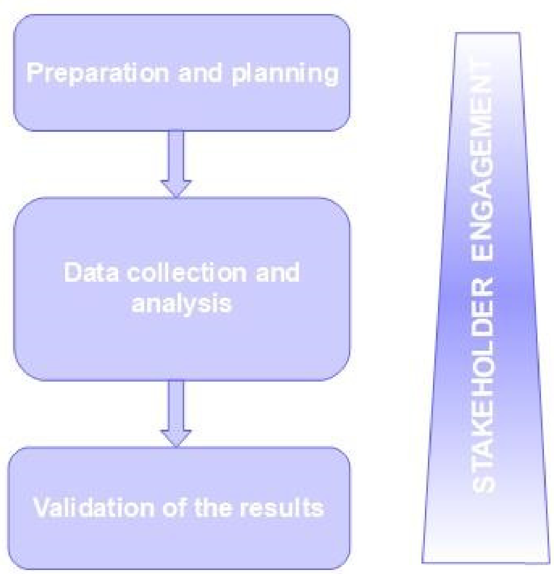
[31] Source: https://www.iucn.org/theme/forests/our-work/forest-landscape-restoration/restoration-opportunities-assessment-methodology-roam.

- A short list of the most relevant and feasible restoration intervention types across the assessment area
- Quantified costs and benefits of each intervention type
- Estimated values of additional carbon sequestered by these intervention types
- Analysis of the finance and investment options for restoration in the assessment area
- A diagnostic of 'restoration readiness' and strategies for addressing major policy and institutional bottlenecks.

Out of the above set of possible deliverables, the present study did not produce estimated values of additional carbon sequestered by intervention types due to existing limitations. A thorough analysis of the potential carbon benefits to be gained through various types of the proposed interventions was beyond the scope, timeline, and budget of the present study. Such analysis may be carried out as a separate exercise in the course of WMLROA implementation.

The key inputs of ROAM are stakeholder engagement and ownership, and they involve three main phases of work: preparation and planning, data collection and analysis, and validation of the results (Figure 30).

Figure 30. Key steps in ROAM process



Individual components of this process and the order in which these steps are undertaken may vary to some degree from one assessment to another. The present study focused on the identification and prioritization of landscape degradation hot spots and the selection of landscape restoration activities upstream and downstream of the targeted Sioni irrigation reservoir located in eastern Georgia.

4.3. Problem Setting and FLR Objectives

For FLR to yield a tangible outcome, it is necessary to make a problem statement, identify specific challenges, and define FLR objectives. The assessment team of the present study defined major problems and FLR objectives by considering the following:

- SDG Indicator 15.3.1- Land Productivity, Land Cover, Soil Organic Carbon
- Results of the soil erosion assessment carried out using RUSLE
- GIS/remote sensing analysis - LULC changes
- Field visits (visual inspection, ground truthing)
- Stakeholder involvement (local knowledge = best knowledge).

Formulation of main problems to be addressed

- Forest land is degraded; multiple trees are extracted from the landscape.
- Excessive and uncontrolled grazing occurs, exacerbating ongoing soil erosion processes as well as triggering erosion in new locations (one of the root causes of soil erosion).
- Poor farming practices are applied, especially excessive and uncontrolled surface irrigation that leads to soil erosion (one of the root causes of reservoir sedimentation).
- Water quality suffers from untreated wastewater discharges.
- Sand and gravel extraction from the Iori River significantly distorts the natural equilibrium of the stream channel. By removing sediment from the active channel bed, in-stream mines interrupt the continuity of sediment transport through the river system, disrupting the sediment mass balance in the river downstream.

The overall goal of the WMLROA was defined as

> "Curtail soil erosion in the Sioni catchment to and reduce sedimentation of the reservoir, and its impacts on the irrigation infrastructure further downstream through landscape restoration aimed at enhancing its ecological functions and improving livelihood of communities residing in the degraded landscapes."

FLR objectives:

- Control erosion and improve watershed management.
- Improve the resilience and productivity of vulnerable forest land.
- Halt and reverse land degradation while attaining climate benefits.

- Conserve biodiversity and foster ecological corridors.
- Improve environmentally damaging practice of sand and gravel extraction from the riverbed.
- Enhance ecosystem capacity to provide environmental services.

4.4. Identifying Land Use Challenges and Potential FLR Options

Land use challenges are circumstances limiting the benefits from a land resource due to its unsustainable management as well as external factors negatively affecting its physical, chemical, and biological parameters. The assessment team identified the most pressing land use challenges currently faced in the study area and the ways in which they could be addressed through FLR.

Relevant stakeholders were consulted to compile a preliminary list of unsustainable land use practices that contribute to land degradation. The following land use challenges were identified as the main concerns and, some of them believed to be the subject for mitigation through landscape restoration:

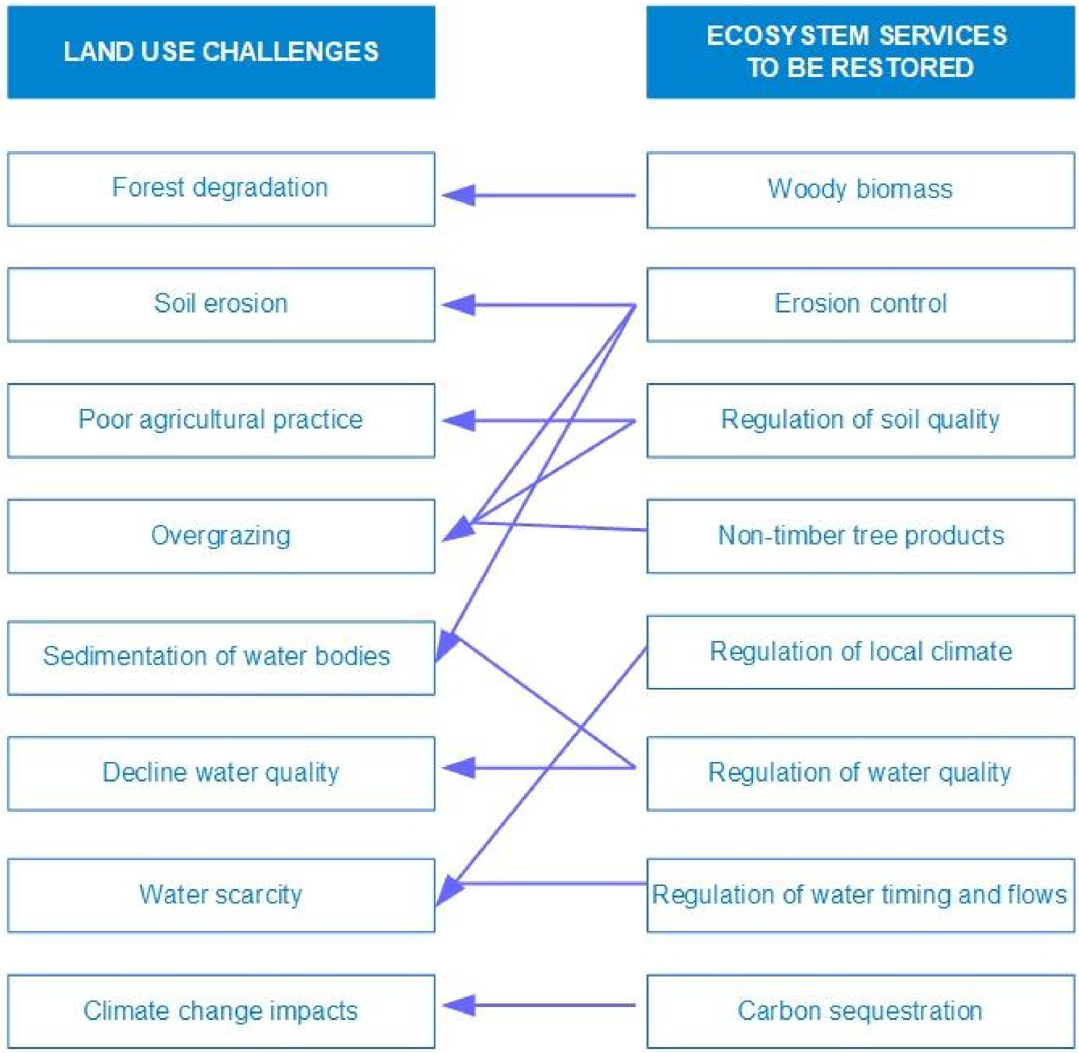
- Forest degradation/deforestation resulting from unregulated/excessive logging and firewood extraction
- Soil erosion and gullying
- Unsustainable agronomic and irrigation practices
- Overgrazing/unregulated grazing, especially in or nearby already eroded areas and water bodies
- Sedimentation of water bodies decreasing efficiency of irrigation infrastructure and limiting delivery of irrigation services to farmers
- Environmentally damaging practice of sand and gravel extraction from riverbeds
- Climate-induced change in the water balance, causing scarcity of both surface water and groundwater resources
- Increasingly uneven annual distribution of precipitation, extreme weather events, and other impacts of climate change.

The assessment of ecosystem services is a participatory process that helps address land use challenges (Figure 31). By increasing the number of trees and expanding forest cover, progress can be made toward restoring lost or degraded ecosystem services. The optimal choice depends on the main ecosystem services intended for restoration. Stakeholders identified the following main restoration options that could help address the land use challenges and at the same time restore the ecosystem services that are currently lacking:

- **Restocking degraded forests.** Increase the stock of existing degraded forests, including degraded high forests and woodlands. Enrich planting and assist natural regeneration to restock degraded forests.
- **Agroforestry.** Increase the number of trees on the existing crop, pastoral, and agro-pastoral land with sparse tree cover.
- **Soil and water conservation.** Provide check dams, gully protection, terracing, contour bunds, infiltration trenches, and/or ridges.
- **Tree-based buffer zones along rivers, lakes, and reservoirs.** Expand secondary forests; facilitate natural regeneration of forests; stabilize riverbanks; protect rivers, lakes, and reservoirs; and control sedimentation.

These restoration options can potentially help reduce erosion, decrease the intensity of flooding, improve water and soil quality, capture more carbon, and increase the health of forest habitats supporting wildlife.

Figure 31. Main land use challenges and to-be-restored ecosystem services identified for the study area



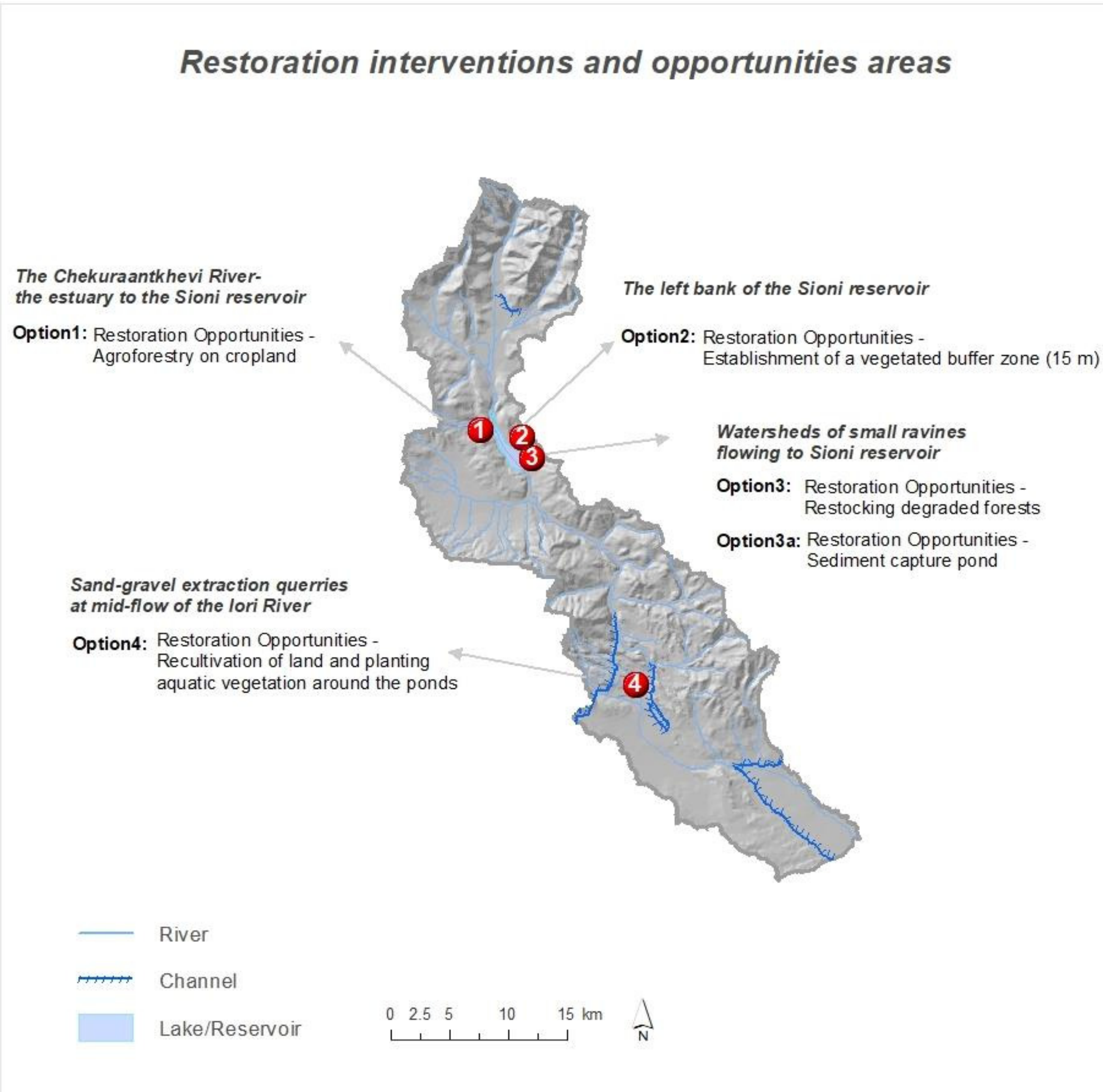
There are various landscape restoration options that can contribute to addressing multiple land use challenges and, at the same time, supply multiple ecosystem services. Some restoration options may be more helpful than others in addressing specific land use challenges. In the process of consultation, stakeholders pointed at a few restoration interventions which, from their perspective, are best suited for restoring the degraded lands in the study area.

4.5. Restoration Interventions and Opportunity Areas

The key activities of the assessment group were field visits and consultations with rural communities and actors at the field levels. These field visits provided opportunities to discuss with communities what land use challenges, drivers of degradation, and ecosystem services losses are most prevalent and then identify what types of specific restoration interventions or approaches could work best to address these issues. Fieldwork included identification/confirmation of property and user rights to the land plots eyed for interventions. There are no privately owned forests in Georgia at present, although the

Law of Georgia on the Forest Code of Georgia does provide for it. Therefore, forest stands selected for restocking are all on the state ownership. Former mining areas prioritized for reinstatement were checked against the electronic database of mining licenses operated by the NAMR to confirm that these abandoned mines are not covered by an active license for resource extraction. Field visits, desktop work, and stakeholder consultations enabled the assessment group to identify critical landscape challenges and synthesize and prioritize the restoration interventions across the assessment area (Figure 32).

Figure 32. Opportunities areas within the assessment area



Source: RECC

The tentative list of restoration interventions identified during the preparatory phase is presented below. **It is recommended that these proposed restoration options are revisited and refined in**

the second iterative phase, where stakeholders and experts can decide whether and how they want to adjust the scope and type of candidate FLR interventions. For this next phase, stakeholders will need to consider the results of the cost-benefit analysis of implementing the suggested actions (which is presented in the following section), as well as other sector-specific spatial and economic considerations.

Restoration option 1: Agroforestry in croplands

Type of restoration - mosaic

Agroforestry interventions that fall under the umbrella of FLR focus on incorporating trees into agricultural landscapes such as degraded, low-yielding croplands. There are several areas where on-farm trees or the use of agroforestry could potentially be increased. This can be done through various interventions such as field border planting, woodlots, agroforests, and interplanting trees with crops. Agroforestry can be scaled up to reduce erosion, improve soil fertility, and diversify livelihoods. To implement this type of FLR at scale, it is necessary to engage farmers in the protection and maintenance of planed shrubs and trees through farmer-managed natural regeneration (FMNR), as well as by combining FMNR and tree planting with conservation agriculture and climate-smart agriculture. Buffer strips and hedges are applicable to all agricultural land uses—arable fields, perennial crops, pastures, and heterogeneous agricultural areas.

The area proposed for this type of intervention is within the Chekuraantkhevi River watershed (Figure 33).

Figure 33. Proposed area for agroforestry intervention - the Chekuraantkhevi River catchment

Source: RECC

Buffer strips are areas carrying natural vegetation (grass, bushes, or trees) at the margin of fields, arable land, transport infrastructure, and watercourses. They may carry several types of vegetation, varying from simple grass to combinations of grass, trees, and shrubs. Due to permanent vegetative cover, buffer strips offer good conditions for effective water infiltration and slowing surface flow, that is, the natural retention of water. They can also significantly reduce the number of suspended solids, nitrates, and phosphates originating from agricultural runoff, thus leading to water quality improvements. Buffer strips can be sited in riparian zones or away from water bodies as field margins, headlands, or within fields (for example, beetle banks). Hedges across long, steep slopes also contribute to reduce soil erosion as they intercept and slow surface runoff water before it builds into the damaging flow, particularly where there is a margin or buffer strip alongside. Vegetation within active gullies also provides immediate reduction of erosion within the gullies and of the rate of transported sediments via the gullies.

This intervention can contribute to sustaining agriculture both by reducing the negative impacts of agricultural activity and by providing habitats for pollinators and bio-control species. They can also reduce the risks and impacts of water and wind erosion. There are several benefits of this intervention.

- **Erosion/sediment control.** Erosion and sedimentation are controlled by buffer strips through both reduction of runoff and filtration by buffer strip vegetation.
- **Filtration of pollutant.** Buffer strips can be very effective in filtering pollutants.
- **Prevention of surface water quality deterioration.** Buffer strips contribute to protecting water quality by slowing and reducing runoff and increasing the filtration of pollutants.
- **Protection for ecosystems.** Buffer strips contribute to the balance of ecosystems by providing habitats and improving connectivity between habitats in the form of wildlife corridors.
- **Sustaining agriculture.** Buffer strips can contribute to sustainable agriculture both by reducing environmental pollution with agrochemicals and nutrients and by providing habitats for pollinators and bio-control species. They can also reduce risks and impacts of water and wind erosion.
- **Climate change adaptation and mitigation.** Buffer strips act as carbon sinks and thus mitigate climate change through increased volume of biomass and soil degradation.

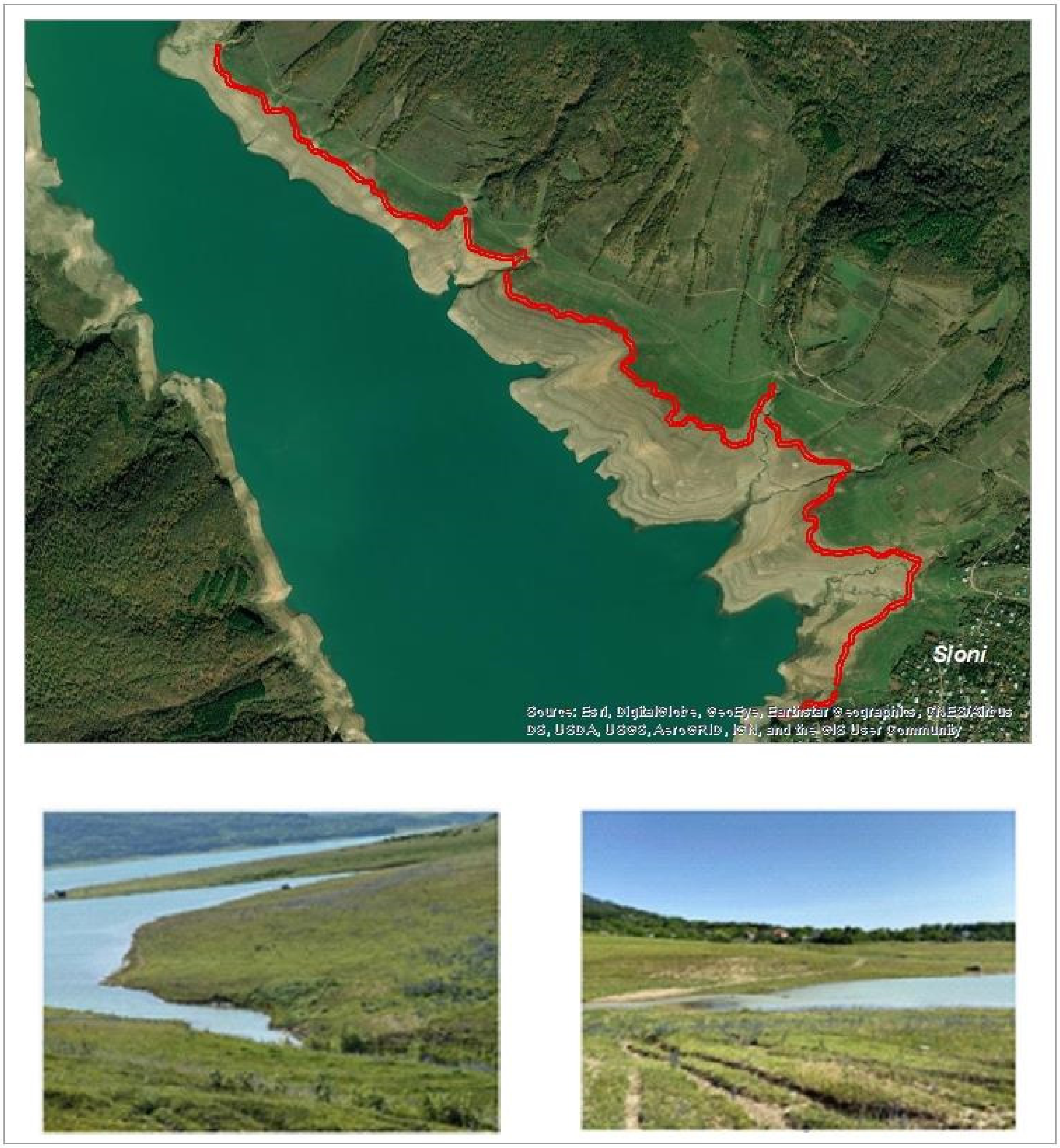
Restoration option 2: Establishment of a vegetated buffer zone

Type of restoration - mosaic

The suggested buffer zone (15 m) is a vegetated area that separates an agricultural production area/urban area from the Sioni Reservoir. The buffer zone is located perpendicular to water flows. It would be used to prevent erosion, and it can have a secondary benefit as a treatment system. It can help protect the reservoir from the impact of adjacent land uses. The buffer can be vegetated with grass, shrubs, and the type of vegetation influencing the services that the buffer can provide.

The area proposed for this type of intervention is the left bank of the Sioni irrigation reservoir (Figure 34).

Figure 34. Proposed area for artificial wetland intervention - the left bank of the Sioni Reservoir



Source: RECC

The main benefits of this intervention are

- **Reduced erosion and/or sediment delivery and control** by ensuring greater vegetation coverage; this reduces surface flow and availability of sediments and
- **Filtration of pollutants.** Higher vegetation coverage and reduced surface flow can result in greater filtration of pollutants.

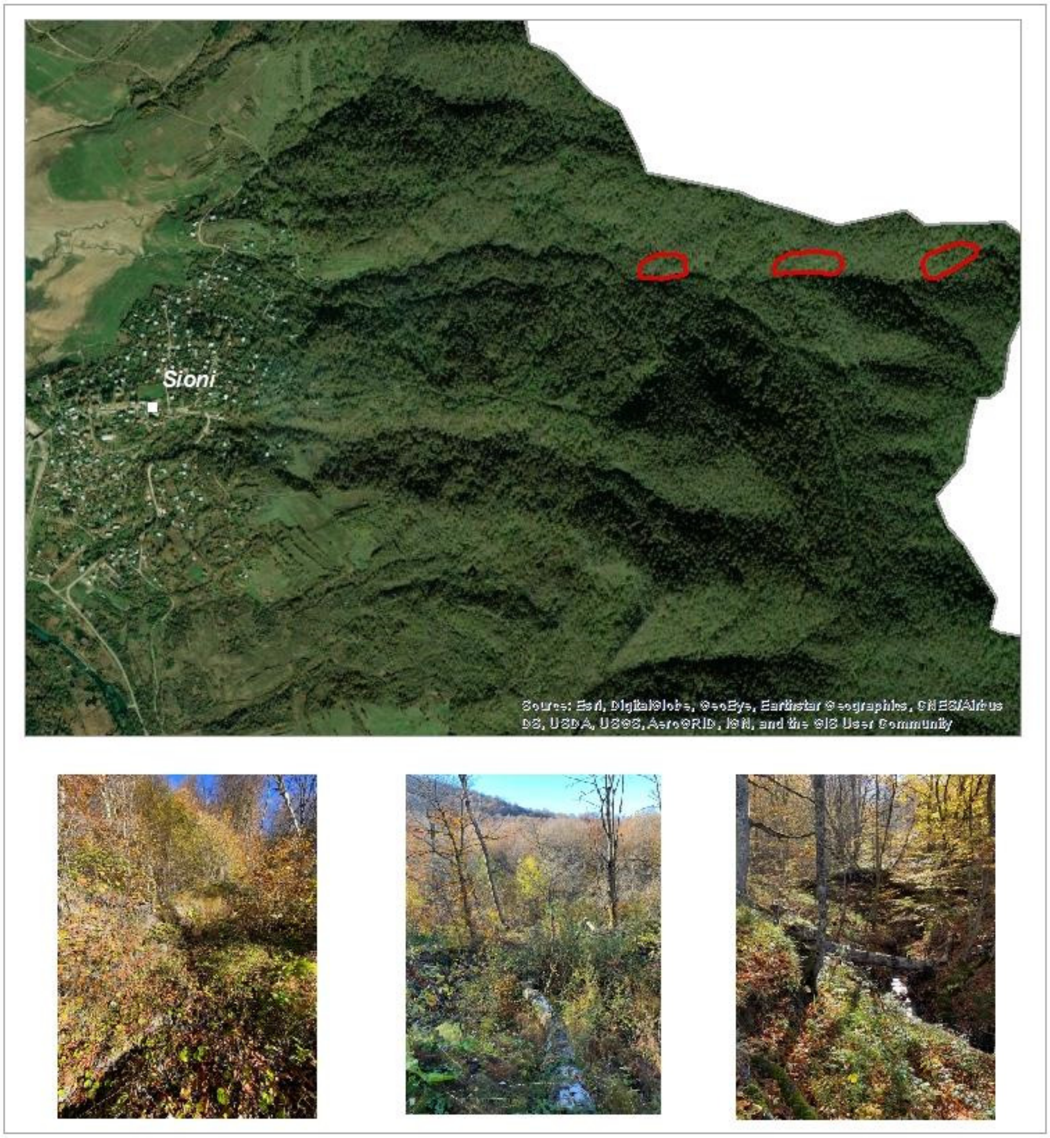
Restoration option 3: Restocking of degraded forests

Type of restoration - large-scale restoration

The area of degraded forests is increasing. Common practices for restocking degraded forests are enrichment planting and assisted natural regeneration. Such an intervention implies rehabilitating existing natural forests that show signs of natural and anthropogenic degradation. The existing forests can be restocked to restore their role in biodiversity conservation, carbon sinking, flood prevention, microclimate regulation, and sustainable income generation. Furthermore, this intervention can contribute to slope stabilization and reduce the risk of landslides.

The area proposed for such intervention is three small ravines in the forested areas adjacent to Sioni village that drain to the Sioni Reservoir (Figure 35).

Figure 35. Proposed area for forest restocking - small ravines draining to the Sioni Reservoir



Source: RECC

Benefits expected from this intervention include the following:

- **Runoff storage/slowing.** Because of their great infiltration capacity, forest soils can store water from excessive precipitation and limit or prevent runoff. Furthermore, because of their great surface roughness and a high water-holding capacity, forest soils can slow runoff like a sponge storing water and slow the rate at which water travels.
- **Reduced erosion and/or sediment delivery.** Compared to bare soils, land under forest cover can significantly reduce erosion and sediment delivery. The energy of rainfall reaching the soil surface is moderated by forest cover, reducing the potential for erosion. The dense organic mat characteristic of many forest soil surfaces is also more erosion resistant than bare soils or soils low in organic matter.

- **Improved quality of soil.** Due to higher organic matter content, greater water-holding capacity, higher porosity, and higher infiltration rates, soils under forest cover are of better quality than soils in the areas with sparse vegetation.
- **Climate change adaptation and mitigation.** The carbon sequestration potential of forests makes them significant contributors to climate change mitigation, while the ability to retain water and stabilize soil surface allows forests to play a role in climate adaptation through the moderation of extreme weather events (floods, flood-induced landslides, droughts, and extreme heat). Biomass harvesting from forest catchments may also contribute to climate change mitigation by the substitution of fossil fuel energy sources. Biomass harvesting has, however, to be balanced against other ecosystem services.

Restoration option 3a: Sediment capture pond (pile wall)

Type of restoration - watershed protection and erosion control

Sediment capture ponds are engineered ponds placed in the runoff path to slow its velocity and facilitate deposition of suspended materials. They are most useful for managing environmental impacts of infrastructure construction and rehabilitation that implies earthworks, as well as the negative impacts of mining. The ponds are also used in forests located on slopy terrains. They may also be useful for capturing sediment in agricultural runoff.

Sediment capture ponds have a limited lifespan, depending on how much suspended material is in the inflowing water and on how robust the design of the related infrastructure is —particularly, the design of spillways arranged to manage overflows. However, sediment ponds' lifetime can be extended by proper maintenance, including the removal of accumulated sediment. As with most other water protection methods, sediment capture ponds function well during base and moderate flow events. Catchment area, hydraulic properties of ditches, discharge rate, and soil characteristics are among the factors influencing the operation of the ponds.

Use of sediment capture pounds in frost landscapes brings the following benefits:

- **Sediment control.** Sediment capture ponds limit the transport of suspended material in forest ditches, preventing its entry to surface water bodies downstream. As a result, water quality does not suffer from high turbidity, and the water body is shielded from excessive siltation.
- **Filtration of pollutants.** Because they slow the velocity of water in forest ditch networks and allow suspended material to sink out of the water flow, sediment capture ponds filter pollutants such as phosphorus and heavy metals carried by suspended particles.
- **Erosion control.** The primary function of sediment capture ponds is not the protection against erosion; however, while slowing runoff to allow for the sinking of particulate matter, kinetic energy of the flow is reduced and so is its ability to erode the soil.

Restoration option 4: Recultivation of sand and gravel extraction quarries on the Iori River and planting aquatic vegetation around the ponds

Type of restoration - mosaic

Gravel and sand are the best-known building materials because the dissoluble and frail fragments of the gravel and sand are removed by the water flow and therefore the stable ones remain. Although sand and gravel mining is regulated by law, illegal extraction also occurs. More importantly, extraction allowed by formally issued licenses within designated boundaries is still excessively damaging for the environment because regulations on the methodology of extraction are weak and so is their enforcement. Noteworthily, negative environmental and social impacts of unsustainable mining in a riverbed are not confined to the mining site but rather are felt beyond it, especially downstream. Degraded river habitats result in the loss of fisheries or in the productivity, biodiversity, and recreation potential of an affected area. The impacts of sand and gravel mining in a riverbed include immediate increase in turbidity of the river water, as well as longer-term impacts such as increased erosion and collapse of riverbanks. Aquatic ecosystems and flora and fauna supported by these ecosystems are receptors highly sensitive to mining impacts.

Since there is no proper planning based on cumulative impact assessment and integrated approach to mining of natural construction material from riverbeds, and no clear requirement for phased reinstatement of worked-out sections of mines, sand and gravel mining on the Iori River has tremendous negative impacts on the natural environment and tangible implications for the livelihood of local communities. Recultivation/reclamation could contribute to the regeneration of land plots disturbed with mining and to the restoration of their productivity.

The land recultivation process comprises two main stages:[32]

Technical recultivation deals with the preparation of land for further intended use. It includes surface leveling, application of fertile soil on the surface being reclaimed, construction of drainage and water delivery canals network, and installation of soil-saving facilities. In countries with a strong regulatory base, technical stage of restoration is performed by mining enterprises along the legally binding conditions of the licenses held.

Biological recultivation involves land treatment aimed at improving soil properties. It includes measures for rehabilitation of the fertility of recultivated lands and planting of aquatic vegetation around the ponds that were cut off from the river. Maintaining beneficial vegetation around a pond is extremely important. Establishing buffer zones takes minimal effort and requires little maintenance.

The area proposed for this type of intervention lies along the sand and gravel extraction quarries located on and near the Iori River (Figure 36).

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[32] Recultivation of lands. 2019. Portal of knowledge for water and environmental issues. Retrieved from http://www.cawater-info.net/bk/index_e.htm.

Figure 36. Area for intervention along the sand and gravel extraction quarries located on and near the Iori River, immediately downstream of the worked-out mining site (in the images the Iori River is shown at its mid flow)

Source: RECC

The main benefits of this intervention are as follows:

- **Improved water quality.** Recultivation of worked-out sand and gravel mines helps diminish water runoff and weaken soil erosion. Proper vegetation management in the buffer zones allows for filtration of excess nutrients such as phosphorus and nitrogen from the water column, as well as from inflowing water runoff from the surrounding watersheds that typically occur after every rain event.

- **Erosion and sediment control.** Cultivating vegetation around ponds generated from mining activities helps maintain shoreline stability and prevent erosion and sedimentation.
- **Provision of aquatic habitat.** Buffer zone vegetation contributes to the diversification of habitats around a river. The use of relevant vegetation management techniques and buffer zones may create/sustain habitats not only for small fish, amphibians, and insects but also for native avifauna as well.

It is important to note that land recultivation should follow an integrated approach (that is, provide for future use for land for various purposes). Recultivation period may last 5–10 years and more and thus requires consistent, long-lasting commitment.

4.6. Cost Estimation of the Suggested Interventions to Study Area

For estimating costs and benefits associated with the implementation of the proposed restoration activities, the following assumptions were made (the assumptions are the same across all options, unless noted differently):

- The exchange rate for Georgian lari to US dollar is the average exchange rate during 2021, according to which US$1 = GEL 3.2216.[33]
- Instead of present inflation rate, a long-run target inflation rate was used for the present study, which equals 3 percent while the inflation rate as of January 2022 is 13.9 percent.[34]
- To estimate the present value (PV), the minimum refinancing interest rate (as of January 2022) of 10.5 percent is considered as the discount rate.
- The PV is calculated based on the assumption that the suggested actions will start taking place during 2022.

4.6.1. Restoration Option 1: Agroforestry in Croplands

The area of intervention under option 1 covers the territory surrounding the Chekhuraantkhevi River (flowing into the Sioni irrigation reservoir). The suggested action to prevent soil erosion mainly caused by intense agriculture is to practice agroforestry. Arranging buffer strips along the riverbanks is also recommended. However, the identification of the exact areas where either agroforestry activities or buffer strips can be introduced is a matter of further discussion with the stakeholders. For this reason, only a general overview of the expected expenditures related to the implementation of those activities is included hereby.

According to international literature, agroforestry planning and implementation differs from the approach to most of the other agricultural activities. The planning horizon (time over which direct

33 National Bank of Georgia.
34 National Bank of Georgia.

implementation costs are incurred) is longer than one year because of the time needed to grow the tree components (Godsay 2018). The main costs that should be considered for agroforestry interventions are as follows:

- Establishment costs, including site preparation (mechanical/chemical), seedlings, planting (labor and equipment), and irrigation
- Maintenance costs, including fertilization, pest and disease control, grafting, thinning, pruning, and replacement of plants failing to survive (Godsay 2018).

In the available literature on the topic, the average cost of starting an agroforestry activity is estimated to be GEL 1,400 per ha (US$435). Maintenance may be required for any time ranging from 2 years to 60 years, and the total cost depends on the type of forest, total covered area, and the geographical characteristics of the area (Godsay 2018). Moreover, while starting an agroforest, the previous use of the target land parcel is to be carefully considered. Forgone revenue from not practicing agriculture in the plots selected for starting agroforestry should be estimated (the amount of forgone revenues varies by land use—pastures or cultivation—and in case of cultivation, the type of crop and productivity).

Together with the extended development of agroforestry, the arrangement of buffer strips around the riverbanks is also considered as a potential solution. Arrangement of buffer strips also includes site preparation, stock planting, and maintenance phases. Notably, the implementation cost varies depending on the type of buffers arranged. The following are the average costs of the arrangement of various types of buffer strips of 3 m width:

- **Riparian forest buffer.** The general use of this type of buffer is to restore riparian plant communities; reduce excess sediments, organic material, nutrients, and pesticides in surface runoff; and increase carbon storage. According to estimates, the average capital cost of arranging such type of buffer ranges between GEL 1,037 and GEL 2,800 per ha (equivalent to US$322–871) This cost does not include the expenses on planting and maintenance (European Commission 2013).
- **Vegetative filter strip.** This type of buffer is generally used to reduce suspended solids and associated contaminants in runoff, reduce dissolved contaminant loadings in runoff, and reduce suspended solids and associated contaminants in irrigation tailwater. Vegetative filter strips are usually narrower than riparian forest buffer and are situated predominantly between the potential pollution sources and the water body receiving the runoff. According to literature sources, the average cost to arrange such type of buffer is estimated to be GEL 740 per ha (equivalent to US$230) (Tyndall 2016a).
- **Saturated buffer.** The main purpose of such an intervention is to reduce suspended solids and associated contaminants in the runoff, reduce dissolved contaminant loadings in runoff, and reduce nitrogen loading from redirected tile drainage. The estimated minimum capital cost of this arrangement is GEL 1,160 per ha (equivalent to US$360) (Tyndall 2016b).

The total cost of establishing buffer strips under option 1 will depend on the total area within the territory identified as suitable to host buffer zones as well as the specifics of the selected approach for the buffer zone development. The suggested restoration interventions will be reflected in significant economic benefits for the region. First, restoration is likely to affect the monetary value of the agricultural land in the area. According to the available data, the average price of the agricultural land in Tianeti Municipality (as of January 2022) is US$12 per m^2 (equivalent to GEL 39 per m^2).[35] The price of land plots varies depending on the location, productivity, and access to the utilities, including potable water, electricity, and irrigation services. Recurrent revenues are generated from the agricultural use of the land. The following are the average prices of the main products cultivated in Tianeti Municipality:

- **Maize.** According to Geostat data, the farm gate price of 1 kg of maize in 2020 was GEL 0.69 (the latest available data). Considering the 13.9 percent yearly inflation rate, the average estimated price of maize for 2021 is GEL 0.79 per kg.
- **Potato.** GEL 0.69 per kg during 2020; estimated price for 2021 with inflation GEL 0.79 per kg.
- **Beans.** GEL 4.62 per kg during 2020; estimated price for 2021 with inflation GEL 5.26 GEL per kg.

Alternatively, if the agricultural land is used for pastures, the following prices are relevant:

- **Beef.** Farm gate price was GEL 16.84 per kg during 2020; estimated price for 2021 with inflation GEL 19.18 per kg.
- **Sheep and goat meat.** GEL 15.44 per kg during 2020; estimated price for 2021 with inflation GEL 17.59 per kg.
- **Milk.** GEL 1.09 per liter during 2020; estimated price for 2021 with inflation GEL 1.26 per liter.

The above figures illustrate the value of agricultural land if well maintained or restored using the above suggested interventions. Additionally, practicing agroforestry may become a direct source of revenue. First, local communities may enjoy material or monetary benefits from non-timber forest products, such as wild berries, honey, and fodder. However, such earnings do not emerge immediately after the commencement of agroforestry. The generation of the non-timber products requires minimum 5 years and average 16 years.

[35] The average price is calculated based on the available market prices form real estate agencies.

4.6.2. Restoration Option 2: Establishment of a Vegetated Buffer Zone

To arrange buffer strips, it is recommended to use a mix of trees, shrubs, and groundcover. The total cost of arranging vegetated buffer zones greatly varies and depends on different factors, such as the width of the zone, the type of used vegetation, soil amendments, and so on.[36]

According to the literature, for the arrangement of a buffer zone, the following costs should be accounted:

(a) **Site preparation costs.** This includes the identification of the points where the plants will be placed, as well as the meanders through the buffer.

(b) **Planting.** This includes several activities starting from digging the whole area for buffer zones which will be as wide as plant root balls are, with plant, water, and fertilizer buffers;

(c) **Mulching.** To suppress weeds, provide slow nutrients, and allow for the retention of additional moisture, it is recommended to spread mulch over the root zone of plants (University of New Hampshire 2007).

Table 13 summarizes the estimates of the main cost of installing buffer zones per ha.

Table 13. Cost of installing buffer zones (GEL per ha)[37]

Type of Cost	Minimum Possible Value	Maximum Possible Value
Site Preparation	140	600
Seeds	700	1,700
Planting	240	550

Source: Author's own calculations based on available literature and public information.

Moreover, indirect costs of the creation of buffer zones should be considered as well. The cost for farmers to find another place for grazing their domestic animals should be considered. This cost mainly includes the time expenditures of the farmer, the alternative value of which is the amount of income the farmer can generate within that period. Additionally, the cost will include the value of the land that will be occupied by the buffer zones and will not be accessible for agricultural activities.

After installing the buffer zones, the operation and maintenance costs need to be considered as well. This includes watering (every day during the first week, every other day during the second week, and then twice a week through the first growing season), weed control, and other measures to maintain healthy vegetation. Operation and maintenance costs are highly influenced by the total area of coverage, type of vegetation used, and so on.

The installation of the riparian buffer zones is expected to provide significant economic benefits. The main economic benefit associated with the creation of meadows is the increased value of the land that

[36] Environmental Protection Agency.

[37] The costs are adjusted by the average yearly inflation rate and the exchange rate.

would be protected from erosion at current market prices. As mentioned earlier, the average price of the agricultural land in Tianeti Municipality (as of January 2022) is US$12 per m^2 (equivalent to GEL 39 per m^2).[38] More benefits come from cleaner water—as long as vegetated buffer zones have a pollutants filtration function and can promote reduction of water pollution.

4.6.3. Restoration Option 3: Restocking of Degraded Forests

According to the existing literature, the costs of afforestation can be categorized into three main types: (a) direct implementation costs, which are usually high and include the costs of raw materials (tree seedlings, fencing, irrigation, labor, transportation, and so on); (b) opportunity cost of afforestation which, in this case, will include the forgone opportunities of using the area for grazing as well as the alternative value of the time of farmers who have to find different grazing areas for their domestic animals; and (c) transaction costs which, in this case, include mainly the cost of monitoring of the restocked area (Wainaina 2020). Based on international experience and publicly available data, the average direct cost of afforestation is GEL 2,255 (US$700) per ha at current prices.

Literature sources suggest that the minimum period required to see the results of afforestation is 5 years, while the average is 16 years from the experience of 30 countries across the world (Wainaina 2020). If monitoring of the afforestation process is provided over 5 years and three persons are sufficient to undertake it on a given plot, the PV of the total personnel cost needed for monitoring is estimated at GEL 200,412, which is equivalent to US$62,209.[39] In addition to that, any associated transaction costs necessary for monitoring should be considered.

The implementation of the suggested measure is associated with several direct and indirect benefits, including the following:

- Benefits from reduced land erosion, the value of which will be the equivalent of the market value of the land plots in Tianeti Municipality (currently US$12 per m^2). However, the exact amount of the potential benefit from this activity depends on the total area of the land that is protected from erosion.
- After afforestation, the area can potentially become an additional source of revenue generated from the extraction of timber as well as non-timber forest products. However, the revenue will not be generated immediately and can only be expected after the formation of forest (in most cases, that takes a minimum of 5 years and 16 years on average, while in some cases, certain benefits may be expected earlier that 5 years, for example, revenue from honey production). The potential revenue depends on the species of trees to be planted. Moreover, the utilization of timber will also be associated with additional monitoring costs for the NFA to exclude illegal cutting of the trees.

[38] The average price is calculated based on the available market prices form real estate agencies.
[39] Based on the average wage data provided by the National Statistics Office of Georgia.

4.6.4. Restoration Option 3a: Sediment Capture Pond (Pile Wall)

Option 3a suggests building capture ponds around the area left to the Sioni Reservoir. The cost of developing capture ponds highly depends on the landscape and the nature of the terrain in the intervention area, as well as the number of ponds necessary to mitigate the flow of sediments, the area of each pond, and so on. For this assessment, the costs of development of three ponds within the intervention area will be considered.

The existing literature reveals that the direct costs of arranging a sediment capture pond include the following: labor, construction materials (including wooden logs and slate stones) and construction tools (such as shovel, hammer, and machine tools), land preparation, and transportation of materials and labor (GIZ 2019).

According to the existing literature, the cost of arranging one pond varies between GEL 3,800 and GEL 16,400 (US$1,180–5,091), while the average value is expected to be GEL 10,000 (US$3,104). The exact cost of ponds highly depends on their size, materials used for construction, and the geographic location. Table 14 summarizes the costs of arranging tree ponds in the study area for all three cases. However, the literature suggests that the probability of incurring the maximum possible cost is very low for this intervention because of the geographical characteristics of the area that are not particularly adverse.

Table 14. Estimated costs of pond arrangement

	Minimum Possible Costs		Average Possible Costs		Maximum Possible Costs	
	GEL	US$	GEL	US$	GEL	US$
Cost of arranging one pond	3,800	1,180	10,000	3,104	16,400	5,091
Cost of arranging three ponds	11,400	3,540	30,000	9,312	49,200	15,273

Source: Author's own calculations based on the literature.

In addition to the direct costs of creating ponds, the cost of their maintenance should also be considered. These costs mainly include maintenance of ponds to ensure overflow passage and the removal of accumulated sediments. Total expenditure on maintenance depends on the intensity of pond sedimentation and respective volume of material to be removed, as well as accessibility of the location.

Economic benefits of the suggested intervention come from the avoided/reduced erosion, the total value of which depends on the land area and its market price. Moreover, potential benefits can be generated form non-timber products generated in the area shielded from erosion. Obviously, this type of revenue depends on the type of non-timber products that may be produced in a given agroclimatic zone and accessibility of the area for product collection. Increased benefits from ecotourism are also likely. However, the incremental change is not expected to be high, because the surrounding area of the intervention territory is already quite attractive for tourists.

4.6.5. Restoration Option 4: Recultivation of Sand and Gravel Extraction Quarries of the Iori River and Planting Aquatic Vegetation around the Ponds

The cost of land recultivation varies among different sites and highly depends on factors such as location, type of soil, and equipment required. Under this section, each component of the two stages of land recultivation will be assessed.

The technical recultivation stage includes several components:

- **Stripping and storing of fertile soil layer.** Cost of stripping and storing the soil depends on various factors, including the location of the site, the amount of soil, and the required equipment type. Considering these factors, the average cost of striving and storing the soil varies from GEL 150 to GEL 450 per m^2 (Dignac 2017).
- **Surface leveling.** According to the United States Department of Agriculture, to assess the cost of surface leveling, the following costs should be considered: equipment (such as tractors and scraper), labor cost, and mobilizing of large equipment. As the relevant literature suggests, the cost usually depends on the location of the site and the type of the soil. The average cost of leveling the surface is GEL 3,580 per ha (Miao 2021).
- **Application of fertile soil.** Estimating the cost of this component is complicated as long as it depends on the distance of transportation, type of fertilizer chosen, and total area of land cultivated. Moreover, the labor cost should be considered, which also highly depends on the above-mentioned factors.
- **Installation of soil-saving facilities.** This aims to save land from degradation. The cost of installing soil-saving facilities varies depending on the type of soil-saving method chosen. The most widely used methods are as follows: compost, grow soil-saving plants, establish buffer strips, establish wind breaks, and so on. The chosen method depends on the soil type, location, purpose of the soil usage, and so on.
- **Constriction of drainage and water delivery networks represents one of the costliest activities.** The total cost of developing the network depends on the already existing infrastructure and the total area to be covered. Moreover, the cost of arranging the infrastructure per hectare also varies based on the location, environmental conditions, and so on. According to Georgian Amelioration LTD, the average cost of arranging the drainage system is GEL 8,000 per command ha.

The biological recultivation stage mainly involves activities associated with the treatment of recultivated land. The cost of planting of aquatic vegetation depends on the type of vegetation chosen relevant to the on-site environment and the coverage area. If it is considered to arrange buffer zones around the area, similar costs of direct investment and operation and maintenance costs described in option 2 should be considered.

Recultivation of the degraded land is expected to bring a number of economic and social benefits.

- Avoidance of the further deterioration of the land and the recultivation of the land will be reflected in the market value of the land.
- The mitigated pressure on water through reduced sediments will also reduce the pressure on the irrigation channels in that area. Notably, the nearby cropland territories are widely used for almond cultivation, which requires drip irrigation systems. The large volume of sediments in the river hinders proper functioning of the irrigation system, and thus makes it challenging to supply irrigation water to almond gardens. Improvement of water quality and the corresponding improvement of irrigation service will result in increased productivity of almonds. According to the study conducted by the United States Agency for International Development (USAID), in 2017, the average price of unpeeled almonds on the local market was GEL 10–12, while the price of peeled almonds was GEL 25–27 (USAID 2017). If we consider 3 percent target inflation rate, the estimated price of peeled almonds by the end of 2021 should vary between GEL 11.26 and GEL 13.51, while that for unpeeled varies between GEL 28.14 and GEL 30.39. However, the total benefits for the farmers will depend on the total area occupied by almond gardens, average productivity, impact of the improved irrigation systems on the productivity, and the amount of sold product on the local and/or international markets.
- Additional benefits will be associated with the reduced water pollution and the long-term improvement of aquatic habitat that can be reflected in the additional gains for the fisheries located within the area.

5. STAKEHOLDER CONSULTATION PROCESS

Research, data processing, and the development of the present WMLROA coincided with the COVID-19 pandemic times, including spread of the disease in Georgia and related restrictions on travel and public gatherings. This has obviously been a limiting factor in applying participatory approach validation of study results and planning of mitigation measures. Nonetheless, with much effort invested in finding alternative solutions, WMLROA has been derived through meaningful discussions with communities in the study area, local governments, academia, and government entities at the central level.

As part of the fieldwork, the research team organized and undertook numerous meetings with local residents of Sagarejo and Tianeti Municipalities and communities of Shida Kartli Region falling within the study area. The purpose of the meetings was to understand which aspects of landscape degradation are found most damaging by the population of this area, what they believe to be the reasons for land degradation, and what ways of improvement they see. Conversations with local residents were also useful in locating hot spots of land degradation, especially in the poorly accessible parts of the difficult terrain. Besides on-site community meetings undertaken during field trips of the research team, two structured stakeholder consultation workshops were held in a hybrid format. Workshops connected the World Bank staff and consultants based in various countries, representatives of the relevant agencies of the Government of Georgia based in the capital city of Tbilisi, and local stakeholders gathered at a venue near the Sioni Reservoir in the allowed number and sitting arrangement (as prescribed by the infection control rules by the dates of meetings).

Stakeholder consultation workshops were highly important and beneficial for the delivery of quality output by the research team. They allowed to undertake a reality check of the proposed interventions for landscape restoration. Proposing workable measures needed good understanding of both formal and informal local context, vested interests of various players, actual power and authority exercised on the ground by various institutions, and public perception and buy-in. Stakeholder engagement provided valuable information on the above. Furthermore, workshops with the participation of the government officials from MEPA and its subordinated agencies helped understand the challenge of WMLROA that is not going to be confined to the mandate of a single agency but would rather require financing and implementation of various interventions by different agencies at the central and local levels in a highly coordinated and well-harmonized manner. All of these inputs were reflected in the recommendations and implementation modality proposed for WMLROA.

6. IMPLEMENTATION OF LANDSCAPE RESTORATION

Table 15 provided in this chapter presents the proposed approach to the implementation of the measures proposed in this WMLROA. It consists of an implementation schedule; interim milestones to track implementation of the management measure; and the criteria to measure progress toward meeting watershed goals, monitoring activities, and technical and financial assistance needs. The proposed schedule has a time span of seven years, which means that if implementation was to start in 2023, all proposed activities would be completed by 2029.

The program includes recommended policy and institutional measures designed to support implementation of the technical measures for reducing the amount of surface runoff and water-induced erosion and to support FLR within the Sioni Reservoir watershed.

Implementation of these activities and their effectiveness/impact should be periodically reviewed, current results analyzed against the interim milestones, feedback provided to stakeholders, and necessary adjustments made.

Table 15. Implementation of the proposed measures from this WMLROA

Management objectives	Activities	Timeline	Interim milestones	Indicators	Sources of funding	Responsible institutions
Policy and institutional measures						
Create enabling environment for implementation measures proposed in Sioni Reservoir WMLROA	Identify the existing strategies, plans, and programs at national and municipal levels relevant for the integration of measures included in Sioni Reservoir WMLROA and revise them accordingly.	years 1 and 2	• Identify target policy/planning documents. • Draft required amendments. • Agree on suggested amendments to policy/planning documents with relevant stakeholders.	Measures included in the Sioni Reservoir WMLROA are integrated in relevant policy/planning documents and plans.	• State budget allocations for responsible institutions	• MEPA • Department of BFP • Department of HLM • Local government and self-governing bodies
	Revise the existing policy and legal framework for due integration of FLR concept.	years 2 to 4	• Identify target policy, legal, and regulatory documents. • Assess feasibility of their amendment for the inclusion of FLR concept. • Develop policy, legal, and regulatory amendments. • Agree on proposed policy, legal, and regulatory amendments with relevant stakeholders.	FLR concept included in the existing policy and regulatory framework.	• State budget allocations for responsible institutions .	• MEPA • Department of BFP • NFA • Parliament of Georgia
	Strengthen regulations on the extraction of natural construction materials from riverbeds through strengthening sustainability of extraction practice and incorporation of adequate landscape restoration principles.	years 1 and 2	• Undertake detailed analysis of extraction regulations to identify deficiencies allowing unsustainable extraction. • Draft revisions to the legal and regulatory documents aimed at addressing legal gaps. • Undertake stakeholder consultations toward consensus-building between various interest groups in the Government and in the private sector.	Sand and gravel extraction regulations are amended and carry sufficient requirements to ensure sustainability of the allowed mining practices.	• State budget allocations for responsible institutions	• MEPA • MESD • NAMR • Parliament of Georgia

Management objectives	Activities	Timeline	Interim milestones	Indicators	Sources of funding	Responsible institutions
	Strengthen control on tree-cutting in Sioni watershed by switching to centralized supply of firewood in lieu of individual tree-cutting by beneficiaries of 'social cutting' scheme and by decreasing demand for firewood.	years 1 and 2	• Timely establish and equip 'business yards' for switching to timber supply by NFA and phasing out tree-cutting by population based on forest use tickets. • Promote adoption of solar panels, utilization of biomass for fuel, and use of energy-efficient stoves for cutting demand for firewood.	Sufficient number of 'business yards' are established and technically equipped to supply firewood meeting local demand for hard fuel. Demand for firewood going down as a result of increased use of energy-efficient appliances and alternative sources of energy.	• State budget supplemented with donor funding	• NFA • Municipalities of Tianeti and Sagarejo
	Establish Coordination Council for Sioni Reservoir WMLROA implementation.	year 1	• Develop terms of reference (TOR) of the Coordination Council. • Agree on the concept and TOR of the Coordination Council with key stakeholders. • Establish Coordination Council at its first meeting.	Coordination Council is established and fully functioning with agreed TOR.	n.a.	• MEPA
	Awareness-raising and capacity building on FLR concept	years 1 and 2	• Develop conceptual approach and undertake planning for awareness-raising and capacity-building campaign. • Initiate the campaign for promoting FLR concept.	FLR concept promotion campaign is designed and integrated into 2023 annual workplan of responsible institutions and its implementation launched.	• Budget allocation of MEPA	• MEPA • Environmental Education and Information Center (EEIC) • Department of BFP • NFA

Management objectives	Activities	Timeline	Interim milestones	Indicators	Sources of funding	Responsible institutions
	Training of NFA, Georgian Amelioration LTD, National Agency for Sustainable Land Management and Land Use Monitoring staff and representatives of municipal governing and self-governing bodies in the WMLROA coverage area	years 1 and 2	• Assess capacity-building needs. • Develop training modules. • Undertake training of trainers. • Plan and undertake training for practitioners and technical staff of target institutions.		• State Budget • Relevant donor-financed projects	• MEPA • Department of BFP • Department of HLM • Municipalities of Tianeti and Sagarejo
Technical measures						
Reduce sedimentation of surface water bodies and Sioni Reservoir through sediment control.	Undertake mosaic restoration of croplands by application of agroforestry in Cekhuraantkhevi River watershed.	years 2 to 5	• Define exact location of areas for intervention in close cooperation with local stakeholders. • Prepare detailed design of the agroforestry intervention areas. • Plan for operational and maintenance of agroforestry plots. • Undertake actions planned and designed for starting agroforestry in the selected plots.	Agroforestry is sustained in target plots and sedimentation of Chekuraantkhevi River shows downward trend.	• State budget • Donor-financed projects	• MEPA • Georgian Amelioration LTD • Tianeti Municipality Mayor's Office

Management objectives	Activities	Timeline	Interim milestones	Indicators	Sources of funding	Responsible institutions
	Establish a vegetated buffer zone on the left shore of Sioni Reservoir.	years 3 to 6	• Define exact location of areas for intervention in close cooperation with local stakeholders. • Prepare detailed design of the vegetated buffer strip. • Plan for operation and maintenance of the newly established buffer strip. • Undertake planting and maintenance of the buffer strip.	Planted vegetation buffer strip is sustained and downward trend is observed in the concentration of nutrients and sediment levels in Sioni Reservoir.	• State budget • Donor-financed projects	• MEPA • Georgian Amelioration LTD • Tianeti Municipality Mayor's Office
	Restock degraded forests within the watersheds of small ravines nearby Sioni Reservoir.	years 2 to 7	• Identify degraded forest stands for restocking in close cooperation with local stakeholders. • Prepare detailed design of the restocking intervention. • Identify operation and maintenance needs and plan for maintenance. • Undertake restocking of the selected forest stands.	Improved quality of forest vegetation and subsequent downward trend of sedimentation in the downstream surface water bodies	• State budget • Donor-financed projects	• MEPA • NFA • Tianeti Municipality Mayor's Office
	Build capture ponds around the area left to Sioni Reservoir.	years 2 and 3	• Define exact location of areas for the arrangement of sediment capture ponds. • Prepare detailed design of capture ponds. • Plan for operation and maintenance of capture ponds. • Undertake actions planned and designed for the arrangement of the sediment capture plots.	Change in concentration of nutrients and sediment levels in Sioni Reservoir Change in number of eroded ravines	• State budget • Donor-financed projects	• MEPA • NFA • Tianeti Municipality Mayor's Office

Management objectives	Activities	Timeline	Interim milestones	Indicators	Sources of funding	Responsible institutions
	Recultivate worked-out sand and gravel mines on the Iori River and arrange buffer vegetation around ponds formed in the excavated depressions.	years 2 to 7	• Identify worked-out mining sites in the vicinity of the Iori River and ensure they are not covered by any active extraction license. • Produce detailed design of recultivation in consultation with local stakeholders. • Identify maintenance needs of recultivated areas and plan for their provision. • Undertake planned recultivation measures and vegetation planting.	Selected former mining sites are sustainably recultivated and level of sedimentation shows downward trend in the surface water bodies downstream of the areas of intervention.	• State budget • Donor-financed projects	• MEPA • NAMR • Sagarejo Municipality Mayor's Office

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Annex 1. Climate Characteristics of the Study Area

Station Name	District	Elevation	Observation years	Years of averaged data	Precipitation			Average temperature (°C)			Average annual wind speed
					Average annual	Min	Max	Average annual	Min	Max	
Akhmeta	Akhmeta	567	1928–1993	1992–2004	55.09	0.0	84.4	12.0	8.5	18.2	1.8
Birkiani	Akhmeta	758	1961–2005	1982–1991	91.87	1.1	82.9	—	—	—	—
Gombori	Sagarejo	1,085	1989–2005	1995–2005	57.68	0.0	73.3	8.8	2.7	14.9	0.95
Lelovani	Tianeti	1,000	1961–2005	1996–2005	61.77	0.0	91.9	—	—	—	—
Magharoskari	Dusheti	920	1958–operational	2011–2020	66.68	1.5	87.5	—	—	—	—
Orkhevi	Tianeti	950	1960–2006	1993–2006	56.92	0.0	58.5	—	—	—	—
Sagarejo	Sagarejo	806	1916–operational	2011–2020	58.71	0.1	85.5	13.0	17.7	1.8	1.1
Sioni	Tianeti	1,047	1927–1988	1974–1987	69.8	0.5	58.5	8.7	13.3	4.0	2.52
Chinti	Dusheti	680	1972–2005	1993–2005	58.84	0.0	72.0	—	—	—	—
Tianeti	Tianeti	1,105	1914–operational	2011–2020	46.99	0.4	70.4	9.5	14.9	4.0	0.6
Jinvali	Dusheti	727	1941–1992	1974–1983	55.41	0.3	69.0	—	—	—	—

Source: NEA.

Annex 2. Demographics of the Study Area

Distribution of population by administrative units and gender

	Name of settlement	According to the General Population Census, 2014, National Statistics Office of Georgia			According to the data provided by municipalities, December 2021–January 2022		
		Total	Men	Women	Total	Men	Women
	Tianeti Municipality	**9,468**	**4,828**	**4,640**	**13,772**	**7,216**	**6,559**
	Territorial body of Daba Tianeti	**2,642**	**1,320**	**1,322**	**3,971**	**2,029**	**1,942**
	Daba Tianeti	**2,479**	**1,238**	**1,241**	**3,755**	**1,927**	**1,828**
1.	Tetrakheva	39	21	18	40	18	22
2.	Mamadaanebi	51	25	26	61	27	34
3.	Satchure	0	0	0	2	1	1
4.	Tchurtchelaurebi	73	36	37	113	56	57
	Territorial body of Daba Sioni	**920**	**465**	**455**	**1,124**	**615**	**509**
	Daba Sioni	**371**	**183**	**188**	**436**	**231**	**205**
5.	Badaani	...	...	...	12	7	5
6.	Botchorma	105	51	54	157	91	66
7.	Grdzelvelebi	...	...	...	32	18	14
8.	Omaraani	92	47	45	97	59	38
9.	Orkhevi	235	115	120	258	139	119
10.	Sadjinibo	22	14	...	21	12	9
11.	Pitchviani	...	...	...	13	7	6
12.	Kudro	75	44	31	98	51	47
	Community of Artani	**293**	**157**	**136**	**444**	**241**	**203**
13.	Zemo Artani	30	15	15	30	17	13
14.	Bodakheva	11	...	...	30	16	14
15.	Duluzaurebi	58	31	27	100	52	48

	Name of settlement	According to the General Population Census, 2014, National Statistics Office of Georgia			According to the data provided by municipalities, December 2021–January 2022		
		Total	Men	Women	Total	Men	Women
16.	Tetraulebi	16	...	...	23	12	11
17.	Kvernaula	40	22	18	65	35	30
18.	Lisho	62	33	29	90	50	40
19.	Sakhevi	...	...	...	4	4	0
20.	Skhlovani	...	...	...	20	10	10
21.	Kvemo Artani	46	25	21	60	33	27
22.	Kushkhevi	16	11	...	22	12	10
	Community of Akhalsopeli	**492**	**259**	**233**	**869**	**468**	**401**
23.	Akhalsopeli	226	118	108	365	189	176
24.	Gojiaanebi	70	31	39	120	71	49
25.	Katsalo	...	...	...	9	5	4
26.	Chabano	174	95	79	347	183	164
27.	Tchiaura	16	11	5	26	19	7
28.	Khaisho	...	...	...	2	1	1
	Community of Zaridzeebi	**683**	**360**	**323**	**1,174**	**625**	**552**
29.	Zaridzeebi	298	150	148	462	247	215
30.	Butchkinta	0	0	0	1	1	0
31.	Verkhveli	19	11	8	45	27	18
32.	Zemo Sharakhevi	0	0	0	39	22	17
33.	Zenamkhari	0	0	0	6	3	3
34.	Iarajulebi	123	64	59	187	96	91
35.	Ivliantgori	0	0	0	0	0	0
36.	Lakhato	0	0	0	3	2	1
37.	Sakretchio	86	49	37	127	64	63

	Name of settlement	According to the General Population Census, 2014, National Statistics Office of Georgia			According to the data provided by municipalities, December 2021–January 2022		
		Total	Men	Women	Total	Men	Women
38.	Kvemo Sharakhevi	19	...	11	39	22	17
39.	Khopca	37	23	14	98	56	42
40.	Jijeti	101	55	46	206	104	102
	Community of Nakalakari	**678**	**347**	**331**	**979**	**520**	**459**
41.	Zemo Nakalakari	161	84	77	252	126	126
42.	Betsentsurebi	...	...	...	15	6	9
43.	Doreulebi	69	33	36	89	47	42
44.	Vedzatkheva	44	21	23	95	54	41
45.	Zurabebi	53	27	26	61	31	30
46.	Magraneti	224	118	106	316	168	148
47.	Kvemo Nakalakari	118	60	58	151	88	63
	Community of Jebota	**791**	**397**	**394**	**1,047**	**519**	**528**
48.	Jebota	531	274	257	719	359	360
49.	Tegeraanebi	61	25	36	119	57	62
50.	Tkhila	0	0	0	0	0	0
51.	Lelovani	57	28	29	81	42	39
52.	Zebniaurebi	142	70	72	128	61	67
	Community of Simoniantkhevi	**909**	**452**	**457**	**1,323**	**706**	**617**
53.	**Simoniantkhevi**	258	134	124	352	184	168
54.	Gorana	169	81	88	174	90	84
55.	Tolenji	208	99	109	358	185	173
56.	Meliaskhevi	71	41	30	124	72	52
57.	Nadokra	152	77	75	243	138	105
58.	Chitaurebi	0	0	0	0	0	0

	Name of settlement	According to the General Population Census, 2014, National Statistics Office of Georgia			According to the data provided by municipalities, December 2021–January 2022		
		Total	Men	Women	Total	Men	Women
59.	Tsalugelaantkari	51	20	31	72	37	35
	Community of Tushurebi	**487**	**258**	**229**	**594**	**294**	**300**
60.	Tushurebi	344	179	165	423	208	215
61.	Alatchani	51	25	26	70	35	35
62.	Kakhoianebi	62	37	25	65	33	32
63.	Tsikvliaantkari	27	15	12	34	17	17
64.	Jervalidzeebi	...	...	...	2	1	1
	Community of Gulelebi	**707**	**353**	**354**	**782**	**407**	**375**
65.	Gulelebi	260	127	133	310	158	152
66.	Balebiskhevi	54	29	25	57	26	31
67.	Gudanelebi	50	28	22	50	29	21
68.	Tokholcha	22	...	12	11	5	6
69.	Trani	88	46	42	104	57	47
70.	Kvernula	74	37	37	72	37	35
71.	Kviriaskhevi	17	...	...	15	7	8
72.	Siontgori	49	21	28	50	26	24
73.	Tolaantsopeli	42	23	19	54	34	20
74.	Tskarotubani	23	...	15	35	15	20
75.	Khadoelebi	28	15	13	24	13	11
	Community of Chekuraantgori	**161**	**91**	**70**	**287**	**151**	**136**
76.	Chekuraantgori	52	29	23	78	43	35
77.	Aloti	75	42	33	75	40	35
78.	Bokoni	...	...	...	26	13	13
79.	Evjenti	25	14	11	48	23	25

	Name of settlement	According to the General Population Census, 2014, National Statistics Office of Georgia			According to the data provided by municipalities, December 2021–January 2022		
		Total	Men	Women	Total	Men	Women
80.	Velebi	0	0	0	55	29	26
81.	Dzikvniani	0	0	0	5	3	2
	Community of Khevsurtsopeli	**705**	**369**	**336**	**1,092**	**598**	**494**
82.	**Khevsurtsopeli**	215	119	96	309	156	153
83.	Devenaantkhevi	132	71	61	135	76	59
84.	Sakdrioni	358	179	179	648	366	282

	Name of settlement	According to the General Population Census, 2014, National Statistics Office of Georgia			According to the data provided by municipalities, 2021		
		Total	Men	Women	Total	Men	Women
	Sagarejo Municipality[a]				**21,464**		
	Sagarejo	**10,871**	**5,154**	**5,717**	**12,266**		
	Community of Gombori	**888**	**439**	**449**	**1,046**	**480**	**566**
1.	Gombori	681	334	347	813	348	465
2.	Askilauri	70	33	37	79	40	39
3.	Vashliani	19	...	11	18	10	8
4.	Verona	57	32	25	76	47	29
5.	Rusiani	61	32	29	60	35	25
	Community of Kotchbaani	**318**	**169**	**149**	**632**	**144**	**172**
6.	Kotchbaani	132	74	58	113	53	60
7.	Botko	0	0	0	3	1	2
8.	Gorana	74	38	36	84	37	47
9.	Ikvlivgorana	13	...	...	17	12	5
10.	Otaraani	19	...	...	19	6	13
11.	Sasadilo	80	40	40	80	35	45
12.	Khintchebi	0	0	0	316	...	...
	Village Ninotsminda	**1,904**	**924**	**980**	**1,904**	**924**	**980**

	Name of settlement	According to the General Population Census, 2014, National Statistics Office of Georgia			According to the data provided by municipalities, 2021		
		Total	Men	Women	Total	Men	Women
13.	Ninotsminda	1,904	924	980	1,904	924	980
	Village Patardzeuli	**2,829**	**1,373**	**1,456**	**2,916**	**1,436**	**1,486**
14.	Patardzeuli	2,829	1,373	1,456	2,916	1,436	1,486
	Village Sataple	**74**	**36**	**38**	**74**	**36**	**38**
15.	Sataple	74	36	38	74	36	38
	Community of Ujarma	**479**	**224**	**255**	**500**	**250**	**250**
16.	Ujarma	445	206	239	...	...	...
17.	Padlo	18	...	...	...	...	...
	Village Khashmi	**1,632**	**816**	**816**	**2,200**	**1,000**	**1,200**
18.	Khashmi	1,632	816	816	2,200	1,000	1,200

Note: a. Only the population of settlements within the study area is provided.

	Gardabani Municipality	According to the General Population Census, 2014, National Statistics Office of Georgia			According to the data provided by municipalities, 2021
		Total	Men	Women	Total
	Community of Sartitchala	**10,219**	**5,072**	**5,147**	**14,244**
1.	Sartitchala	6,009	2,972	3,037	8,200
2.	Mughanlo	4,210	2,100	2,110	6,044

Demographics of Tianeti Municipality

	2015	2016	2017	2018	2019	2020	2021
Population of Tianeti Municipality (thousands)	9.7	9.8	9.9	10.0	10.1	10.2	10.3
Percentage change compared to previous year (%)	2.10	1.03	1.02	1.01	1.00	0.94	0.90
Share in the population of Mtskheta-Mtianeti Region (%)	10.34	10.47	10.57	10.66	10.77	10.91	11.00
Share in the total population of the country (%)	0.26	0.26	0.27	0.27	0.27	0.27	0.28
Share of urban population (%)	30.93	31.63	31.31	32.00	31.68	32.35	33.01
Share of rural population (%)	66.07	68.37	68.69	68.00	68.32	67.75	66.99

Source: Author's own calculations based on Geostat data.

Demographical characteristics of Sagarejo Municipality

	2015	2016	2017	2018	2019	2020	2021
Population of Sagarejo Municipality (thousands)	51.9	52.1	52.1	52.3	52.2	52.2	52.3
Percentage change compared to previous year (%)	0.39	0.26	0.09	0.29	−0.04	0.02	0.19
Share in the population of Kakheti Region (%)	16.28	16.38	16.49	16.60	16.72	16.85	16.91
Share in the total population of the country (%)	1.39	1.40	1.40	1.40	1.40	1.41	1.40
Share of urban population (%)	21.05	20.87	20.67	20.50	20.31	20.18	20.14
Share of rural population (%)	78.95	79.13	79.33	79.50	79.69	79.82	79.86

Source: Author's own calculations based on Geostat data.

Annex 3. Types of Economic Activity and Their Contribution to the GVA of Tianeti and Sagarejo Municipalities

Types of economic activities and their contribution in the GVA of Tianeti Municipality, GEL, millions, at current prices[40]

Economic activities	2015	2016	2017	2018	2019
Agriculture, forestry, and fishing	9.76	10.79	10.71	11.98	11.13
Manufacturing	11.74	10.63	14.04	19.70	23.56
Electricity, gas, steam, and air conditioning supply	2.25	2.49	3.11	4.90	5.44
Water supply, sewerage, waste management, and remediation activities	1.00	1.07	1.30	1.46	1.89
Construction	5.57	5.43	6.64	1.63	2.76
Wholesale and retail trade; repair of motor vehicles and motorcycles	4.00	2.21	2.58	3.04	5.04
Transportation and storage	1.20	0.97	1.02	1.65	2.11
Accommodation and food service activities	8.58	4.66	5.86	8.49	7.51
Information and communication	0.98	1.43	0.88	2.06	3.61
Financial and insurance activities	3.21	0.19	2.11	2.86	1.59
Real estate activities	13.08	14.02	14.94	15.71	17.55
Professional, scientific, and technical activities	0.36	0.73	1.43	1.63	0.34
Administrative and support service activities	0.41	0.79	1.58	2.09	2.64
Public administration and defense; compulsory social security	7.77	6.47	10.17	10.06	11.48
Education	4.29	4.06	4.35	4.50	5.25
Human health and social work activities	1.92	1.46	4.98	5.12	6.40
Arts, entertainment, and recreation	2.13	2.83	1.93	2.90	3.29
Other service activities	1.83	2.08	2.03	3.04	3.56
Activities of households as employers; undifferentiated goods and services producing activities of household for own use	0.00	0.19	0.09	0.04	0.08
Total GVA produced in Tianeti Municipality	**80.06**	**72.48**	**89.75**	**102.85**	**115.23**

Source: Author's own calculations based on Geostat data.

Economic activities and their contribution in the GVA of Sagarejo Municipality, GEL, millions, at current prices[41]

Economic activities	2015	2016	2017	2018	2019
Agriculture, forestry, and fishing	74.81	72.01	79.77	97.73	106.52
Mining and quarrying	2.80	3.84	4.34	3.95	4.90
Manufacturing	23.67	27.83	36.18	34.07	35.87
Electricity, gas, steam, and air conditioning supply	4.54	6.51	8.02	8.47	8.29
Water supply; sewerage, waste management, and remediation activities	2.02	2.79	3.34	2.53	2.88
Construction	3.56	5.87	10.32	6.53	8.42
Wholesale and retail trade; repair of motor vehicles and motorcycles	9.80	9.21	14.39	13.43	20.58

[40] Estimations are made based on the population, land use pattern, and existing industries in the municipality.
[41] Estimations are made based on the population, land use pattern, and industries operating in the municipality

Economic activities	2015	2016	2017	2018	2019
Transportation and storage	0.46	0.74	3.50	1.29	1.61
Accommodation and food service activities	2.40	3.58	3.96	8.60	10.08
Information and communication	3.59	3.78	3.73	4.38	7.61
Financial and insurance activities	8.69	14.78	19.69	21.93	17.18
Real estate activities	24.17	25.19	26.33	27.02	29.81
Professional, scientific, and technical activities	2.55	2.01	3.67	3.55	5.83
Administrative and support service activities	1.44	1.48	2.68	3.82	3.10
Public administration and defense; compulsory social security	15.06	21.36	26.02	21.34	24.84
Education	18.69	15.17	18.69	23.12	24.74
Human health and social work activities	11.48	11.70	14.41	15.20	13.56
Arts, entertainment, and recreation	8.69	9.11	11.89	8.86	8.50
Other service activities	2.58	2.78	2.56	3.57	2.54
Activities of households as employers; undifferentiated goods and services producing activities of household for own use	0.10	0.36	0.17	0.20	0.33
Total	**221.09**	**240.09**	**293.67**	**309.59**	**337.20**

Source: Author's own calculations based on Geostat data.

Annex 4. Forestry within the Study Area

Distribution of forest areas, licenses for commercial logging, and wood production within the study area

Name of Forestry Unit	Area (ha)	Area included in the Emerald Network (ha)	Licenses for commercial logging (ha)	Number of timber resources to be obtained annually by commercial logging (m^3) (*License terms*)	Wood Production during 2020 (m^3)	
					Logging for social purposes	Logging by NFA
Akhmeta Forestry District						
Zemo Khodasheni	22	17			5,283.0	3,057.20
Ilto	61				2,227.5	
Akhmeta	48				841.0	
Kistauri	32	32			440.8	1,580.26
Telavi Forestry District						
Telavi	~~8~~	~~7~~			~~6,910.0~~	
Sagarejo Forestry District						
Ujarma	4,525	557			290.5	
Khashmi	4,940	3,578			709.0	
Sagarejo	3,697	2,049			487.8	
Patarzeuli	3,431	1,932			532.1	
Giorgitsminda	150	0.7			992.3	
Gombori	9,282	3,035			3,359.0	474.87
Barisakho Forestry District						
Choporta	36				185.0	
Bulachauri	88				286.5	
Tvalivi	2				292.5	
Jinvali	1				154.0	
Tianeti Forestry District						
Simoniantkhevi	3,540				441.0	
Artaani	6,518		2,793[a]	9,080	1,385.0	
Akhalisopeli	6,606		4,126[a]		744.5	
Zaridzeebi	3,280				1,756.5	3,081.16
Tianeti	38,998		38[b]	521,500	3,119.0	1,176.25
Sioni	3,500				1561.1	1,376.95
Ghulelebi	1,156				902.0	
Bochorma	3,823	1,368			463.5	
Gardabani-Marneuli Forestry District						
Satskhenisi	700				569.5	
Total	**59,263**					

Source: NFA.

Note: a. Under license #100041, issued Oct 9, 2008, until Oct 9, 2028 to the Ltd Georgia Wood and Industrial Development Co.

b. Under license #1000010, issued 15.10.2008 until 16.10.2028 to the Ltd M. House+ and 366 ha under license #1000045 transferred from Ltd M. House+ to Ltd Rash in 2014

Forest fires recorded in 2013−2021 within the study area

Forestry district	Forestry unit	Burned area (ha)	Date
2013			
Barisakho	Choporti	0.8	29.10.2013
Tianeti	Sioni	3	30.10.2013
Barosakho	Choporti	2	07.11.2013
Tianeti	Sominiantkhevi	4	08.11.2013
2014			
Barisakho	Tvalivi	0.5	24.02.2014
Tianeti	Artaani	2	04.03.2014
Tianeti	Simoniantkhevi	7	04.03.2014
Barisakho	Tvalivi	0.8	04.03.2014
Barisakho	Bulachauri	3	06.03.2014
2015			
Tianeti	Sioni	2,5	13.08.2015
2016 – no cases recorded			
2017			
Akhmeta	Akhmeta	5	21.08.2017
Barisakho	Tvalivi	14	22.08.2017
2018 – no cases recorded			
2019			
Akhmeta	Kistauri	15	18.02.2019
Akhmeta	Akhmeta	4	09.03.2019
Akhmeta	Akhmeta	5	13.03.2019
Sagarejo	Giorgitsminda	3	05.08.2019
Sagarejo	Gombori	2	19.08.2019
Akhmeta	Ilto	2	22.08.2019
Akhmeta	Zemo Khodasheni	10	16.11.2019
2020			
Akhmeta	Zemo Khodasheni	7	01.01.2020
Akhmeta	Kistauri	4	16.02.2020
Akhmeta	Akhmeta	3	23.02.2020
Akhmeta	Kistauri	2	24.02.2020
Akhmeta	Akhmeta	7	25.02.2020
Telavi	Telavi	2	26.02.2020
Telavi	Telavi	8	27.02.2020
Telavi	Telavi	8	27.02.2020
Sagarejo	Gombori-Khashmi	3	27.02.2020
Telavi	Telavi	10	28.02.2020
Akhmeta	Khodasheni	2	28.02.2020

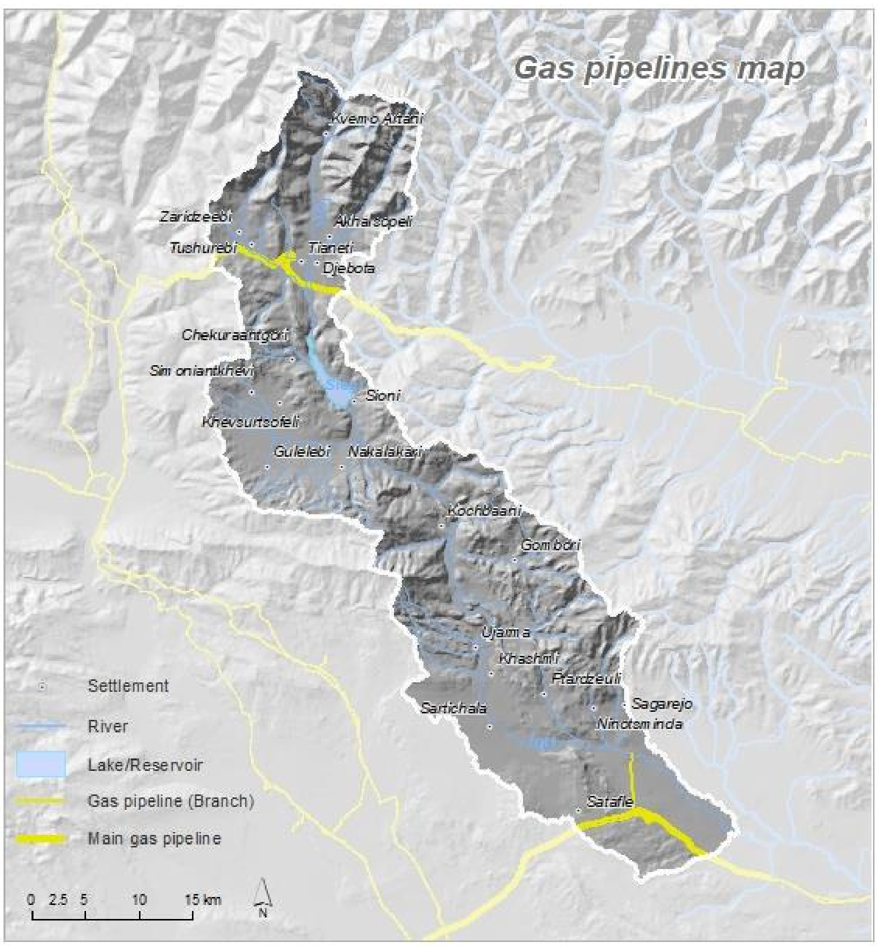
Forestry district	Forestry unit	Burned area (ha)	Date
Sagarejo	Gombori	3	05.03.2020
Akhmeta	Kistauri	2	15.03.2020
Akhmeta	Kistauri	3	13.04.2020
Akhmeta	Kistauri	3	15.04.2020
Tianeti	Akhalsopeli	25	08.03.2020
	Tianeti	6	09.03.2020
	Artani	15	20.03.2020
	Bochorma	20	27.03.2020
Barisakho	Bulachauri	15	09.03.2020
2021 - no cases recorded until November, 2021			

Source: NEA.

Annex 5. Gas Pipelines within the Study Area

The study area is crossed by the Rustavi-Telavi-Zhinvali DN 500 mm main gas pipeline, the Rustavi-Telavi-Zhinvali DN 300 mm main gas pipeline, Rustavi-Sagarejo DN 300 mm main gas pipeline, and Sagarejo DN 200 mm branch pipeline operated by the Georgian Gas Transportation Company Ltd. By the definition provided in the Resolution №. 365 Government of Georgia dated December 24, 2013, on the *Protection of Main Pipelines (Oil, Petroleum Products, Petroleum and Petroleum Products and Their Transformation Products) and on Establishing Their Protection Zones,* the study area is located in the following types of protection zones of the main gas pipeline: Protection Zone I (extends to 4 m on both sides of the main pipeline axis), Protection Zone II (extends to 21 m on both sides of the outer boundary of the first protection zone), Protection Zone III (extends 175 m on both sides of the outer boundary of the second protection zone), and Protection Zone IV (extends 300 m on both sides of the outer boundary of the third protection zone).

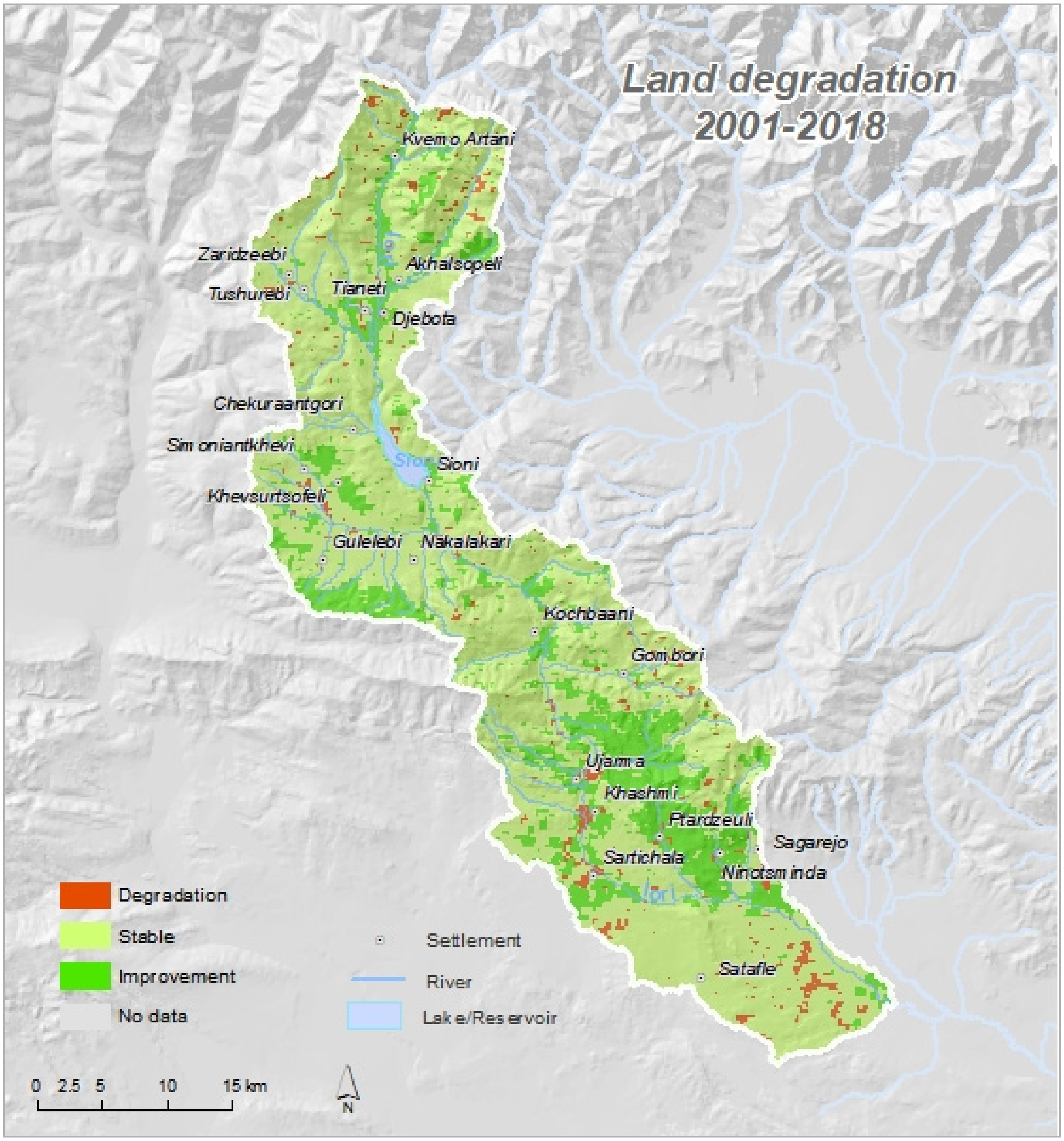
Gas pipelines within the study area



Source: RECC

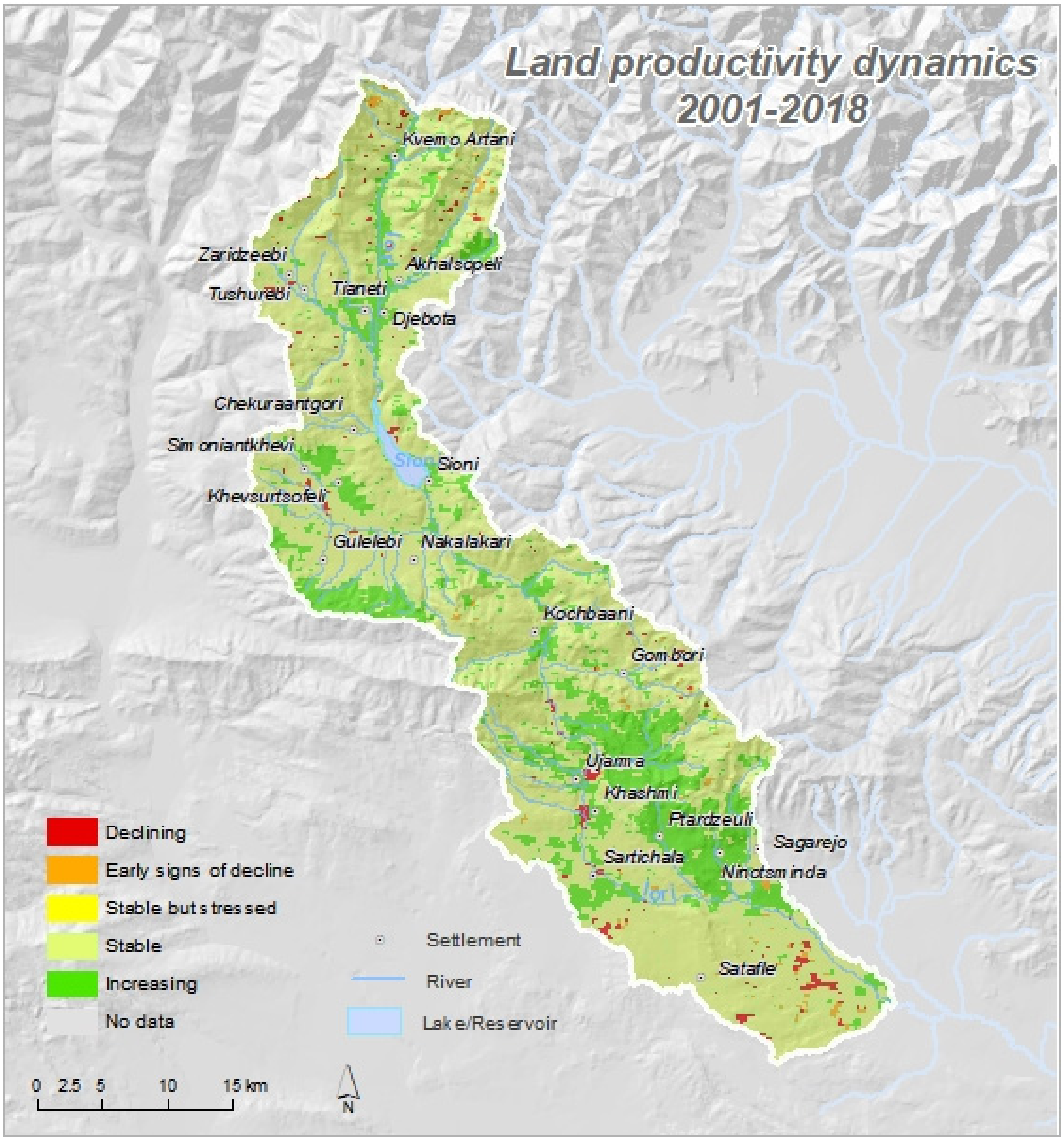
Annex 6. SDG Indicator 15.3.1 - Land Productivity, Land Cover, and Soil Organic Carbon Maps

Land degradation map of the study area



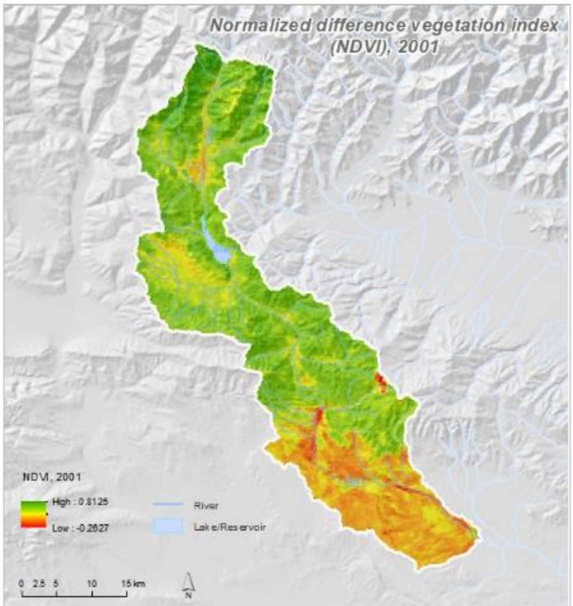
Source: RECC

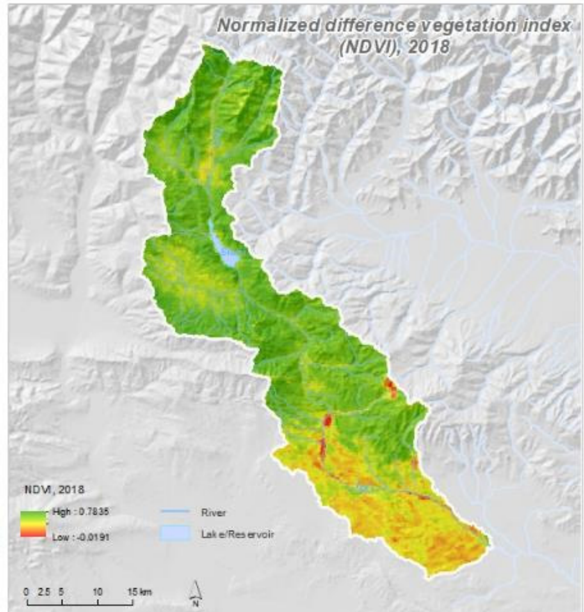
Land productivity dynamics map of the study area



Source: RECC

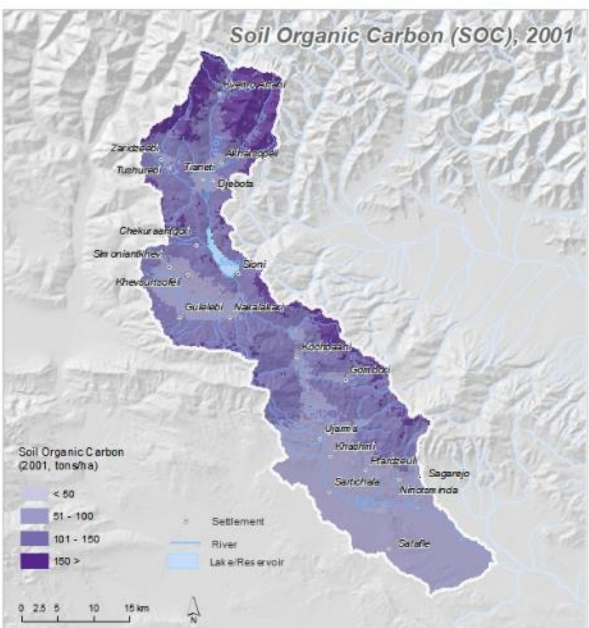
NDVI maps of the study area

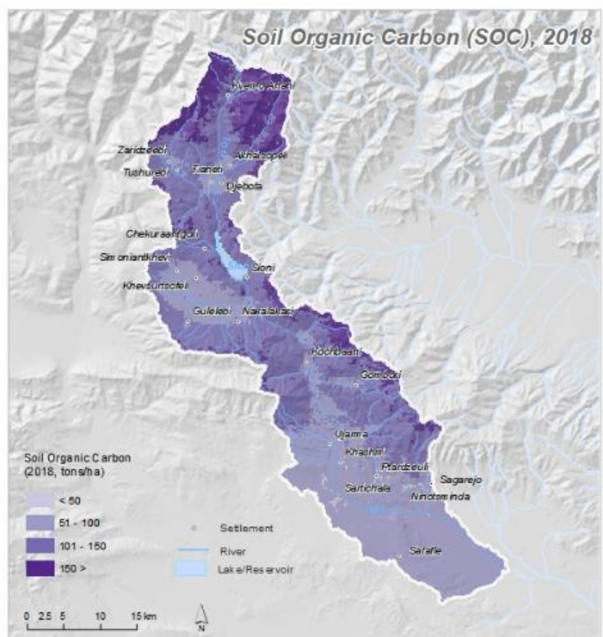




Source: RECC

Soil organic carbon maps of the study area





Source: RECC

This assessment report presents the results of a study focused on the Sioni Reservoir watershed, which is subject to seasonal sediment loads affecting the sustainability of water for hydropower generation and irrigation. The study reveals the major causes of landscape degradation within target watershed and sediment loads to the Sioni Reservoir affecting the suitability of water for irrigation and the lifetime of the dam. The study also identifies the main interventions for landscape restoration and a provides brief analysis of the institutional and policy gaps and recommendations that are applicable for other watersheds in the region as well.