Upper Svaneti Adaptation Strategy to the Climate Change

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The present report is drafted in the process of preparation of Georgia's Third National Communication to the UNFCCC. The preparation process involved a large group of specialists, representing: the Ministry of Environment and National Resources Protection of Georgia; the Ministry of Agriculture of Georgia; the Ministry of Energy of Georgia; the Ministry of Economy and Sustainable Development of Georgia; the Ministry of Labor, Health and Social Affairs of Georgia; the Ministry of Regional Development and Infrastructure of Georgia; the Ministry of Education and Science of Georgia; Georgian National Agency of Cultural Heritage Protection; National Environmental Agency; Institute of Geography; individual academic institutes; representatives of local government of Mestia municipality and local consultants engaged in tourism, health and agriculture, independent experts and NGOs.

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Abbreviations

ADA - Austrian Development Agency
CDM - Clean Development Mechanism
CTCN – Climate Technology Centre and Network
CVD- Cardiovascular Diseases
ENVSEC -Environmental Security Initiative
EU –European Union
EWS – Early Warning Systems
GCF - Green Climate Fund
GDP –Gross Domestic Product
GEF - Global Environment Facility
GIZ -German Agency for International Cooperation
GoG – Government of Georgia
GWP- Global Warming Potential
HDRMP – Health Disaster Risk Management Plan
HI – Heat Index
IOM -International Organization for Migration
IPCC -Intergovernmental Panel on Climate Change
UNISDR – United Nations International Strategy for Disaster Reduction
KfW-German Government Owned Development Bank
LEPL -Legal Entity of Public Law
LNG – Liquefied Natural Gas
MENRPG - Ministry of Environment and Natural Resources Protection of Georgia
MLHSAG- Ministry of Labour Health and Social Affairs of Georgia
MoA - Ministry of Agriculture
NAMA-Nationally Appropriate Mitigation Actions
ND – Natural Disasters
NEA - National Environmental Agency
PHCU - Primary Health Care Unit
SPI - Standardized Precipitation index
TCI- Tourism Climate Index
UNDP - United Nations Development Programme
UNEP –United Nations Environment Programme
UNESCO – United Nations Educational, Scientific and Cultural Organization
UNFCCC- United Nations Framework Convention on Climate Change
USAID - United States Agency for International Development

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Introduction

Upper Svaneti holds a distinguishing role in the diverse unity of Georgia's regions. This role is determined by its inimitable nature, as well as centuries-old history, which left a unique footprint on the cultural heritage of this region.

Upper Svaneti is located on the southern slopes of the Central Caucasus. The majority of high peaks of this mountainous massif are concentrated in this part of the Caucasus, among them Shkhara (5 203 m ASL), Tetnuldi (4 858 m), Ushba (4 700 m), Tikhtingeni (4 617 m) and Shkhelda (4 368 m). Glaciers and permanent snow-capped peaks stand on top of villages flanked on the slopes and terraces, from which the regional center - Mestia Settlement located in the hollow stands out.

The slopes are covered with forests up to the height of 2 400 m ASL. Higher they are followed with alpine meadows transient in glaciers. Svanetian towers built in the villages for the avalanche protection enrich the local landscape and make it even more peculiar. Because of this, the region has become a Mecca for mountain climbing and mountain tourism in Georgia. The rivers flowing from glaciers gather in Enguri River, which, when leaving the boundaries of the region create Jvari Hydro Reservoir.

Upper Svaneti is from all sides surrounded by ridges as high as 4 000 m. The only access entrance road runs along Enguri Gorge. This fact has historically accounted for Upper Svaneti's protection from enemy invasions. Therefore, art and artefacts since the ancient times, architectural monuments of the follow-up of the early medieval period have been preserved in local churches, chapels and neighbourhoods. Along with the unique beauty of the nature, this rich historical heritage further reinforces Upper Svaneti's attractiveness for cognitive tourism lovers.

Here, difficult terrain of the region results in the considerable diversity of the climate zones. Hypsometric heights in the region include a large range starting from 500 meters above sea level at the banks of Jvari Reservoir to 5 203 meters at the peak of Shkhara Mountain. Accordingly, the climate in Upper Svaneti changes from the warm humid maritime climate characteristic for Colkhida Lowland to the high mountain humid climate with permanent snow and glaciers and according to the modern classifications includes 5 climate zones. Naturally, all of these zones depending on local conditions in some ways respond to global climate change. In this sense, the most sensitive system in Upper Svaneti appeared to be the glacier ecosystem, which along with the retreat started in the alpine glaciers in the early 19th century has undergone a noticeable degradation. Namely, a detailed survey of the glaciers carried out in the Caucasus in 1890 and 1965 revealed a 13% reduction in the total glacier area in Enguri River Basin.

Taking into account that the glaciers, especially in Enguri River Basin, play an important role in shaping the region's water balance, their reduction and gradual disappearance will have a material effect on Upper Svaneti's economy, as well as natural ecosystems. In particular, as of today, the region's major economic sector is agriculture represented by animal husbandry and tourism. Potentially, it is also possible to restore and develop timber processing and mining sectors.

According to the estimates carried out according to the modern climate models, by the end of the century, the average annual temperature in Upper Svaneti is expected to rise by 4.0 ^{0}C, which, undoubtedly, will lead to a substantial reduction in the size of glaciers. This process could bring two contradictory results for the region's economy: Degradation of glaciers will result in the growing mild of the climate in the surrounding areas and the expansion of Alpine meadows at the expense of this. This factor will benefit the development of animal husbandry. On the other hand, the region will lose its tourist attractiveness with the disappearance of glaciers and this factor will have a negative impact on the local economy. It is expected that this negative effect will damage Upper Svaneti more, than the increase in biodiversity related to the climate warming in the alpine zone.

One more negative outcome of ongoing climate change in Upper Svaneti is the increase in the frequency of heavy precipitation and the acidity of atmospheric precipitation, which has an undesirable effect on the historical monuments and leads to accelerating their collapse. At this time, 213 religious, 48 archaeological and 759 secular and defense monuments are registered in Upper Svaneti. Most of the churches and chapels date back to VII-X and XII centuries and archaeological sites to bronze and iron, as well as the Antique period. It is clear that this wealth needs due care and protection, which in the current climate change conditions is accompanied by certain difficulties.

The goal of the present work is to inform the reader about the ongoing climate change trends in Upper Svaneti Region and the predicted characteristics for the end of the century, the variability of the frequency and the intensity of natural disasters caused by the current climate change, responses of forest ecosystems, tourism potential and population's health to observed and expected climate alterations, the current conditions of the glaciers and the results of the potential changes. Based on the conducted assessments, the present document elaborates the Upper Svaneti climate alterations strategy, which focuses on the preparation and implementation of a series of measures aimed at reducing the vulnerability of the region's economy and natural ecosystems.

In this paper, some project proposals targeting climate change adaptation were developed. Their implementation in the conditions of the relevant investment climate will improve the ability to cope with the challenges in Upper Svaneti related to the consequences of global climate change and will promote sustainable development of the economy.

This paper continues the research cycle, which in previous years was devoted to the development of the similar strategy on climate change for vulnerable regions of Georgia, such as Lower Svaneti, Kakheti and Ajara.

1. Climate in Upper Svaneti

Upper Svaneti's climate is determined by specific features of its terrain - unhindered invasion of air masses on its territory occurs only from the south-west through the Enguri Gorge River Valley. From all directions, the region is surrounded by high ridges, many of which are difficult to overcome for the lower layers of air masses. As a result, the region represents a peculiar climate enclave with the pronounced vertical zoning of the climate featuring it. According to the adopted classification, 5 climate zones (Fig.1.1) are observed in Upper Svaneti, from which the lowest - the first zone covers the range of heights of 500-900 m ASL and is characterized with Khaishi Weather Station data, while the highest - the zone with permanent snow and the glaciers is located at the height of 3 000-5 000 m and includes Shkhara, the highest peak in the Georgia's segment of the Caucasus (5 203 m). Between these two zones, a large area is covered by the transitional second and third zones located at the height of 1 000-2 000 m, which can be characterized by Mestia Meteorological Station. First climate zone in the South borders humid maritime climate zone characteristic for Colchida Lowland with mild, warm winter and hot summer, for which the nearest weather station is Zugdidi Meteorological Station.

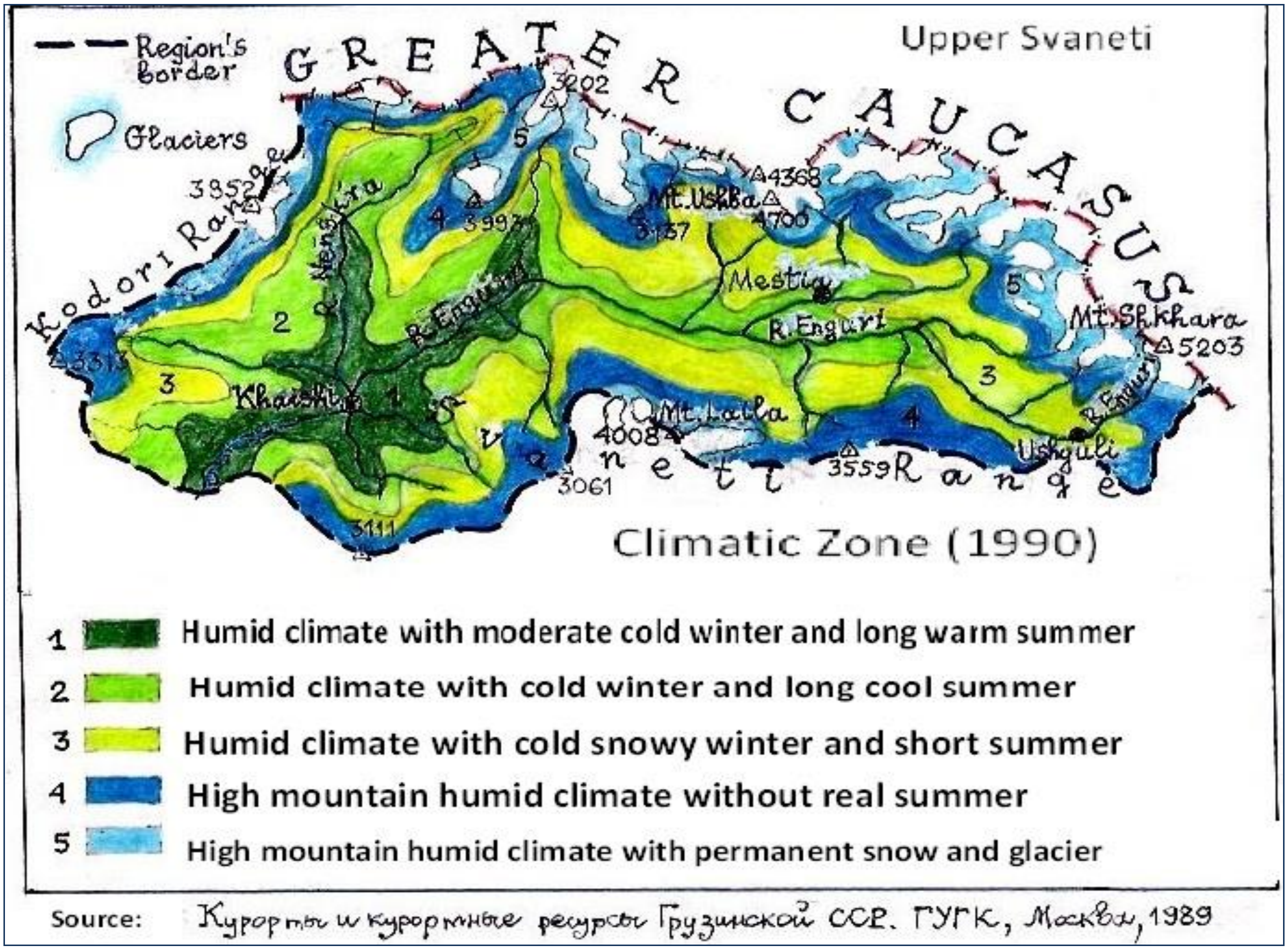


Fig. 1.1. Climate Zones of Upper Svaneti

1.1. Ongoing Climate Change in Upper Svaneti

For describing climate changes in Upper Svaneti influenced by global warming during last 50 years, the meteorological stations in Mestia and Khaishi were selected, as well as Zugdidi Weather Station located in the adjacent climate zone, with almost continuous series of observation, which describes the climate in the lower reaches of the Enguri River.

The period of 1961-2010 was divided into two equal 25-year-long spans and the average values of the climate parameters for this period were compared with each other. In case of having breaks in the observation, the temperature and the precipitation data were restored with the methods used in the climatology: For Mestia - using data of Shovi and Lentekhi meteorological stations, for Khaishi - using Tsageri Meteorological Station data and for Zugdidi - using Samtradia Meteorological Station data.

Mestia Municipality

Mestia

Description of the important territory of Upper Svaneti climate (middle zone) was carried out with Mestia Meteorological Station, which is located at an altitude of 1 441 m ASL (Annex 1). In Mestia, humid climate with cold winter and long, chilly summer is formed. Based on the observations of 1936-1960 an average annual temperature for this territory was +5.7 ^{0}C, the coldest month (January) average was -6.0^{0}C. The warmest month (July) average was +16.4 ^{0}C, the absolute minimum -35 ^{0}C, while the absolute maximum was +35 ^{0}C. The sum of active temperatures (above +10 ^{0}C) was 2 039 ^{o}C degrees, the average annual air relative humidity was 75%, the total annual amount of precipitation was 918 mm, with a maximum monthly sum which usually fell in October and was 95 mm, while the minimum fell in February (61 mm). The average annual wind speed equaled 1.1 m/s. Mostly the northern and the south-western winds were prevalent in the surrounding area.

Temperature. The analysis of the change of climate elements between the periods of 1961-1985 and 1986-2010 demonstrated that the average annual temperature in the middle zone of Mestia Municipality has increased by 0.3 ^{0}C and in comparison to the period of 1936-1960 by +0.4 ^{0}C. Warming, basically, is occurring at the expense of summer (+0.7 ^{0}C) and autumn (+0.5 ^{0}C), although slight cooling was observed in the winter (-0.1 ^{0}C), and slight warming in the spring (+0.1^{0}C). The observed changes are stable and are confirmed by the trends only in the summer. In the period of 1961-2010, the average temperature change rate was 0.25 ^{0}C/10 yr. he absolute maximum temperature increased during all seasons and the annual increment amounted to 3.3 ^{0}C, while the absolute minima changed in both directions from -4.0 ^{0}C to +2.4 ^{0}C and the annual growth reached 2.4 ^{0}C. The average maximum temperature between two discussed periods increased slightly (+0.2 ^{0}C), while the average annual minimum value increased significantly (+0.5 ^{0}C). The average daily temperature amplitude at seasons changed from -1.1 to +0.8 ^{0}C and on the average decreased slightly by -0.3 ^{0}C.

Precipitation. The annual precipitation sums between two periods increased by 97 mm or 10%. The increment amounted to 15% in comparison with the level existing in the period of 1936-1960. As for daily maximum precipitation, a substantial decline of their absolute values from 145 mm to 78 mm was observed in a very short period of the summer season, but this value changed slightly from +17 to -2 mm during other seasons.

The annual and seasonal **values of air relative humidity** increased by 2-3% between the examined two periods, as well as with respect to the span of 1936-1960.

Average wind speed between two discussed periods appeared to be equally reduced in all seasons by 0.3-0.6 m/s.It was significantly reduced compared to the average of 1936-1960.

Winter in the discussed zone of Mestia Municipality has become a little tougher during the last 25 years. The average temperature decreased slightly (-0.1 ^{0}C). The absolute minimum significant warming (+2.4 ^{0}C) did not compensate the average maximum significant cooling (-0.7^{0}C). The seasonal number of frosty days increased on the average by 7 days, that increases the risk of frosts. The seasonal precipitation sums increased by 30%. The **spring** average and the average minimum temperature between two periods turned out to be almost unchanged (± 0.1^{0}C), although the minimum temperature extremes significantly decreased (-4.0 ^{0}C), which increased the risk of spring frosts. The precipitation sums also increased at this season by 18%.

The **summer** average temperature between two periods has (+0.7 ^{0}C) increased significantly. The maxima (+1.0 ^{0}C), as well as the minima (+0.9 ^{0}C) are significantly increased. The seasonal precipitation sum decreased by 8% and the average wind speed is steadily declining. Thus, summer in Mestia became warmer and relatively dry. **Autumn** also became warm. The average temperature increased by 0.5 ^{0}C. The absolute maximum increased by 3.4 ^{0}C and the absolute minimum decreased by -1.6 ^{0}C. The seasonal precipitation sum increased by 10%. So, autumn in Mestia became increasingly warm and rainy.

Thus, between two discussed periods, summer became the warmest (+0.7 ^{0}C), while winter got slightly cooler (-0.1 ^{0}C) in Mestia. From the seasons, precipitation increased the most in winter (+ 30%) and decreased the most in the summer (-8%).

From extreme events, the recurrence of heavy rainfall between the periods changed significantly. The number of days with heavy rainfall (≥50 mm) almost halved in comparison with the previous period. This change happened at the expense of the summer season. This demonstrates that in this zone, which is attributed to the mudflow and avalanche high-risk area, the risk of mudflows in the summer is reduced, while the risk of avalanches in winter has increased. Almost all time-scale droughts have decreased in the second period of the Municipality's middle zone, this is why the agricultural sector here does not face the problem with the precipitation deficit.

Khaishi

Featuring of the lower zone of Mestia Municipality was conducted using the data of Khaishi Meteorological Station, which is located at an altitude of 730 meters (Annex 1).

The humid climate with cold winter and long, warm summer has formed here. Based on the observations carried out prior to 1933-1960, the average annual temperature of this territory was +10.6 ^{0}C, the coldest month (January) average was -0.1 ^{0}C, the warmest month (August) average was +21.0 ^{0}C, the absolute minimum was -22 ^{0}C and the absolute maximum was +41 ^{0}C. The sum of active temperatures (above +10 ^{0}C) was 3 293 ^{0}C, the relative average annual air humidity was 76%. Total annual precipitation comprised 1 301 mm, with the maximum monthly sum, which usually fell in October equaled to 135 mm. East-west direction winds were mainly prevailing on the surrounding territory.

Temperature. The climate element analysis between the periods of 1961-1985 and 1986-2010 demonstrated that the average annual temperature in the lower zone of Mestia increased by 0.4 ^{0}C while by 0.3 ^{0}C in comparison with the period of 1933-1960. Warming, basically, is taking place at the expense of summer and especially, autumn, when the increment equals to +0.8 ^{0}C. The average temperature change in winter and spring virtually cannot be revealed. The observed changes are stable and are confirmed with the trends in summer and autumn; the average annual temperature change rate amounted to 0.32 ^{0}C/10 yr. The absolute temperature maxima dropped to the range of -0.9 - -1.6 ^{0}C on all seasons except for spring (+1.0 ^{0}C). The absolute minima, on the contrary, increased at all seasons, from the average annual increment of +0.7^{0}C to the maximum warming in summer (+4.0 ^{0}C). The average temperature maxima increased in summer and autumn (+0.7, +1.0 ^{0}C), while decreased in spring (-0.5 ^{0}C). The average minima in the 0.2-0.4 ^{0}C range increased on all seasons except for winter (-0.1 ^{0}C). The average daily temperature amplitude decreased in spring (-0.7 ^{0}C) and increased in other seasons in the interval of 0.1-0.7 ^{0}C.

Precipitation. Total annual precipitation between two discussed periods increased by 185 mm in Khaishi, which amounts to +15% of the first period. In comparison with the average of the period 1933-1960, the amount of precipitation also increased, although to a lesser extent (+ 8%). The maximum number of daily precipitation in the second period increased on every season in the range of 8-40 mm except for summer, when the rate dropped by 15 mm.

The seasonal and annual **average air relative humidity** values between two periods increased in the range of 1-2%, while the average **wind speed** showed a decreasing trend.

Winter in the lower zone of Mestia Municipality according to the median, as well as the extreme temperature characteristics has not in fact changed between the periods. Only the average minimum temperature decreased slightly (-0.1 ^{0}C), which was determined by the increase in the number of seasonal frosty nights. The risk of winter frosts increased in connection with this. Seasonal precipitation sums increased by 12%. Maximum daily precipitation increased by 40 mm. Two days with extremely abundant precipitation (≥90 mm) were observed in the second period, which did not occur in the first period. Air relative humidity increased by 2-3%. So, at the background of the basically unchanged temperature, winter in Khaishi became more humid. The climate element change picture in **spring** is similar to that in winter. The average temperature between two periods almost has not changed (+0.1^{0}C). The average maxima cooling (-0.5 ^{0}C) is partially compensated by the warmer minima (+0.2 ^{0}C). The number of frosty days and, in particular, frosty nights decreased significantly, that reduces the risk of spring frosts. Seasonal precipitation increased sharply in the second period (+22%), which is confirmed by the relevant trend. At the backdrop of increased precipitation, relative humidity also steadily increased. Thus, same to winter, in the unchanged temperature periods spring also becomes relatively humid and rainy. The average **summer** temperatures between two periods increased by +0.4 ^{0}C. The average maxima (+0.7 ^{0}C), as well as the average minima (+0.4 ^{0}C) became warmer. All other indicators of warming are also present during the summer season. At this background, seasonal precipitation increased slightly (+3%) and daily maximum precipitation decreased by 15 mm. Almost all time-scale droughts decreased in Khaishi as a result of increased precipitation. So, summer in the lower zone of the municipality became quite warm at the background of slightly increased precipitation. **Autumn** in comparison with summer became even warmer. The average temperature increased by 0.8 ^{0}C. Warming mainly occurs at the expense of the increased maxima (+1.0 ^{0}C), but the minima have also become warmer (+0.3 ^{0}C). From the extremes, the minimum increased significantly (+2.0^{0}C). Just like in summer, all warming indicators are evident in autumn; however, in the conditions of the slight increase in the recurrence of frosty days and nights, the risk of frosts still remains. The seasonal precipitation sums in the second period increased by 14%, relative air humidity also increased by 1%. The number of days with precipitation increased in autumn, that increases the mudflow risk. Finally, autumn became warmer, more humid and abundant in rainfall.

Thus, between two discussed periods, autumn in the lower zone of Mestia Municipality became the warmest (+0.8 ^{0}C) and spring - the least warm (+0.1 ^{0}C). The temperature has not changed in winter. Precipitation increased at all seasons, especially in spring (21%).

From extreme events, the days with extreme abundant precipitation (≥90 mm) were observed twice, which has not been experienced in the previous period. The number of days with heavy precipitation increased in autumn. The observed trend of increased fall and winter precipitation indicates the increased risk of mudflow and landslide processes at this season. However, the likelihood of all categories of droughts decreased in Khaishi's climate zone.

Zugdidi Municipality

Zugdidi

From the climate point of view, the territory of the municipality belongs to the Sea maritime subtropical climate zone with warm and mild winter and hot summer. The description of the territory was undertaken using the data of Zugdidi Meteorological Station, which is located at an altitude of 117 m ASL (Annex 1). The city of Zugdidi Zugdidi is featured by the humid climate with hot summer and warm, mild winter. Based on the observations conducted prior to 1929-1960, the average annual temperature of this area was +13.8 ^{0}C, the coldest month (January) average was +4.9 ^{0}C, the warmest month (August) average was +22.7 ^{0}C, the absolute minimum was -19 ^{0}C and the absolute maximum was +40 ^{0}C. The sum of active temperatures (above +10 ^{0}C) was 4 159 ^{0}C, relative average annual air humidity was 76%. Total annual precipitation was 1 616 mm, with the maximum monthly sums, which usually fell in September and amounted to 165 mm, while the minimum fell in May (107 mm). The average annual wind speed equaled to 1.3 m/s. The east-west direction winds mainly prevailed on the surrounding territory.

Temperature. According to the climate elements variability analysis between the periods of 1961-1985 and 1986-2010, the average annual temperature increased by +0.3 ^{0}C in Zugdidi. In comparison with the 1929-1960 period, the average annual temperature in Zugdidi increased by +0.4 ^{0}C. Warming is taking place at the expense of summer (+0.9 ^{0}C) and autumn (+0.6 ^{0}C). -0.3^{0}C cooling was observed in winter and the temperature did not change in spring. The observed changes are stable and confirmed by the trends in summer and autumn, as well as by the average annual value. The average annual temperature change rate in the period of 1961-2010 was 0.18 ^{0}C/10 yr. The absolute maximum and minimum temperatures increased on all seasons. The absolute maximum and minimum increments are the largest in autumn (+3.6 and +2.2 ^{0}C, respectively) and the lowest in winter (+0.2 ^{0}C, the absolute maximum) and summer (+0.5 ^{0}C, the absolute maximum). The average maximum temperature between two periods increased fairly (+0.6 ^{0}C), while the average minimum value increased to a lesser extent (+0.4^{0}C). The average daily temperature amplitude increased by 0.7 ^{0}C in summer, but decreased by 0.1-0.2 ^{0}C in autumn and winter, the annual increment being 0.2 ^{0}C.

Precipitation. The annual precipitation sums between two periods remained virtually unchanged in Zugdidi (+1%), but in comparison with the average of the period of 1929-1960 the increment reached 15%. The decrease in summer precipitation (-14%) is offset by almost equal 7-9% growth in other seasons. Daily maximum precipitation increased at all seasons with the greatest absolute accretion in summer (+31 mm).

The **air relative humidity** annual value increased by 2% in the second period. The increment is especially significant during the winter (+ 5%) and is slight in summer (+0.3%).

The **average wind speed** decreased a bit in all seasons and the annual value of reduction made was 0.2 m/s.

In comparison with the previous period, **winter** at the territory of Zugdidi Municipality became relatively colder during the last 25-year period. The average temperature (-0.3 ^{0}C), as well as the average maxima and minima became cooler (both by -0.2 ^{0}C). As a result, the risk of winter frosts increased. At the same time, the absolute maxima (+0.2 ^{0}C) and in particular, the absolute minima (+2.4 ^{0}C) became warmer. Seasonal precipitation increased by 9%. All extreme indexes related to precipitation increased. At this background, relative humidity increased with the reliable trend and the wind speed decreased. So, Zugdidi in winters became colder, more humid and less windy. However, unlike winter, the average temperature has not changed in **spring**. The increase in the maxima (+0.4 ^{0}C) partially is offset by cooling the minima (-0.2 ^{0}C). The absolute minimum dramatically increased (+5.5 ^{0}C) with the increase in the absolute maximum. Nevertheless, the number of seasonal frosty nights and days actually has not changed and therefore, the risk of spring frosts remains. Precipitation increased by +7% during the season.

Relative humidity also increased by 2%. Summer between the discussed two periods became warmer by +0.9 ^{0}C. The average maxima (+1.5 ^{0}C), as well as the minima (+0.9 ^{0}C) significantly increased. The seasonal precipitation decreased by 14%, while relative humidity remained virtually unchanged. Thus, **summer** in Zugdidi became warmer and relatively dry. Autumn, as well as summer, became warmer. With the rise of the average temperature (+0.6 ^{0}C), the maxima (+0.7 ^{0}C), as well as minima (+0.8 ^{0}C) increased significantly and the temperature extremes also increased by 2-4 ^{0}C. As a result, the **autumn** frost risk has been reduced. On the background of the relatively small increase in precipitation (+7%), the number of days with abundant rainfall increased, however, the recurrence of wet days decreased.

Thus, between the discussed two periods, summer in Zugdidi became warmer (+0.9), while temperatures have not changed in spring. Precipitation decreased the most in summer (-14%) and increased by 7-9% in other seasons.

From extreme events, which are characterized with abundant precipitation, the decrease in the number of days with abundant (≥50 mm) and extremely heavy (≥90 mm) precipitation was observed with the average of 0.4 days annually between two discussed periods at the territory of Zugdidi Municipality. However, their recurrence is high and reach the annual average of 10. This decline occurred at the expense of the summer season. Because of this, in the upper part of the municipality, where the risk of mudflows and landslides is high, the likelihood of floods decreased in summer, but increased during the transitional seasons.

As for the drought recurrence change, the number of moderate and severe droughts at the territory of Zugdidi Municipality increased by 10-15% during the last 25-year period, mainly in the summer season. Taking into account that this territory is located in the humid climate zone, the impact of this situation on agricultural production requires a separate discussion.

Hence, we can conclude that global warming in Upper Svaneti taking place during the last 50 years (1961-2010) led to the most significant increase in temperature during autumn in Khaishi (+0.8 ^{0}C) and during summer in Mestia (+0.7 ^{0}C).

The seasonal temperatures on both meteorological stations remained virtually unchanged in winter and spring (in the range of ≥0.1 ^{0}C). Precipitation on both stations increased by 10-15% in all seasons with respect to the annual amounts. Mestia is an exception, where summer precipitation was reduced by -8%. From extreme events, the recurrence of abundant precipitation (≥50 mm) halved in the summer season during the second 25-year period, although extremely heavy precipitation (≥90 mm) in Khaishi was observed twice in autumn, which did not take place during the previous period.

Summer (+0.9 ^{0}C) and autumn (+0.6 ^{0}C) became warmer at the territory of Zugdidi Municipality, but winter became colder (-0.3 ^{0}C). Precipitation decreased by -14% in summer, the recurrence of heavy rainfall was also reduced. requency of droughts decreased in Upper Svaneti and increased slightly in Zugdidi (by 10-15%).

Table 1.1. Seasonal Characteristics of the Climate Change in Upper Svaneti Region between the Periods of 1961-1985 and 1986-2010

Season / Station	Winter	Spring	Summer	Autumn	Year
Mestia	Insignificant chilling during the season (-0.1 ^{0}C), precipitation has increased by 30%	Insignificant warming of the season (+0.1^{0}C), precipitation has increased by +18%	Season has warmed +0.7 ^{0}C, precipitation has deacresed by -8%	Season has warmed +0.5 ^{0}C, precipitation has increased +10%	Warming +0.3 ^{0}C, increase of precipitation +10%
Khaishi	Seasonal temperature has not been changed, precipitations has been increased +12%. 2 days with extreme precipitation were fixed during the second period (≥90 mm) day	Insignificant warming of the season (+0.1^{0}C), precipitation has increased +21%	The season has warmed +0.4 ^{0}C, precipitation has increased insignificantly (+3%)	The season has warmed +0.8 ^{0}C, precipitation has increased +14%	Warming +0.4 ^{0}C, increase of precipitation +15%
Zugdidi	Chilling up during the season (-0.3 ^{0}C), precipitation has been increased by +9%	Seasonal temperature was not changed, precipitation has increased +7%	Seasonal temperature was warmed +0.9 ^{0}C, precipitation has decreased -14%	Season has warmed +0.6 ^{0}C, precipitation has increased +7%	Warming +0.3 ^{0}C, precipitation was almost unchanged (+1%)

As for the change in agroclimate characteristics in Upper Svaneti for the past half-a-century and their forecasted values until 2050, the calculations were made using the Mestia weather station data, as this station describes well this forest-free territory of Upper Svaneti, where the region's majority of agricultural land plots are located. By taking agricultural production of the region into account, where potatoes, cabbage, legumes, root crops and hay field-pastures play a leading role, the calculations were carried out for three threshold temperatures: 5, 8 and 10^{0}C. The results are summarized in Table 1.2.

This Table demonstrates that between two discussed periods (1961-1985 and 1986-2010), the duration of the vegetation period increased most significantly (by 15 days) for the threshold temperature of 5 ^{0}C and the average temperature of the vegetation period (+0.6 ^{0}C) and the active temperature total (+327 ^{0}C) also noticeably increased. This circumstance should play a positive role for the development of animal husbandry. The increase in the average temperature of the vegetation period is also evident for the threshold temperature of 10 ^{0}C.

Table 1.2. Actual and Projected Changes in Agro Climate Parameters in Mestia (1961-2050) for Different Germinate Temperatures

Margin temperature, ^0C	Parameters / Periods	Δt, day	ΔT avg, ^0C	ΔTΣ ^0C	ΔP, mm	Δτ day
5	From (1961-1985) to (1986-2010)	+15	+0.6	+327	+12	+4
	From (1986-2010) to (2021-2050	0	+0.8	+137	+64	-4
8	From (1961-1985) to (1986-2010)	+4	+0.4	+132	-7	
	From (1986-2010) to (2021-2050)	+18	+0.7	+386	+107	
10	From (1961-1985) to (1986-2010)	+3	+0.6	+118	-18	
	From (1986-2010) to (2021-2050)	+17	+0.7	+377	+115	

Symbols: *changes Δ of the following temperature:*

t – duration of the vegetation period

T_{avg} - average temperature of the vegetation period

T_{Σ} - sum of active temperatures

P – sum of precipitation of the vegetation period

τ – duration of the no-frost period

The duration of the frost-free span between two past periods increased by 4 days.

1.2. Expected Climate Change on the Territory of Upper Svaneti

Similar to the territory of Adjara, the expected climate change for the territory of Upper Svaneti was evaluated for the years of 2021-2050 and 2071-2100 in comparison with the baseline period of 1961-1990. The future climate change scenario was evaluated using the regional RegCM4 model, in which the global ECHOM5 model and the world's socio-economic development A1B scenario were used. The calculations were made using the data of two meteorological stations: Mestia and Khaishi, where observations began in 1933. In addition, the data of Zugdidi Meteorological Station was also used (1929).

The following Tables list the predicted values of temperature and precipitation changes.

Table 1.3. Climate Parameters for Mestia generated with models ensemble

Season	Temperature ^{0}C					Precipitation , mm				
	Temperature in the baseline period 1961-1990	Increment for the baseline temperature ∆ 2021-2050	Increment for the baseline temperature ∆ 2071-2100	Temperature 2021-2050	Temperature 2071-2100	Precipitation in the baseline period 1961-1990	Increase from the baseline period, % 2021-2050	Incerment for the baseline period, % 2071-2100	Precipitation 2021-2050	Precipitation 2071-2100
Winter	-4.3	1.2	3.6	-3.1	-0.7	185	29.7	16.2	240	215
Spring	5.5	0.9	3.2	6.4	8.7	236	-0.8	6.4	234	251
Summer	15.2	1.7	4.8	16.9	20.0	296	19.2	6.1	353	314
Autumn	6.7	2.0	4.6	8.7	11.3	247	1.6	-13.0	251	215
Year	**5.8**	**1.5**	**4.0**	**7.3**	**9.8**	**964**	**11.8**	**3.2**	**1 078**	**995**

Table 1.4. Climate parameters forecast for Khaishi generated by the model ensamble

Season	Temperature ^{0}C					Precipitation, mm				
	Temperature in the baseline period 1961-1990	Increment for the baseline temperature ∆ 2021-2050	Increment for the baseline temperature ∆ 2071-2100	Temperature 2021-2050	Temperature 2071-2100	Precipitation in the baseline period 1961-1990	Increase from the baseline period, % 2021-2050	Incerment for the baseline period, % 2071-2100	Precipitation 2021-2050	Precipitation 2071-2100
Winter	0.8	1.3	3.5	2.1	4.3	330	27.6	9.7	421	362
Spring	10.5	0.5	3.0	11.4	13.5	264	-6.8	0.4	246	265
Summer	19.6	1.6	4.8	21.2	24.4	292	13.0	-11.6	330	258
Autumn	11.1	2.1	4.6	13.2	15.7	333	3.3	-10.5	344	298
Year	10.5	1.5	4.0	12.0	14.5	1 219	9.6	-3.0	1 341	1 183

Table 1.5. Forecast of Climate Parameters for Zugdidi Generated with Models Ensemble

Season	Temperature ^{0}C					Precipitation, mm				
	Temperature in the baseline period 1961-1990	Increment for the baseline temperature ∆ 2021-2050	Increment for the baseline temperature ∆ 2071-2100	Temperature 2021-2050	Temperature 2071-2100	Precipitation in the baseline period 1961-1990	Increase from the baseline period, % 2021-2050	Incerment for the baseline period, % 2071-2100	Precipitation 2021-2050	Precipitation 2071-2100
Winter	6.1	1.3	3.2	7.4	9.3	427	42.6	2.3	609	437
Spring	13.0	0.9	2.7	13.9	15.7	397	-10.8	-2.0	254	405
Summer	21.6	1.3	3.6	22.9	25.2	567	29.8	-16.8	736	472
Autumn	14.9	2.0	4.2	16.9	19.1	454	6.4	13.0	483	395
Year	13.9	1.4	3.4	15.3	17.3	1 845	18.3	-7.4	2 182	1 709

The climate indices change for all three meteorological stations of Samegrelo-Upper Svaneti region for the periods (actual) of 1961-1985 and 1986-2010, as well as for the period of 2021-2050 and 2071-2100 (projected) are given in Annex 1 (Table. 1.1-1.3). The spreadsheet analysis gives a possibility to make the following conclusions:

Average Temperature. As seen from the Table, by 2050, the rise of the mean annual temperature by 1.5 ^{0}C compared to the average of 1961-1990 is expected on the whole territory of Upper Svaneti. The increase is observed in all seasons, but especially in autumn (2.0-1.0 ^{0}C), as well as in summer (1.6-1.7 ^{0}C). The spring average temperature will increase the least (0.5-0.9 ^{0}C). For the years of 2071-2100, the warming process will be more activated and the annual average temperature increase in comparison with the years of 1961-1990 will reach 4.0^{0}C, which will be evident by particular warming of summer (4.8 ^{0}C);

Total annual precipitation in 2021-2050 will increase by 10-12% in both climate zones of Upper Svaneti. The particular major growth is expected in the winter season (28-30%), but this increase will be partly compensated in spring by the decrease in spring seasonal precipitation sums from 1 (Mestia) to 7% (Khaishi). The significant increase in precipitation is expected in summer (13-19%), followed by the slight increase in autumn (2-3%). As for the period of 2071-2100, the climate change in these years will have more significant effect on precipitation, that will be reflected in a slight increase in the annual sums in Mestia (3%) and the reduction of the same magnitude in Khaishi. The significant reduction in precipitation in both climate zones is expected in autumn (10-13%), but the trends between climate zones might become reverse in summer. At the background of almost 12% reduction in the precipitation sums in Khaishi, the 6% increase is expected in Mestia.

Thus, until 2100, we need to expect a rather spotted picture of the precipitation variability on the territory of Upper Svaneti at the background of undeniable temperature increase, the main feature of which will be the decrease in precipitation during spring for the first period and in autumn during the second period. In both periods, in both climate zones, the substantial increase in precipitation is projected in winter.

From the forecasted agroclimatic data to 2050, the significant increase in the duration of the vegetation period is expected for the threshold temperatures of 8 and 10 ^{0}C (by 18 and 17 days respectively). The essential rises are also expected in the average temperature of the vegetation period (+0.7 ^{0}C) and the active temperature sums (386 and 377 ^{0}C respectively). In both discussed cases, the important, more than 100 mm increase in the precipitation sums is expected in the vegetation period.

The length of frost-free period is expected to decrease by 4 days for 2050. In addition, the predicted significant increase in active temperatures and precipitation for all three threshold temperatures in the vegetation period should create favorable conditions for the growth of agricultural crops and noticeable improvement of their quality in Upper Svaneti.

2. Impact of Climate Change on Mestia Municipality

2.1. Impact of Climate Change on Glaciers in Enguri Basin

2.1.1. General Description of Glaciers in Enguri River Basin

According to their number and occupied area, Enguri River Basin glaciers are unevenly distributed in different river basins. According to the 1965[1], 250 glaciers with a total area of 288 km^2 were represented here (Fig. 2.1). The small glaciers comprise the majority with the surface area of 0.5 km^2. They account for 73% of the total number of the glaciers. However, it should be noted that they occupy only 13% of their total area. According to the territory, large-sized glaciers hold a leading place (>10 km^2), they occupy 48% of the total area of the glaciers of the entire basin, but they make only 3% of the total number of glaciers. The median size glaciers account for the 39% of the area and the 24% of the number of glaciation of the entire basin (Table 2.1). According to the data of 2014[2], 269 glaciers with a total area of 223.4 km^3 are located in Enguri Basin.

[1] Water resources of the Caucasus, edited by G.G. Svanidze and V. Sh. Tsomaya, L. Gidrometeoizdat,1988 (in Russian).
[2] Tielidze L. Glaciers of Georgia TSU Inst. of Geography, Tbilisi, 2014 (in Georgian).

Table 2.1. Distribution of Enguri River Basin Glacier according to the areas [3]

Type of the glacier	Number	%	Area in km²	%
Small <0,5 km²	173	73	38	13
Medium 0,5-10 km²	70	24	113	39
Large >10 km²	7	3	137	48
Total	**250**	**100**	**288**	**100**

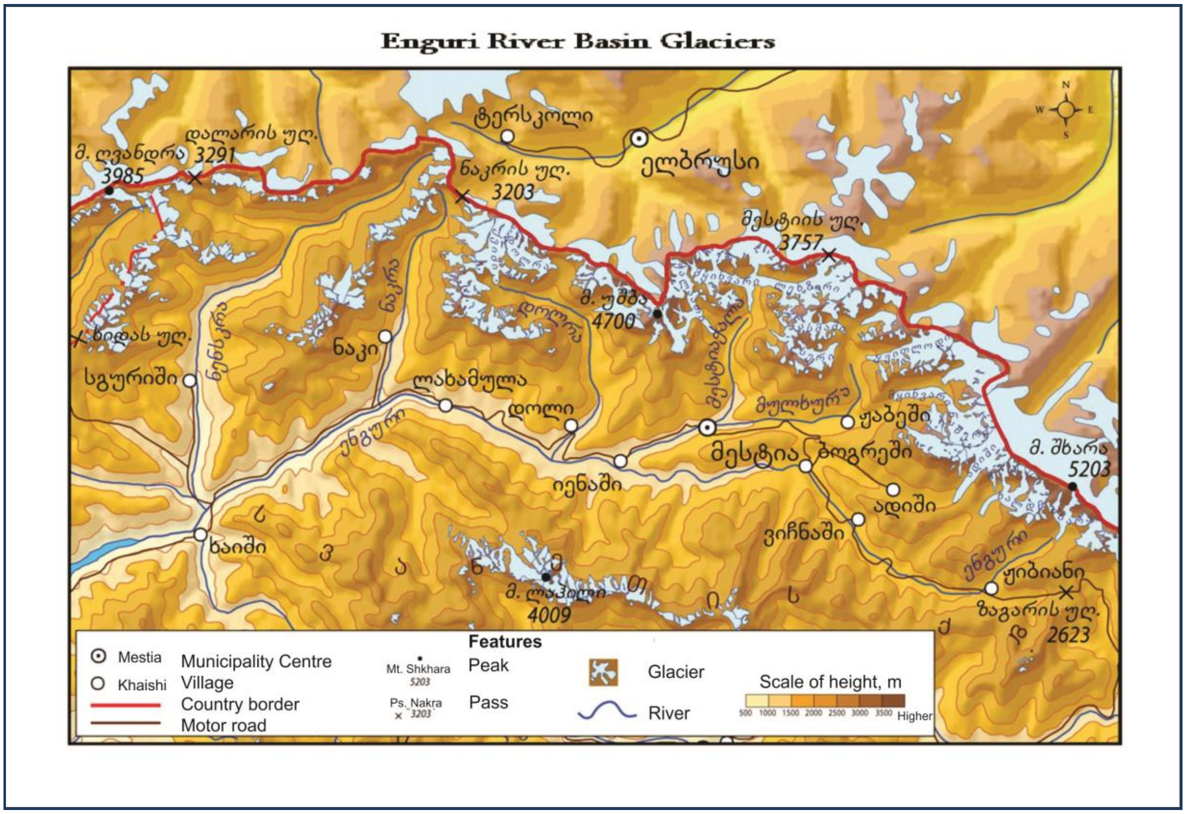


Fig. 2.1 Enguri River Basin Glaciers

Because of the complex and highly fragmented landscape, all types of glaciers areformed in the Enguri River Basin. Their distributions by numbers and percentages are given in the Table 2.2.

Table 2.2. Distribution of glaciers of the Enguri River Basin according to morphological types [3]

Morphological type	Amount	%	Areas km²	%
Carrean	123	48	8	2.5
Gorges	40	16	40	14.0
Hung	34	14	4	1.5
Carrean-Gorges	30	12	9	3.0
Gorges Complex	6	3	136	47.0
Gorges	17	7	93	32.0

[3] Gobejishvili R., Kotliakovi V. Glaciology. Tbilisi, 2006, p.226.

Characteristics of some of the complex glacier types in Enguri River Basin are given in Table 2.3. Here, their distribution by the basins and the area, the measurement period and the retreat rates are given. However, it should be noted that information is incomplete about some of the glaciers as the complexity of the glaciological studies (human, material and technical resources) makes it impossible to undertake simultaneous observation on several glaciers. The glaciers given in this Table, along with other glaciers play an important role in the formation of the glacial runoff of Enguri River Basin, which at the hydrological post of Khaishi amounts to 0.908 km^3/yr(1). Glacial rivers contribute to the Enguri River streamflow until Khaishi village, after this stretch, Enguri River runoff is regulated by the Jvari Reservoir.

Table 2.3. Features of glaciers in Enguri River Basin(3)

Glacier	River basin	Length, km	Area , km^2	Height of tongue's end m	Morphological type	Exsposition	Years of retreat, Length, km
Shdavleri	Nenskra	3.35	2.28	2 690	Gorges	Northern	
Kharikhra	Nenskra	2.70	2.60	2 300	Gorges	Northern-eastern	
Nakra	Nakra	2.80	1.76	2 750	Gorges	Western	
Leadashti	Nakra	2.70	1.72	2 740	Gorges	North-Western	
Dolra	Dolra	5.90	8.00	2 600	Gorges	South-Eastern	
Ushba	Dolra	5.75	9.40	2 430	Gorges Complex	Western	
Kvishi	Dolra	8.40	19.14	2 460	Gorges Complex	Southern-Eastern	
Tsaneri	Mulkhra	10.55	28.70	2 520	Gorges Complex	Western	
Tviberi	Tviberi	7.80	23.00	2 200	Gorges Complex	Southern	1889-1987yy. 4.34
Kvitlodi	Tviberi	7.00	11.90	2 340	Gorges		
Lekhziri	Mestiachala	12.0	35.60	2 020	Gorges Complex	Southern	
Chalaati	Mestiachala	7.80	9.70	1 800	Gorges	Southern	1974-2011yy. 0.436
Adishi	Enguri	7.40	10.00	2 420	Gorges	Southern-Western	
Khalde	Emguri	7.80	10.30	2 550	Gorges	Southern-Western	
Shkhara	Enguri	4.70	5.40	2 540	Gorges	Southern	

Table 2.3 presents the glacier characteristics (length, area, tongue ending height) that were obtained as a result of processing the 2005 LANDSAT satellite images. Under the impact of global warming, all glaciers at the southern slopes of the Greater Caucasus retreat, but this process is individual for all of them.

2.1.2. Impact of Global Warming on Glaciers in Enguri Basin

Tviberi River Basin glaciers are a good example of the glacier degradation caused by global warming. From the second half of the XIX century until the beginning of the XX century, the glaciers were connected to each other and formed a complex-type glacier of the valley. Their common tongue was coming down to 2 030 m ASL (Fig. 2.2). On the topographic map dating back to 1890, Tviberi Glacier is represented by the uniform system (with an area of 43.1 km^2, length of 10.24 km). Treatment of the 1959-1960 aerial images and the analysis of topographic maps for the same period demonstrated that Tviberi Glacier underwent pretty significant changes. The glacier length decreased by 2.14 km during the years of 1890-1960 and the area decreased by 3.0 km^2, respectively. From the left side, its largest branch Kvitlodi separated from the glacier and became the independent glacier. Currently, the Kvitlodi Glacier tongue is 800-900 meters away from Tviberi Glacier and ends at the height of 2 290 m ASL. 5 small size glaciers were also separated from the Tviberi Glacier system, namely - Seri (Photo 2.1), Asmashi, Toti, Iriti and Lichati. The glaciers are 200-500 m away from each other. Asmashi glacier is the longest and the largest, its tongue ends at the height of 2 450 meters ASL. The glacier tongue surface slopes are covered with 0.5-2.0 m thick clastic material and a 200-meter-wide pure ice flow is encroached between them.

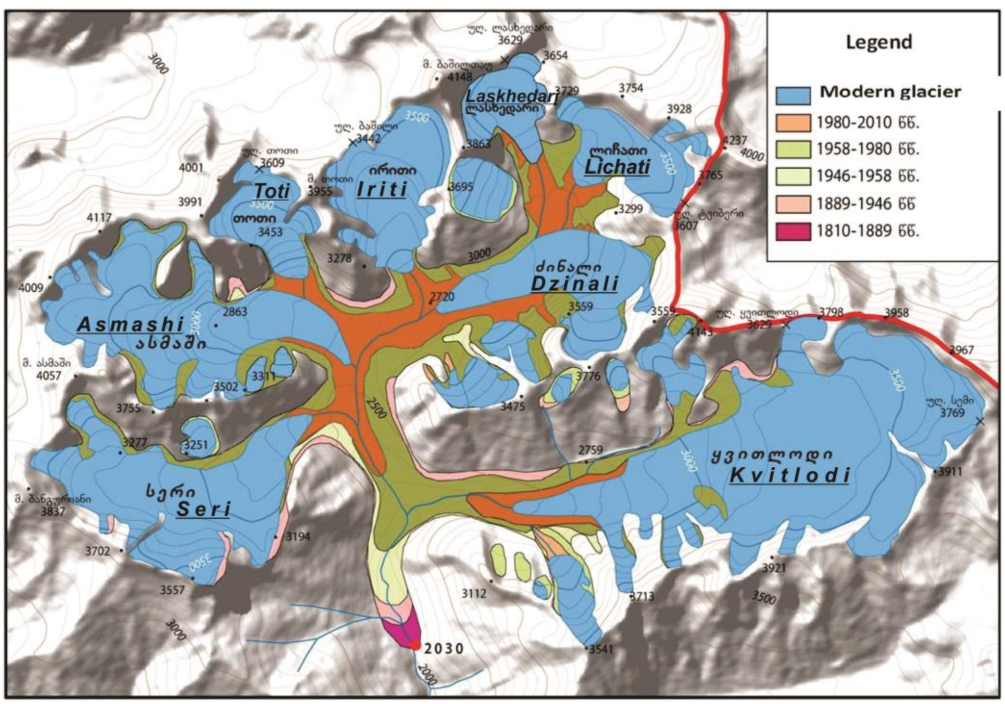
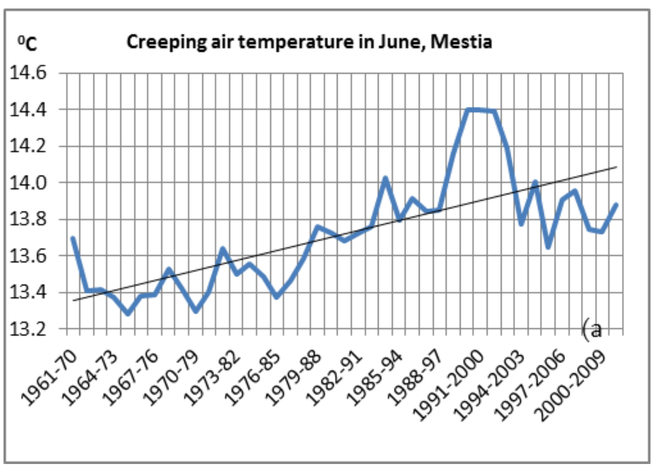


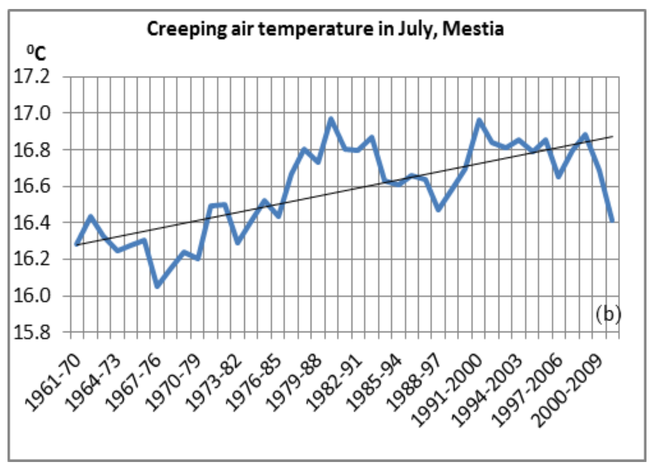
Fig. 2.2. Retreat of the Tviberi Glacier in 1810-2010

The firn line altitudinal movement gives an interesting picture. The firn line on Tviberi Glacier rose by 100 meters from 1889 to 1960, by 50 meters from 1960 to 1987 and still more than 50 meters in the years of 1987-2010.

Photo 2.1. Seri Glacier, 2011

The glacier retreat (at the ablation expense) primarily is determined by the high temperature in comparison to the norm during the summer. As there is no continuous meteorological observation range on any of the glaciers in Enguri River Basin, examination of the meteoelements regime in the basin is only possible by using the Mestia Meteorological Station data. To do this, the graph was drawn with the air temperature decennial creeping for the years of 1961-2010 obtained from Mestia Meteorological Station (Fig. 2.3), which in all three summer months showed an upward temperature trend. This was particularly sharply demonstrated in July in the form of the upward cycle for the years starting from 1976-1985 to 1982-1991 and from 1990-1999 to 2001-2010.





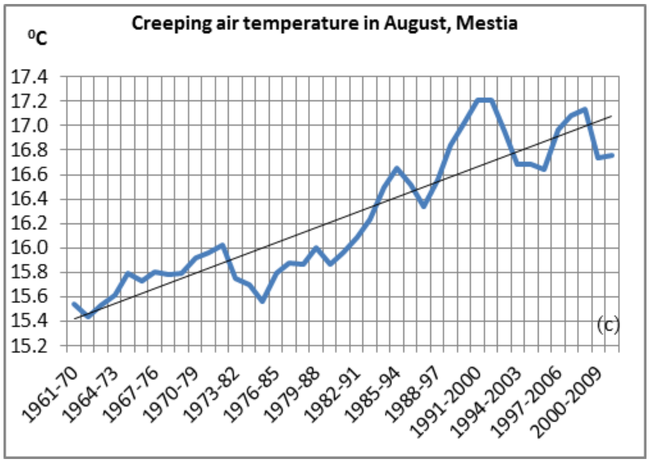


Fig .2.3. Shifting decadals of air temperature in Mestia in June a), July b) and August c).

Thus, as evidenced by the Chalaati Glacier data, it is likely that in Enguri River glacial area, the air temperature regime was characterized with the same trend: The retreat of 1974-1988 corresponds to the decennials from 1976-1985 to 1985-1994 and made 183 m.; The retreat of 2004-2011 with 69.0 m corresponds to the decennials from 1990-1999 to 2001-2010. The results of the observation at Tviberi Glacier for the same period: The retreat by 50 meters in 1987-2010. Enguri River Basin is rich in different morphological glacier types, but it is more convenient to conduct the complex glacio-hydro-meteorological studies on valley-type glaciers because they are relatively easy of access. For this reason, Chalaati, the Glacier in the Mestiatchala River Basin was selected. We note in advance that according to the 1960 data, 25 glaciers with the total area of 57.5 km^2 were located in the Mestiatchala River Basin. According to the data of 2014, the number of the glaciers decreased by 4, while the glacier area lessened to 44.0 km^2 (by 23.4%).

Chalaati Glacier

General Characteristics

The only representative glacier in Enguri River Basin, where the comprehensive, glacio-hydro-meteorological studies were conducted in different years (1959, 1960, 2000 and 2011) is Tchalaati. Its representation is determined by the following factors:

1. It is the only glacier in the South Caucasus, which encroaches into the forest zone and is relatively easily accessible;
2. Because of the favorable glacier morphological and morphometric characteristics it is relatively easy to conduct the instrumental glacio-hydro-meteorological study;
3. Chalaati Glacier with its geomorphological, meteorological, glaciological conditions and dynamics is representative for the glaciers in Enguri River Basin.

Chalaati Glacier is the complex valley-type glacier and intrudes of two flows. It is located in the Mestiatchala River Basin and is nourished from the slopes of the 4 000 meter high peaks: Ushba, Chatini, Kavkasi and Bjedukhi. From glaciers located on the slopes of the Caucasus Mountains it descends to the lowest point and encroaches into the forest zone. The glacier area is 9.7 km², the length is 7.8 km. Its left stream is the principal (Photo 2.2). Three ice falls are formed on its surface, which indicates the existence of riegels at the sub-glacier terrain. The height of the most powerful ice fall is 300 meters and the width is 600 meters (Photo 2.3). The two lower icefalls are relatively small. In the vicinity of the ice falls, the glacier tongue is cut up with clefts of several directions (hillocks).

Photo 2.2. Main left flow of the Chalaati glacier, 2011

Photo 2.3. Upper Icefall of the Chalaati glacier, 2011

According to the 1810 data, during the (XVI-XIX centuries stadial glaciation), the glacier tongue descended down to 1 620 meters that is evidenced by the last stadial moraine in the valley and erratic boulders (Photo 2.4). In the years of 1810-1960, the length of the glacier was reduced by 1 500 meters and the area by 2.3 km².(In 1960, the glacier area was 12.3 km² and length was 8.0 km). In 1970-1973, the glacier was in the stationary condition and small moves upwards were observed (1-2 meters). The stationary situation and the small raises were observed on many glaciers of the Caucasus, to which the formation of micro-stadial moraines are associated. The results of measuring the glacier retreat with the labeling method demonstrated that from 1974 to the year of 2011, the glacier tongue retreated by 436 meters with the average rate of (-11.8 m/sec). The stepping back by specific years is given in Table 2.4.

Table 2.4. Dynamics of the Chalaati Glacier Tongue by Years with the Marking Method

Years	Movement of glaciers
1970-1973	Stationary state and insignificant move forward (1-2 m)
1974-2011	Retreat -436 m, avg. rate -11.8 m/yr.
1974-1988	Retreat -183 m, avg. rate -13.0 m/yr.
1988-2004	Retreat -184 m, avg. rate -11.5 m/yr.
1989-1995	Move forward 15 m, avg. rate -2.5 m/yr.
2004-2011	Retreat 69.0 m, avg. rate -9.0 m/yr.

The comparison of the glaciological studies conducted by the Institute of Geography in 2011, as well as the spacecraft image of 2010 (Photo 2.5) with the topographic map of 1960 demonstrated that Chalaati during this period underwent substantial changes. The space imagery clearly shows that the both glacier flows were still in contact with each other. The right stream underwent noticeable changes. Two glaciers were separated from it, one glacier located on Chatini slopes with the surface area of 1.0 km^2 and the other glacier located on the right side with the surface area of 1.5 km^2. The glacier tongue decreased by 0.15 km^2 in the same period and in total, the glacier area lessened by 2.6 km^2. At the same time the number of glaciers increased by two.

Photo 2.4. Right flow of the Chalaati Glacier, 2011

The Chalaati Glacier firn line and consequently, the firn basin begin from the height of 3 150 m ASL. A number of glacial streams are gathered in the firn. The main is the flow descending from the Kavkasi Peak. The firn basin covers the territory from the height of 3 150 meters to 3 800 meters. The firn area is 4 km^2. The middle part of the glacier tongue is strongly inclined and cracked.

Photo 2.5. Satellite imaginary of the Chalaati Glacier,2010.

Results of the surveys conducted on Chalaati Glacier at different times are given in Annex 2.

The main source of the glacier-fed river streamflow is the ablation processes taking place at the glacier surface and inside it. Therefore, these types of river level and discharge depend on the glacier regime, which is even reflected in the water interannual discharge distribution. A major part of the river discharge on these types of rivers occurs during the summer months. They are featured by exceptional high waters in the spring season, when the snow cover accumulated in the valley during winter starts melting. Later, from July the ice melting process starts, which continues until October.

The most important part of the Chalaati River interannual runoff fells exactly on Chalaati glacial streamflow. The data obtained by the ablation laths were used for calculating the surface melting for different periods (Table 2.5).

Table 2.5. Surface melting of Chalaati glacier calculated with the ablation rod network data

Period	Total ablation, cm	Average rate of ablation, cm/day
08.07.11 - 14.07.11	74	12.3
14.07.11 - 20. 07.11	56	9.3
20.07.11 - 28.07.11	71	8.9
28.07.11 - 04.08.11	73	10.4
04.08.11 - 14.08.11	97	9.7
14.08.11 - 23.08.11	56	5.6
Sum	**427**	

The downward trend of reducing the surface melting by the height is sharply expressed (Fig. 2.4).

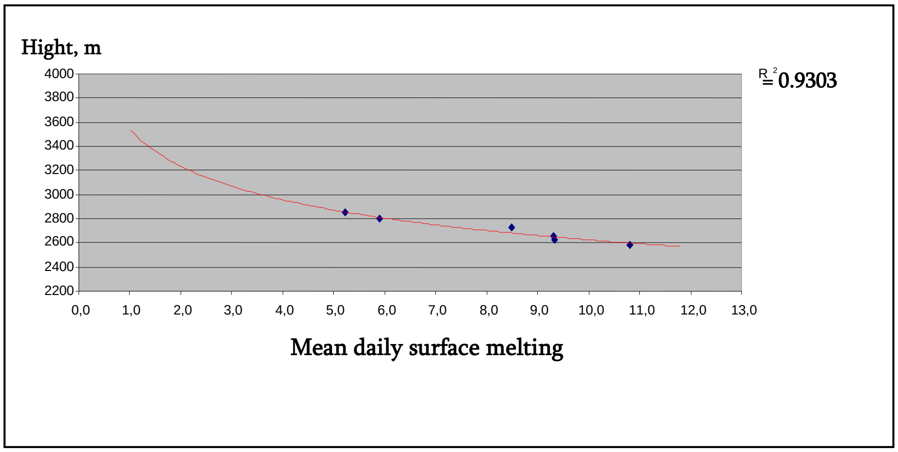


Fig. 2.4. Correlation between the mean daily surface melting and site elevation

According to the altitudinal zones, with the surface ablation and the actual size distribution data, the surface melting total area was calculated by the altitudinal zones in water equivalent (Table 2.6).

The hydrological observation revealed that the glacier melting by 1 mm amounted to 9 500 m^3 of water. The results of the observations in 1959 revealed 9 000 m^3 of water per 1 mm of melting. As it turns out, during 50 years from 1959 until the year of 2011, the Chalaati Glacier area decreased by 2 km^2 and streamflow increased by 500 m^3.

Table 2.6. Distribution of Areas on Chalaati Glacier according to the Height Zones and Ablation Volume

Hight zone, m	Area, thousand m^2	Ablation, thousand m^3
770	265	1900-2000
1 090	567	2000-2100
1 000	984	2100-2200
480	1 112	2200-2300
470	1 138	2300-2400
700	1 238	2400-2500
1 150	1 497	2500-2600
1 010	1 385	2600-2700
870	1 032	2700-2800
320	106	2800-2900
270	109	2900-3000
150	98	3000-3100
40	91	3100-3200
30	80	3200-3300

The seasonal glacier mass balance (Fig. 2.5) by altitudinal zones was calculated based on the accumulation and the surface ablation data.

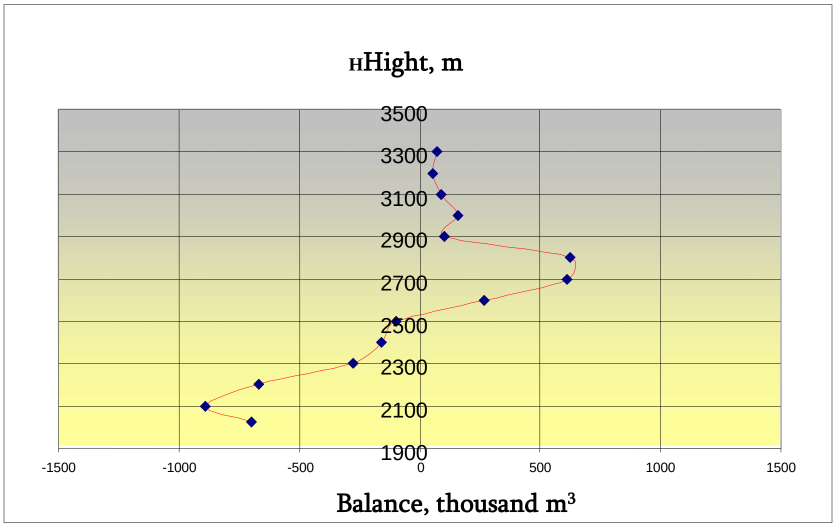


Fig. 2.5. Chalaati Glacier Seasonal Mass Balance for June-July-August 2011

The research revealed that in the summer of 2011, Chalaati seasonal glacier mass balance was negative. The diagram shows that from 2 550 m ASL accumulation exceeds the ablation, from 2 900 to 3 300 m accumulation is relatively less, that could be explained by the location on the sharply inclined glacier slope in this section, where the snow accumulation process is complicated. The highest ablation index is observed at the elevation of 2 100-2 300 m above sea level, that is caused by the location of the glacier tongue on the relatively flat surface.

Additional data of various studies conducted on Chalaati Glacier are given in Annex 2.

On the background of global warming, for the evaluation of the glacier degradation it is hard to make judgment based on the glacio-hydro-meteorological research data of only one particular year. This is why the results of the surveys for the previous periods were also used for developing forecasts for the glacier dynamics, the glacial streamflow and the ice mass of Enguri River Basin glaciers for the next 100 years.

2.1.3. Impact of Ongoing Warming on the Enguri River runoff

General Information

Enguri River holds an eminent place in Georgia's hydropower development plans, that is determined by the existence on this river of Enguri Hydro Power Plant, the largest HPP in the Caucasus region and the possibilities of further the use of Enguri's water resources in the future. All typical components, such as groundwater, glacier, and snow and rain nourishment participate in the formation of total annual discharge in the Enguri River Basin. According to the data given in the monograph[4], their contribution to the total river runoff is distributed as follows (Table 2.7).

[4] Vladimirov L. A., Shakarashvili D. I., Gabrichidze T. N., Water Balance of Georgia, Metsniereba (Science), Tbilisi, I974, p. 144 (in Russian);

Table 2.7. Distribution of Shares of total Annual River Runoff Components in Enguri River Basin(*).

River-point	Area of the watershed, km^2	Average height of the basin, m	Share of annual runoff %				Annual runoff, million m^3
			Underground	Glacier	Snow	Rain	
Enguri-Latali	1 000	2 570	23.7	39.5	28.7	8.1	1 415
Enguri-Lakhamula	1 370	2 520	23.6	33.0	27.4	16.0	1 920
Enguri-Dizi	1 620	2 490	21.8	25.7	38.3	14.2	2 250
Enguri-Jvari	3 170	2 220	30.0	21.0	32.0	17.0	4 670
Enguri-Darcheli	3 660	2 020	34.7	16.8	25.9	22.6	5 300
Mulkhra-Latali	435	2 680	19.0	53.0	13.0	15.0	672
Nenskra-Lakhami	468	2 270	26.2	19.3	40.2	14.3	959

**The data given in the Table are based on the measurements carried out in the years of 1931-1968.*

As it is seen from this Table, groundwater alimentation along Enguri River flow increases by approximately 24% to 35%, while the share of glacial feeding decreases by about 40% to 17%. The Table also shows that within Upper Svaneti boundaries, including Jvari Hydrological Post, snow (average 32%) and the glacial (30%) components dominate annual runoff. As the glaciers in Enguri Basin undergo evident transformatio in recent decades related to global warming, the assessment of the current and projected climate change impact on Enguri River has a practical interest. According to the data given in this monograph, which concern the period of 1931-1968, the share of glacial feeding on various hydrological posts in the middle of Enguri River Basin and its tributaries varied in the range of 20.0-47.2% and was 27.3% on the average (Table 2.8). According to other estimates that are based on the measurements conducted in 1937-1980 on Khaishi Hydrological posts at Enguri River, the share of glacial feeding at this section in total annual runoff amounted to 26.2% (a catchment area of 2 780 km^2, the basin average height - 2 320 m, the glaciation - 288 km^2). Taking into account that this last number reflects the reference data for the longer period at the station, where the discharge of all rivers in Enguri River Basin with glacial nourishment gather, we considered 26.2% as the value concerning the 80s of the last century. The given data related to Enguri River glacial streamflow during the 1958-1976 was obtained as a result of the expeditions conducted by the Department of the Hydrometeorological Service, the Institute of Hydrometeorology and the Institute of Geography and are reflected in the publication.

The systematic observations at the Khaishi post on Enguri River runoff were interrupted in the 90ies of the last century. Because of this, the assessment of the changes in discharge amount as a result of climate warming is only possible with the indirect data. In particular, in 2000, with the financial support provided by USAID, the National Agency on Climate Change conducted the complex glacial streamflow measurements on 4 glaciers of Enguri River(5) (Tchalaati, Lekhziri, Kvishi and Dolra), but because of technical reasons, the share of this discharge in the seasonal river runoff was not determined. However, a number of important patterns were established in the four-month ablation period, which together with the data obtained in the past years, allows to estimate with first approximation the connection of the river Enguri's water resources with the predicted warming process.

Table 2.8. Glacial runoff* in basin of R. Enguri(4)

River-Point	Area of the water collector, km ^{2}	Glaciation km ^{2}	Gracial runoff	
			Million. m ^{3}/yr	% of total annual
Enguri – Lakhamula	1 370	232.0	614	33.0
Enguri-Dizi	1 620	250.0	741	28.9
Enguri-Purashi	3 170	302.0	942	20.0
Mulkhra-Latali	435	141.0	278	47.2
Nenskra-Lakhami	468	32.9	177	20.2
			Average	27.3

**The glacial runoff contains 2 components. First of them is "Grotto water" pouring all-year-round from the bottom of the glacier, to which the surface melting water is added in summer. The latter exceeds several times the first component in summer months.*

Formulation of the Problem

As a result of the impact of global warming, which intensified since 1980s, the degradation of glaciers was observed in all regions of the world, including the central part of the Greater Caucasus. Discharge of rivers that have glacial nourishment increased in the conditions of the glacier melting and retreat. At the same time, this process, because of the reduction in the glacier area and their ice stock, leads to the streamflow reduction, which after complete thaw of glaciers will be only turned into streamflow of atmospheric precipitation and groundwater nourishment. Moreover, it is possible that the latter will be changed with the disappearance of the glaciers. According to the latest estimates, in the conditions of the current degradation pace of the Caucasus glaciers and the forecasted temperature growth, this mountainous system will be likely free from the ice cover by the years of 2150-2160.

According to the results obtained in the framework of Georgia's Third National Communication, for 2100, in Upper Svaneti region, which includes the upstream part of Enguri River Basin, it is expected that the average annual temperature will be increase by 4.0 ^{0}C in comparison with 1986-2010 average. This will certainly have a significant effect on the geometrical dimensions of glaciers and glacial streamflow in the basin. For assessing this estimated impact, we used already existing data on the observed basin glacier degradation and the measured as well as predicted temperature changes in the region.

Decrease in the Glacier Areas due to the Current Warming

As mentioned above, according to the data cited in the monograph[6], 250 glaciers with a total area of 288.3 km ^{2} were registered in Enguri River Basin in the second half of the 20 th century. The following glaciers were distinguished among relatively large glaciers: Lekhziri (38.1 km ^{2}), Kvishi (13.8 km^2), Chalaati (13.2 km^2) and Dolra (8.8 km^2). Glacial streamflows from the rivers of Nenskra, Nakra, Dolra, Mestiatchala, Mulkhra and others are gathered in the closing section near Khaishi Hydrological Post, where according to the data of the 1937-1980 years, the average annual discharge amounted to 110 m^3/s, while the full annual flow was 3 465 km^3. By taking the glacial streamflow shares into account (26.2%), the average annual glacial discharge of Enguri River for this period was equal to 0.908 km^3, i.e. 908 million m^3.

According to the same study[6], the total glacier area in Enguri River Basin was reduced from 332 km^2 to 288 km^2 in the period of the 1890-1965 years, which is 13.0% reduction. This process is consistent with the observed glacier degradation, which since 1890 has been taking place in various regions of the world with the increasing pace.

For assessing the temperature conditions of the glacier area reduction in Enguri Basin, we reviewed the data of the nearest long-term observation of Kutaisi Weather Station, (Observations in Mestia began only in 1936), according to which the average annual temperature increased by 0.3 ^{0}C between the sub-periods of 1906-1913 and 1954-1963 years.
The analysis of the data obtained from the Hydrometeorological Department demonstrated that in the 33-year period of 1959-1991, the correlation ratio between the average annual temperatures was 0.882 at the meteorological stations in Kutaisi and Mestia. This makes it possible to assume with good approximation that the 0.3 ^{0}C increase in the average annual temperature observed in Kutaisi in the first half of the 20th century also extended to Upper Svaneti Region, which led to the above-mentioned decrease in Enguri River Basin glacier area.
The steady temperature increase trend in the first half of the 20th century in general was observed on the whole European continent. According to the Fourth Report of the IPCC, this increment in the periods of the 1906-1950 years amounted to 0.4 ^{0}C (Fig. 2.6). Taking into account, that Georgia is located on the bordering territory to Asia, where the increment only reached 0.2 ^{0}C in the same period, it can be said that our rate is consistent with the internationally recognized results.

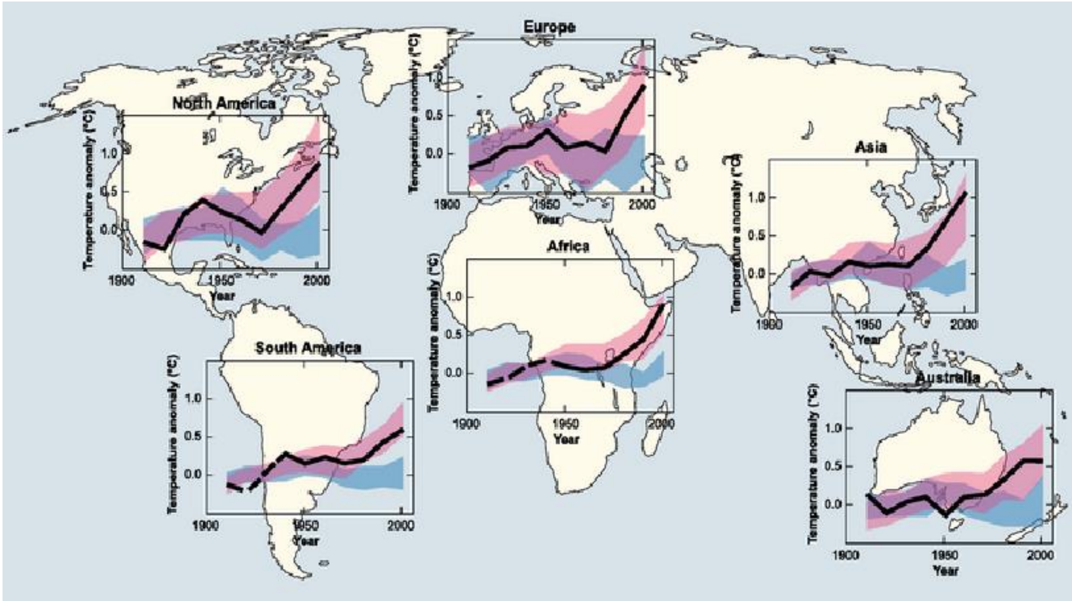


Fig. 2.6. Variations of air temperature decadal averages according to continents in 1906-2005. Anomalies are plotted relative to the average for 1901-1950 [(5)].

Thus, the evaluation of the reduction of the glacier area in Enguri River Basin can be based on the identified actual circumstance that the total glacier area in the basin decreased by 13% in the period of 1890-1965 and was accompanied by the 0.3 ^{0}C increase of the average annual temperature in Upper Svaneti Region.

The analyses conducted within the Third National Communication demonstrated that during the half-a-century period of 1961-2010, the average annual temperature in Mestia Meteorological Station increased by 0.3 ^{0}C. If we assume that the duration of this period is approximately equal to the above-mentioned period of 1906-1963, and both are characterized by the similar temperature increase of 0.3 ^{0}C, we can assume with first approximation that the 13% reduction in the glacier area in the first period was continued with the same pace in the second period of 1961-2010. In this case, the value of the last century (288 km^2) would be replaced by the current approximate of 251 km^2 and glacial runoff will be reduced in proportion from 908 million m^3 to 790 million m^3 per year.

As for the future assessment until 2100, according to the weather forecast, in relation to the average of 1986-2010, it is expected that the annual temperature in Upper Svaneti will increase by 4.0 ^{0}C to the year of 2100. According to the forecast, the temperature increase by 2050 is expected at the relatively slow rate (by 1.2 ^{0}C) and by additional 2.8 ^{0}C by the end of the century. If we present the temperature increase for the period of 2010-2100 with the simplified, linear method, we can take approximately half of the projected increment or 1.8 ^{0}C as the average temperature increase value during this whole period of time. This value in the abovementioned time period (2010-2100) contains six 0.3 ^{0}C increments and if we conclude that the 0.3 ^{0}C temperature rise at each stage is accompanied by the 13% reduction in the glacier area

5 Climate change 2007. The Physical Science Basis. IPCC, 2007.

on the previous stage, we will see that for the year of 2100, the current estimated total glacier area in Enguri River Basin - 251 km^2 will be reduced to 108 km^2 or by 57% (Fig. 2.7.). Accordingly, with the condition of the assumed linear relation between the glacier area and its streamflow, glacial runoff in the basin will be also reduced from the current estimate of 790 million m^3 to 340 million m^3 (without taking an additional melting of the glaciers into account).

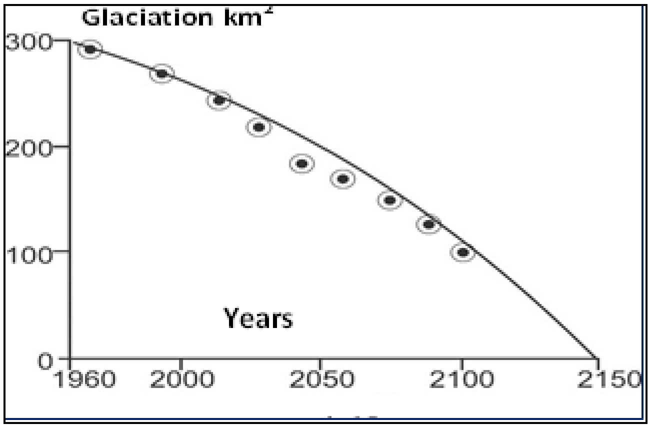


Fig. 2.7. Presumable dynamics of glaciation decrease in the R. Enguri basin accepted based on assumptions.

The graph demonstrates that under the taken assumptions, which on the average envisages the 0.3 ^{0}C temperature rise every 15 years and the relevant 13% reduction in the glacier area, based on the extrapolation of the curve, it is expected that the ice cover in Enguri River Basin will disappear by 2150. This result is close to the estimated forecast, obtained in cited publication[10].

Impact of the Ongoing Warming on Glacial Runoff

The link of the glacier surface melting with air temperature is one of the key issues when studying the relation of the temperature with glacial streamflow. This process is usually described by the glacier surface elevation change during the 1^{0}C average daily temperature rise. In addition to the temperature, the process is significantly influenced by the glacier surface condition (whether or not it is covered by moraine clastic material) and exposition, solar radiation, wind, precipitation and so forth. According to the publication[13], the average melting rate on 1 ^{0}C temperature increment in the Caucasus equals to 6.5 mm. This value practically coincides with the results of the measurements carried out on Chalaati Glacier in 1959, which are shown in Table 2.9.

Table 2.9. Dependence of melting at the Chalaati Glacier on the mean daily temperature[6]

Average air temperature at the glaciers, ⁰C	3	4	5	6	7	8	9	10	11	12
Daily melting, mm	7	11	16	22	29	37	45	55	62	80

For 1960s, the extreme heights of Chalaati Glacier amounted to 1890 m and 4 330 m ASL. The meteorological station characterizing these heights is Mamisoni Pass located in the neighboring region (2 854 m), where the average temperature of the warmest months (July and August) equaled to 7.3 ⁰C and 7.6 ⁰C, while the average maximum was 11.7 ⁰C and 12.1 ⁰C respectively. Thus, if we consider that the temperature range for the ablation period on Chalaati is 4-12 ⁰C, it can be assumed that the 1 ⁰C temperature rise is consistent with the melting increase of 7 mm. The result was confirmed by the measurements carried out by the Institute of Geography at the Chalaati Glacier in 1960[7].

In the paper[14], the following relation between the surface melting and glacier streamflow was obtained for the middle months of the ablation period at the Chalaati Glacier (Table 2.10).

Table 2.10. Correlation between surface melting and glacial runoff. Glacier Chalaati, 1959 [(7)].

Period	Surface melting, cm	Average rate of melting, cm/day	Glacial runoff, million m^3	Runoff per 1mm of melting, 10^3 m^3/mm	Avg.temp. deviation from the norm in Mestia, ⁰C
09.07 – 01.08	186.2	8.4	18.417	9.9	+0.8
01.08 – 01.09	229.4	7.4	19.094	8.3	-1.6
Sum	415.6		37.511		
Average		7.9		9.1	-0.4

The streamflow measurements were made 300 m below the glacier tongue.

The Table demonstrates that on Chalaati Glacier, in the ablation season of 1959, 1 mm melting was on the average consistent with 9 100 m^3 runoff, which, naturally, also included "Grote water" glacier streamflow. It should be noted that consequently, the average monthly temperatures in Mestia in July and August 1959 equaled to 17.2 ⁰C and 14.7 ⁰C, that was higher than the climate norm for July by 0.8 ⁰C and was lower than the climate norm for August by 1.6⁰C. This, to some extent, can explain the 16% decrease of 1 mm melting in August compared to July.

[6] D. Tsereteli et al. Glaciological Observations on Chalaati and Lekhziri Glaciers (Upper Svaneti) in the Summer of 1959. Institute of Geography after Vakhushti. Proceedings, Vol. VIII, 1962, pp. 223-255 (in Georgian);
[7] R. Shengelia, M. Chijavadze, Chalaati Glacier Glacial River Regime in the Summer of 1960. Vakhushti Institute of Geography. Proceedings, Vol. XVIII, 1963, pp. 245-253 (in Georgian).

The next series of the glacio-hydro-meteorological observations on Chalaati Glacier were carried out in 2000[5]. Measurements took place from June 16 till October 15 during the 4-month long ablation period. Results related to the glacial streamflow are collected in Table 2.11.

Table 2.11. Features of the Ablation Period on Chalaati Glacier in 2000[8].

Period	Average total ablation, cm	Avarage ablation rate, cm/day	Avg. glacial runoff, m^3/s	Glacial runoff, million m^3	Runoff per 1mm ablation 10^3 m^3/mm	Avg.temp. deviation from the norm in Mestia, ^0C
16.06 – 05.07	138	6.9	7.1	12.269	8.9	+3.8
05.07 – 01.08	218	8.7	8.4	18.144	8.3	+4.9
01.08 – 01.09	188	6.1	10.9	29.194	15.5	+1.6
01.09 – 15.10	218	4.8	5.8	22.550	10.3	+0.4
Sum	762			82.100		
Average		6.6	8.0		10.7	+2.7

Runoff measurement were made 1.5 km below the tongue of glacier

The data in the Table shows that the ablation season for the year of 2000 in Upper Svaneti was characterized by abnormally high temperature deviations with the average value of +2.7 ^0C, respectively. For comparison, we can say that the anomaly for July-August 1959 equaled to -0.8^0C and in 2100, as it is shown below, amounted to +1.1 ^0C. This may explain the fact that in 2000, streamflow on Chalaati Glacier in the ablation period on 1 mm melting on the average amounted to 10 700 m^3, which exceeds the 1959 figure by 18%. It is also noteworthy that according to the footnote 5, Mestiatchala River (river source - Chalaati Glacier) average runoff in Mestia (38.2 m^3/s) in July-September 2000 exceeded the multiannual norm for the same period by 26%.

Based on the results of observations carried out on other glaciers in Enguri Basin and the conclusions made in the footnote 5 of this paper, the correlative link mainly is taking place between the water discharge and the temperature in the river basins during the ablation period and the role of precipitation is insignificant. At the same time, the role of precipitation away from the glacial nourishment source is increasing (Mestiatchala River – Mestia Town). In all, according to the footnote 5, water discharge of the rivers with the glacial basin is mainly determined by the air temperature.

The last glacio-hydrological expedition on Chalaati Glacier was conducted in 2011 by the Institute of Geography at the Tbilisi State University [(2)]. The measurements of the ablation, glacial streamflow and the meteorological elements took place in July-August and their results are given in the Table 2.12.

[8] Janelidze P. (ed). Assessment of the role of glaciers in the formation of river runoff. Nat. Agency on Climate Change, Tbilisi, 2000 (in Georgian).

Table 2.12. Results of Measuring Glacial Streamflow from Chalaati Glacier in 2011

Period	Average total ablation, cm	Avarage ablation rate, cm/day	Avg. glacial runoff, m^3/s	Glacial runoff, million m^3	Runoff per 1mm ablation 10^3 m^3/mm	Avg.temp. deviation from the norm in Mestia, ^0C
08.07-14.07	74	12.3	15.5	8.035	10.8	+2.1
14.07 – 20.07	56	9.3	14.6	7.569	13.5	
20.07 – 28.07	71	8.9	14.7	10.161	14.3	
28.07-04.08	73	10.4	15.1	9.132	12.5	
04.08 -14.08	97	9.7	9.7	8.381	9.6	+0.6
14.08-23.08	56	5.6	8.4	7.258	13.0	
Sum	427			50.536		
Average		9.4	13.0		12.1	+1.4

Runoff measurement were made 500 m below the tongue of glacier

The comparison of the results of this expedition with the results of two previous expeditions demonstrates that the melting characteristics on Chalaati Glacier increased. Namely, if during the previous ablation period the average ablation rate varied in the range of 7-8 cm/day, this number exceeded 9 cm per day during the last season.

The same applies to 1 mm glacial streamflow melting, which increased from 9 100 m^3/mm in 1959 to 12 100 m^3/mm in 2011. This fact seems to be related to the acceleration of the pace of glacier degradation, which is reflected in the reduction of its size and in the growth of covering surface debris with the moraine material. For over half a century, the Chalaati Glacier field survey results allow to estimate the expected impact of climate change on Enguri River streamflow at the first approximation. This assessment will be based on the same assumptions that were taken above, in case of the expected change in the glacier area. In particular, if the average daily temperature increase by 1 ^0C causes the increase in glacier melting by 7 mm, the equal average temperature increase by 1.8 ^0C in 2010-2100 will result in the 12.6 mm/per day increase of melting from Chalaati Glacier in the ablation period. During the 4-months period (120 days) this will give 120 x 12.6 mm=1 510 mm melting increment. The average melting index of 7 620 mm observed in 2000 from Chalaati corresponds to the 20% increment. If we assume that this result might be relevant for all glaciers in Enguri Basin, we will see that the temperature increase in the period of 2010-2100 by 3.7 ^0C can increase streamflow by 20% as a result of the melting increase. In all, this outcome will result in compensating approximately 60% deficit of glacial streamflow caused by the decrease in the glacier area, finally resulting in 40% decrease in glacial streamflow in Enguri River Basin in comparison with 2010. Instead of existing 908 million m^3 by the middle of the 20^{th} century, as well as 790 million m^3 by 2010, the decrease in glacial streamflow to 470 million m^3 annually would be expected by 2100, that will constitute almost 14% of the annual average runoff of the River Enguri in the past century observed at the Khaishi Checkpoint.

Impact of Warming on the Total Runoff of the River Enguri

The total annual runoff of the River Enguri determined at the Khaishi Post for the middle period of the last century (3 465 km^3) without glacier component amounted to 2 557 km^3 discharge attributed to atmospheric precipitation and sub-soil nourishment. According to the assessment mentioned above, glacier runoff for 2100 is expected to be 0.470 km^3/yr. by taking this into account, the decrease in total runoff of Enguri River to 2 557+0.470=3.027 (km^3/yr) is expected by 2100, that equals to 87% of discharge existing for the middle of the 20^{th} century.

Consequently, the effect of the expected 40% decrease in glacial streamflow by 2100 as the result of global warming in comparison with the 2010 level will be reflected in the 13% decrease of total annual runoff of the Enguri River compared to the middle period of the last century.

Uncertainties Associated with Assumptions Made

The assessments of the estimated changes in the glacier areas and glacial runoff in Enguri River Basin as a result of climate warming is approximate and relies on a range of assumptions that represent a source of uncertainty. First assumption is related to the decrease of the total glacier areas in the periods after 1961 with the same proportion, which was observed in the period of the 1890-1965. The basis of this admission is the assumption that the response of the glaciers to warming in the following periods may be similar to the response during the previous period due to the permanency of topography in Upper Svaneti glaciation area. However, with the gradual decrease in the glacier area and changes of the radiative characteristics of the underlying surface, this view is increasingly moving away from reality, but in the absence of other data we are forced to use this assumption. The second assumption is related to the simplified representation in the linear form of the projected temperature increase in Upper Svaneti for the years of 2010-2100. It is clear that such simplification is unacceptable for the precise model calculations, but the approach turns out to be in fact justified for the above-mentioned approximate estimates compared to the results obtained by other authors.

The third assumption is related to the proportional ratio of the glacier area and glacial streamflow in Enguri Basin. Due to the absence of the data of direct observations on the Glacier mass balance in the examined region, this assumption could be considered as proper in the first approximation, although the proportion may depend on the height of each glacier, the size, the exposition, the genetic type, the surrounding terrain and other factors which should be taken into account during a detailed review. In order to determine the annual variability of glacier mass balance, the weather station should function near the glacier and the hydrological observations on runoff should be carried out, while the glaciological observations should be periodically carried out on the glacier itself.

According to the fourth assumption, the results obtained for Chalaati Glacier concerning the relation between the ablation amount and the glacial streamflow volume prevails on the whole glaciation territory of Enguri Basin. Obviously, this assumption contains greater uncertainty, since Chalaati is the third-largest glacier in Enguri Basin and most glaciers are much smaller in size and therefore, it is highly controversial to spread attribute revealed for Chalaati to them. Nevertheless, due to the lack of observation data on some glaciers, we have to accept this assumption, as well as the assumption on the validity of the connection between the temperature increase by 1 ^{0}C and the melt growth by 7 mm throughout the ablation period. It should be also noted that in the research reports conducted on Chalaati Glacier in 2000 and 2011, the term "ablation" is identified with the surface melting, which is associated with the neglect of evaporation from the glacier surface.

This assumption in the conditions of regular strong winds during the ablation period can result in a large error, although according to the climate data, this event is not frequent in Upper Svaneti. At the same time, disregarding evaporation is somewhat compensated by including "Grote water" discharge in melt streamflow.

In order to substantially reduce uncertainties determined by these and other, more minor assumptions, such evaluations should be conducted with the model calculation that will be based on the satellite data on the number and the size of the glaciers in Enguri River Basin as well as the modern mathematical models and the experimental data demonstrating the processes of glacier melting and the formation of glacial runoff.

2.2 Impact of Climate Change on Agroclimatic Zones in the Mestia Municipality

On the basis of the meteorological observations undertaken till 1990, 5 agroclimatic zones were identified at the territory of Upper Svaneti (Fig. 2.8), which mainly coincided with the distribution of the climate zones. First, the lowest zone, described by the data of Khaishi Meteorological Station, was spread in the interval of the elevation between 500-1000 m ASL and was characterized by the $T>10\ ^0$C active temperature sums of 2 500-3 000 ^{0}C and precipitation amount of 600-700 mm during the vegetation period. This zone was favorable for cereal (corn), vine, fruit, nut, walnut and vegetable production.

The second zone in the altitude range of 1 000-1 500 m ASL was spread mainly along the valleys of Enguri River and its main tributaries (featured by Mestia Meteorological Station) and was characterized by the sum of active temperatures of 2 000-2 500 ^{0}C and precipitation in the amount of 500-600 mm during the vegetation period. In the distribution of precipitation in this zone, Mestia Hollow is an exception, where as the result of the influence of orography, the precipitation sum during the vegetation period amounts to 360 mm. Production of the heat-loving crops in the zone was somewhat limited, this is why mainly cereals (early corn, barley, oats, rye), early varieties of vines (1 200-1 300 m ASL), vegetables, potatoes, fruit, nuts and berries were prevalent here.

The third agroclimatic zone in the interval between the elevations of 1 500-2 000 m ASL covered mountain slopes around the second zone and was characterized by the sum of active temperatures of 1500-2 000 ^{0}C and precipitation of about 400-500 mm during the vegetation period. The climate mode of this zone because of the lack of the weather stations on these heights and above, may be characterized comparatively approximately with the data of Shovi (1 507 m ASL) and Koruldashi (1 943 m) meteorological stations. In the zones reviewed above - barley, oats, potatoes, vegetables and berry crops, root crops for the livestock fodder were produced and hey fields and pastures were also developed.

The fourth agroclimatic zone in the range of 2 000-2 500 m ASL, actually represented the alpine zone with the sum of active temperatures of 1 000-1 500 ^{0}C and precipitation sum of about 300 mm during the short vegetation period. From the agricultural crops, production of early potatoes, oats, barley, vegetables and root crops for the livestock fodder was possible here. In addition, hayfields and pastures were developed. According to the climate regime, this zone (also with the approximation) can be characterized by the data of the relatively closely located meteorological station to the eastern border of Upper Svaneti - Mamisoni Pass (2 854 m).

The fifth zone located above 2 500 meters ASL was directly bordering permanent snow and the glaciers. The sum of active temperatures was less than 1 000 ^{0}C here and it was not used for agricultural production.

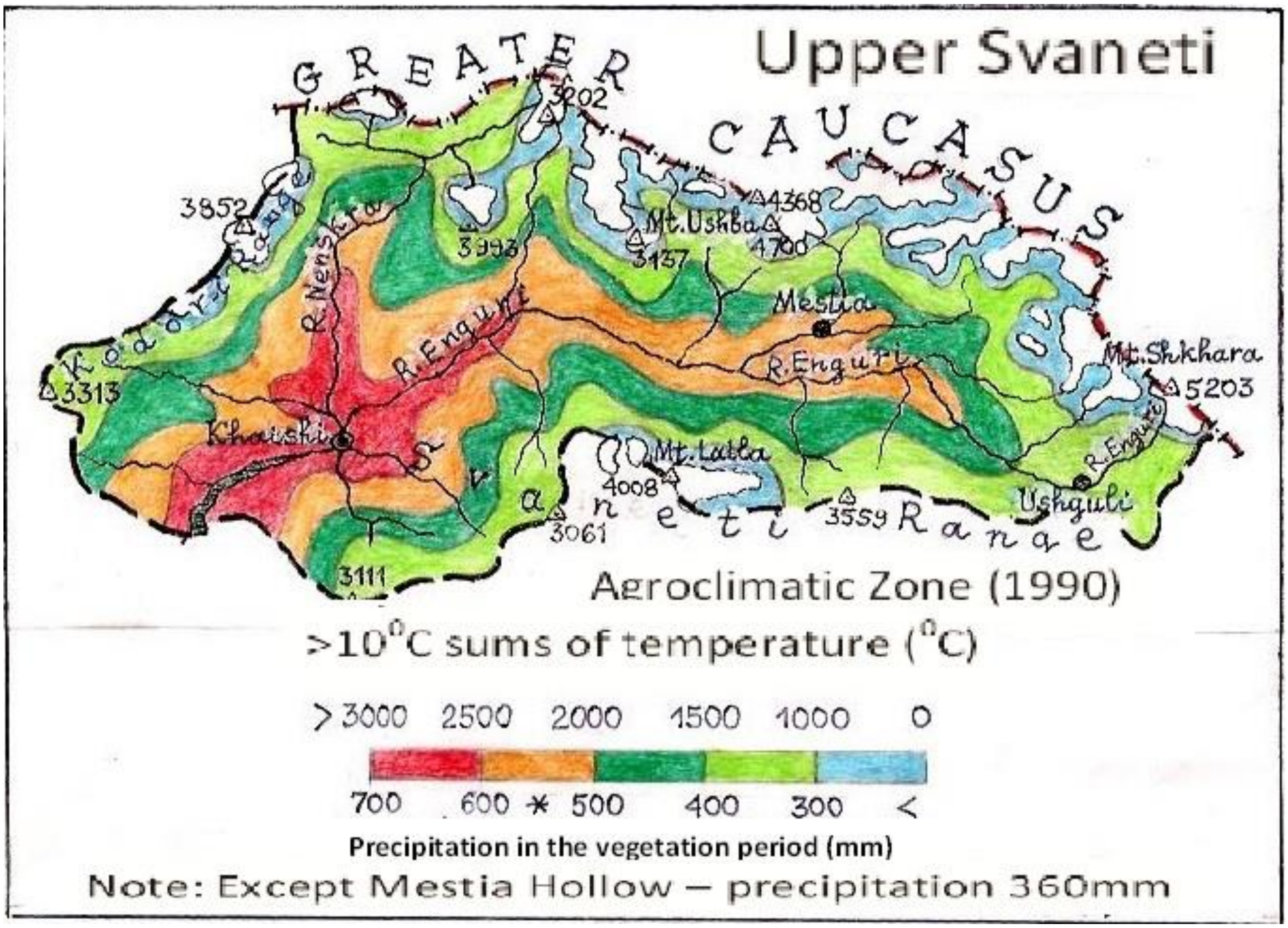


Fig. 2.8. Distribution of Upper Svaneti Agroclimatic Zones according to the Baseline Period Data

The model calculations conducted within Georgia's Third National Communication demonstrated that by 2100, the increase in the average annual temperature by 4.0 ^{0}C in comparison with the baseline period (1961-1990) and slight increase in precipitation (+ 3%) is expected on the territory of Upper Svaneti. At the same time, these changes may take more drastic character during the vegetation period, i.e. spring and summer. In particular, if the seasonal temperature increment in spring would be 3.2 ^{0}C, this index will reach 4.8 ^{0}C in summer.

The significant increment (+6%) is expected in the sum of spring and summer seasonal precipitation as well. Such significant increase in the main elements of climate change will result in the new distribution of climate, and therefore, agroclimate zones on the territory of Upper Svaneti by the year of 2100. If we take into account the data of separate weather stations, Khaishi's average annual temperature, which in the baseline period equaled to 10.5 ^{0}C, will reach 14.5 ^{0}C by 2100. This will transform the first agroclimate zone into the humid subtropical agroclimate zone characteristic for Colchida Lowland, which can be conditionally called as the "zero" agroclimate zone. During the basic period, the average annual temperature at the weather stations characteristic for this zone was as follows: Zugdidi - 13.8 ^{0}C, Kutaisi - 14.6 ^{0}C, Samtredia - 14.4 ^{0}C, Poti - 14.5 ^{0}C and Anaklia - 14.0 ^{0}C. With the increase in temperature in this new "zero" zone on the territory of Upper Svaneti, which will replace the first zone described in the Fig. 2.13, the sum of active temperatures (T>10 ^{0}C) will increase to 4 500 ^{0}C and precipitation in the vegetation period will reach 700-800 mm (Fig. 2.9). In the new climate conditions of this zone, production of grain (corn), vegetable-melons, citrus, tea, tropical fruit, technical (tung, laurel), nuts, kiwi and other crops will be ensured, however, achieving full maturity of orange and grapefruit fruits will be limited.

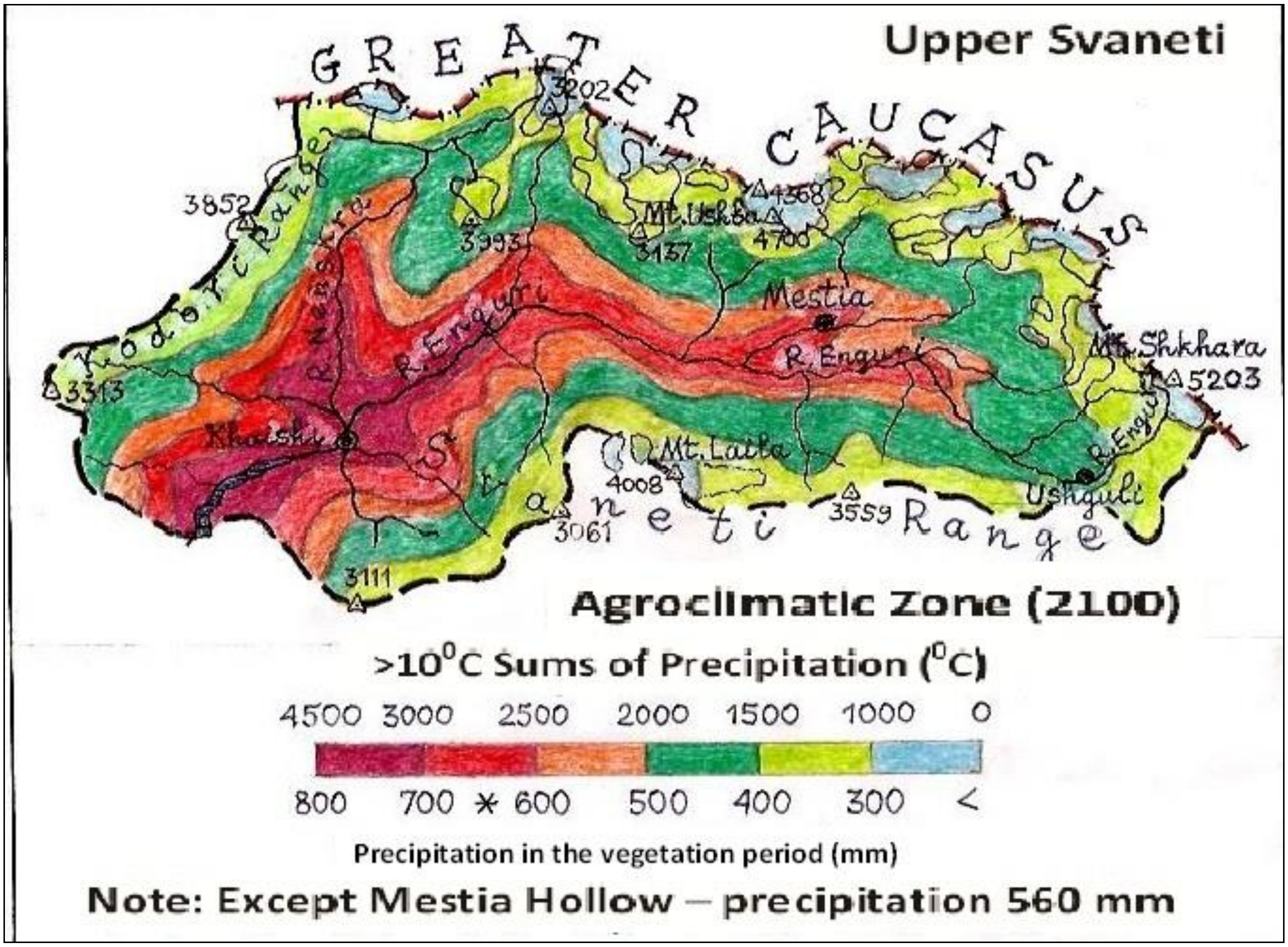


Fig. 2.9. Projected Distribution of Agroclimatic Zones at the Territory of Upper Svaneti by 2100

The second agroclimatic zone discussed in the figure 2.8 will be replaced by the first agroclimate zone with the sum of active temperatures of 2 500–3 000 ^{0}C and precipitation amount of 600-700 mm during the vegetation period. The average annual temperature at Mestia Meteorological Station, which characterizes this zone, will become 9.8 ^{0}C by 2100. This will make its climate regime similar to the current climate at the following meteorological stations: Lentekhi (the average annual temperature of 9.4 ^{0}C in the basic period) and Oni (10.0 ^{0}C). As we mentioned it above, this zone will be advantageous for the production of cereals (corn), vine, fruits, nuts, walnuts and vegetables.

The third agroclimate zone discussed in the Figure 2.8 will be replaced by the second agroclimate zone noted in the same diagram with the sum of active temperatures of 2 000–2

500^{0}C and the subsequent amount of precipitation (500-600 mm). As mentioned above, for this zone located in the range of 1 500–2 000 m, the meteorological stations of Shovi and Koruldashi can be selected as the double station, where the average annual temperatures for 2100 will respectfully reach 9.2-7.2 ^{0}C. Becho (6.5 ^{0}C), Lentekhi (9.4 ^{0}C), Kherga (6.7 ^{0}C) and Lailashi (9.5^{0}C) stations were featured with almost the same temperatures in the basic period. According to the above-mentioned, production of cereals (early corn, barley, oat, rye), vegetables, potatoes, nuts and fruits and berries will be possible here.

In the range of altitudes of 2 000-2 500 m ASL or in the current alpine zone, according to the prognosis, the emergence of the third climate zone highlighted in the Figure 2.8 is expected, where the sum of active temperatures will be 1 500-2 000 ^{0}C and the subsequent amount of precipitation will be 400-500 mm. At Mamisoni Pass Meteorological Station that was selected according to the certain approximation, the basic average annual temperature of -2.4 ^{0}C will be changed with the positive value of +1.6 ^{0}C, the analogue of which in the basic period was only Gudauri Meteorological Station with the average annual temperature of 2.1 ^{0}C. As mentioned above, it will be possible to grow crops like barley, oat, potatoes, vegetables and root crops, as well as the development of pastures and heyfields.

The 5th subnival zone located above 2 500 m (Figure 2.8), which is characterized by the sum of active temperatures of less than 1 000 ^{0}C, was considered as the zone unfit for agricultural production. In the conditions of projected warming, the sum of active temperatures in this zone is expected to move to the interval of 1 000–1 500 ^{0}C by 2100, which will make possible the production of early potatoes, oat, barley, veget able and root crops, as well as spread of the hayfields and pastures here.

Finally, the separate territories highlighted as the 6th zone in Fig. 2.9 might replace partly melted glaciers by 2100. The sum of active temperatures will be less than 1 000 ^{0}C here, soil will be mainly represented by moraine clastic material, which is why even the emergence of alpine meadows is not expected in this subnival zone.

The distribution of the agroclimate zones in the basic period (Fig. 2.8) and the data on prevalence of agricultural crops and production in these zones are presented according to the monograph[9].

2.3 Impact of Climate Change on Forests in Mestia Municipality

Impact of Climate Characteristics on the Forest Ecosystem

As mentioned above during the review of Svaneti's forest massifs, the territory of the Region is divided into two distinct climate zones, namely, the temperate humid zone in the lower part of Enguri Gorge (former Khaishi Forest Farm) and the moderately dry continental climate above

[9] G. Meladze, M. Meladze. Agro-Climate Resources in Western Regions of Georgia, Universal, Tbilisi, 2010.

the middle part of the Valley (former Mestia Forestry). Taking this into account, we will separately discuss changes manifested in the climate characteristics of the past years and based on these data it will be clarified, which forest plants are stressed. Also, any changes in the forest ecosystem will be examined. But, first of all, it is necessary to highlight those main climate features, which have the significant impact of the forest ecosystem. In general, the spatial and temporal distribution of temperature and precipitation mainly determines the plant propagation area. Complex biological phenomena, such as soil formation, assimilation, transpiration, variety change, renewal, self-thinning and other processes going on in woods is the result of logical interrelationships on the one hand between living organisms in the forest and on the other hand, among these organisms and the environmental factors.

Climate and soil conditions are critical for the forest, as are for any plant grouping. If these conditions are optimal for woody species of the forest component, forest growth and development are also normal. The deviation from the optimum conditions negatively affects forest growth and development.

Distribution of forests worldwide has a natural basis. This means that there are different types of forests in different geographical regions in terms of ecological and morphological point of view, which is the result of natural variability of the environmental conditions.

The average temperature for the existence of forests in the temperate zone during the vegetation period should not be lower than 10 °C and relative humidity should not be less than 50%[10]. Both air and soil humidity is crucial for the existence of the woody plants, which depends on the amount of precipitation and evaporation. The higher is the air temperature and the lower is relative humidity the greater is evaporation.

It is not enough to know only the sum of absolute precipitation (annual) for the plant water supply assessment. An insignificant part of precipitation may fall in the beginning of the vegetation period, while the greater part may fall in the second period. Clearly, plant moisture supply cannot be guaranteed in the first case, while it may be subjected to excessive moisture in the second case. Prolongation of the moisture deficit in soil is often accompanied by fading of tree leaves, drying up of the top and death of young saplings.

Excessive soil moisture also negatively impacts growth of forest species. In this case, oxygen is not enough for the respiration of the tree roots; the main root often becomes putrid. As a result, trees grow slowly and remain weak for decades.

Temperature also has a great importance in this regard: despite equal amount of precipitation in two different regions during the vegetation period, even temperature is much higher during this period in one region than in the other region, the plant may not be evenly provided with

[10] V. Darakhvelidze, P. Metreveli, l. Chikhaladze, Forestry Essentials, 1965 (in Georgian).

moisture, as high temperature increases evaporation. Growth, assimilation and respiration processes of woody plants depend on temperature conditions. Minimum, maximum and optimal temperatures of the growth of wood species are considered. In the temperate climate conditions the majority of woody species begins vegetation and finishes at 10 ^{0}C temperature. If the temperature is lower, vegetation interrupts. The growth of woody species is maximal in case of the optimum temperature. The further rise in temperature slows and eventually completely ceases the growth.

Three temperature indicators exist for the assimilation process: minimum, during which assimilation starts, optimum, when assimilation reaches the highest level and maximum, when the process is terminated. In the temperate climate conditions, the majority of the wood species starts the assimilation process at 5-6 °C. The optimum assimilation temperature of wood species in this zone is considered to be 20-30 °C, while the maximum temperature is 40 °C.

Respiration in woody species can also take place at temperatures lower than 0 °C. The optimum respiration temperature is high and equals to 45-50 °C. Respiration is terminated at higher temperatures.

In addition, the temperature conditions determine the distribution of woody species in nature.

According to the modern point of view, in the temperate zone conditions, the number of warm days during the year on the one hand and the number of the cold days on the other hand is a necessary condition for the existence of a woody species. For example, beech can survive in a place, where the vegetation period is not less than 210 days and the average temperature reaches 5 °C. For the existence at the north boundary of its prevalence, the European spruce requires not less than 25 days with the maximum temperature of 12.5 °C but cannot stand more than 65 days with the maximum temperature of 24 °C at the southern border of the prevalence.

It should be noted that soil conditions should be considered when studying the influence of the climate patterns on forest massif, which is one of the main factors to characterize the acceptable location of forest species.

Above, we have highlighted those climate characteristics, which mainly determine the optimal growth and development of wooden plants. For analyzing the impact of climate change on forest massifs in Upper Svaneti, it is necessary to know the changes observed in the past and future climates patterns. Later, it will be possible to analyze and determine the scale of the current and future changes in forest ecosystems.

Changes in Climate Patterns of Upper Svaneti and the Future Forecast

In terms of general climate conditions, Mestia Municipality belongs to the temperature humid subtropical continental climate region, although, as already mentioned, different climate zones are observed on the territory, which are located at different heights: relatively low and woody Khaishi zone, which occupies the western part of the Municipality and the relatively high Mestia zone, which occupies the eastern part of the territory.

Peculiarities of the current climate change for the past half-a-century in these two zones according to the seasons were discussed in detail in Section 1.1 of this report and are summarized in Table 1.1, from which the following conclusions can be made: During the winter season, the air temperature has not changed in Khaishi zone and has become slightly colder in Mestia zone (-0,1 ^{0}C). Warming was observed in both zones during other seasons, the least in spring (+0.1 ^{0}C) and the most in summer (+0.7 ^{0}C, Mestia) and fall (+0.8 ^{0}C, Khaishi). Except for summer, precipitation increased in both zones with different levels. Precipitation increased the most in winter (30%), while the precipitation increment in both zones amounted to 10-20% in spring and autumn. In summer, precipitation significantly decreased in Mestia (-8%), but only slightly (+3%) increased in Khaishi. In addition, extremely abundant (≥90 mm) precipitation in autumn, which took place in the previous period, was observed twice in the lower zone during the second 25-year period.

In Mestia, on the contrary, the number of days with abundant precipitation (≥50 mm) almost halved during the recent period. Also, the recurrence of droughts in both zones was reduced.

As for the impending climate change until 2100, as it is mentioned in Section 1.2., the minimum temperature rise for both zones (2.7-3.0 ^{0}C) is projected in spring, while the maximum increase (4.8 ^{0}C) is forecasted in summer. The average annual temperature increment in both zones is expected in the range of 4.0 ^{0}C. The increase in precipitation in the previous period will continue until 2050, after which, the 10-12% decrease in precipitation during summer and autumn is projected in Khaishi zone for the year of 2100, while the increase by 16% in winter and the reduction by 13% in autumn is expected in Mestia zone.

Description of the Upper Svaneti Forests Zonal Distribution and Main Species

The climate pattern analysis demonstrated that the different changes were observed at the Khaishi and Mestia Meteorological Stations in comparison with each other, as well as in the forecast data.

For analyzing the impact of the past and future climate change on the forest massifs in Upper Svaneti, it is necessary to know what forest types are observed in the forest prevalence area of Upper Svaneti, what are their natural prevalence area, as well as the ecological, morphological characteristics of the main wooden species creating the forest.

After analyzing these data, we will be able to deduce changes resulted by the magnitude of climate change in the forest ecosystem. Therefore, we will below discuss the main forest types and the dominant wooden plants prevalent in Upper Svaneti. Before that we will highlight the variety of the forest massifs according to the vertical zoning. In particular, the vertical forest zoning can be explained by the fact that as sea level, the climate changes at the mountain foothills according to the height, the change in soil and verdure is also possible. In particular, the air temperature decreases along with the locality altitude, therefore, the duration of the plant vegetation period also changes and the amount of precipitation increases up to a certain height (this is related to the geography of the mountain system), which then starts to decrease. Solar radiation intensity, as well as direct radiation, increases along with the altitude above the sea level. The recurrence of strong winds increases. In connection with this, soil, as well as vegetation cover changes. We should take into account the fact that the same vertical zone boundary can be raised or lowered in relation to the mountain slope aspects, soil specificities and other conditions.

Woody species that with their predominance in the given vertical zone create groves and are characterized by relatively large capacity represent the vertical belt indicator. The following vertical vegetation zones with the prevailing wooden plants can be distinguished on the territory of Upper Svaneti:

The Western Part of Enguri Basin (Khaishi Forestry):

- **Chestnut forest belt up to 500-1 000 m ASL.** The forests of this zone are mostly represented with chestnut forests that are replaced by Georgian oak forests at the slopes with great inclination and on lime soils. Chestnut is prevalent here, which occupies mainly the northern and north-eastern humid slopes. The rest of the slopes are occupied with other mixed species, such as: hornbeam, beech and linden. Clearly, chestnut is fond of rich brown loamy soils. This zone is weakly represented here and stretches only along the middle part of Enguri Reservoir slopes. The indicator of this belt is the usual chestnut (Castanea sativa), which is the shadow tolerant variety demanding temperate humidity (mesophyte) and heat. It demands a lot from soil, especially from its depth and cannot stand lime soil (calcophobia);
- **Beech forest belt until 1 000 – 1500/1600 m ASL**. The forests of this zone are a mix of Oriental beech, hornbeam, oak and other varieties. The following plants are met in the sub-forest: Caucasian bilberry, Pontic Rhododendron, nuts, azalea and others, which compose fresh, as well as mixed grove and others. Beech is prevalent (Fagus Orientalis). It is a typical shadow tolerant variety that creates fresh, as well as mixed groves. It is also a moisture demanding mesophyte, requiring deep and humus-rich soils. Beech develops large wood stock in such places. It is enduring cold relatively well, but it should be also noted that as the sapling it is perceptible to frosts, especially during early and late forests;
- **Abies and spruce forest belt up to 1500- 2000/2200 m ASL**, which is bordered by subalpine sparse and crooked forests transient to alpine meadows. This belt is mainly represented by abies and spruce with a mixture of pine-trees (Abies Nordmanniana) and Oriental spruce (Picea Orientalis). The ecological specificities of abies is almost the same as of spruce, this is why both species are often met together.

Eastern Part of Enguri Basin (Mestia Forestry):

- **The southern slopes from 750-800 m up to 1 500 m ASL** are dominated by pure oak and mixed oak forests with the predominance of Georgian oak and the mixture of hornbeam, pine and rarely, oriental spruce. The oriental spruce forests dominate the northern slopes. Rarely, the mixing of beech, spruce-beech and spruce-abies forests is met. We are unable to expose the dominant species here given the fact that the composition of the groves frequently changes according to the mountain slope exposition;
- **The wide pine and birch forest belt is spread out above 1 500 m**, mostly with the mixing of spruce forest massifs on the northern slope exposition. The beech and abies forest massifs are not typical for Upper Svaneti zone, the small groves occupying the insignificant areas are found only here and there. The sub-alpine sparse forests are mainly represented here with pine and birch (mainly with Litvinov birch - Betula Litwinowii with a slight mixture of warty birch - Betula Vorrucosa). As mentioned above, unlike this area, for the mountains in West Georgia (Colchida), particularly for the sub-alpine forests, the belt consisting of Litvinov and warty birches (boreal species) is not characteristic. According to some sources, Georgian endemic variation of Litvinov birch that is spread in this area has separately formed the so called Svaneti birch variety (var. Svanica Doluch), which with some of its features is similar to Radde birch (Betula Raddeana).

The changes identified over the past 30 years in the Upper Svaneti forest ranges as a result of climate change, and future forecast

First, it has to be mentioned that last forest surveying works in Upper Svaneti forest ranges were carried out in 1984; This hampers us to determine the scale of change in forest massifs over the past 30 years. Hence, current analysis of possible impact of climate change is based on the materials obtained from various sources (e.g.: expert assessments, population survey and archive materials); according to which estimated and current impact of climate change on forest ecosystem has been analyzed.

Khaishi

Unlike Mestia, the impact of the climate change on Khaishi forest ranges is not pronounced. We were unable to find respective data in the archives, or determine through survey whether any changes can be observed in the forest ecosystem. At this stage, possible scale of climate change impact on the forest ecosystem was analyzed in terms of climate parameters. Specifically, firstly we can conclude that there is a trend of steady rise of temperature as well as that of unsteady increase and ultimate reduction of precipitation. By analyzing these climate characteristics we can assume that temperature increase will have impact on spruce and fir-tree, despite the increase of precipitation and, respectively, of humidity. However, the increase of evaporation, transpiration should be taken into account. It should be mentioned here that fir-tree and to a high degree – spruce, require cool air, in addition to warm humid air prevalent in the gorges. In particular, rise of temperature will prevent the cones of coniferous trees to fully ripen and due to the prolonged growing period timely process of turning of annual growth ligneous will be hindered; this raises the risk of frost damage of new annual growth.[11] Therefore, the growth and development of the coniferous trees will be delayed, and the productivity of forests will fall. Warming will have especially negative impact on coniferous trees at the lower boundaries of their distribution range area where there will be marked change of climate characteristics. On the other hand, broadleaf trees will have favorable conditions as compared to coniferous trees. While, at the upper boundaries of the line of the distribution range of coniferous trees acceptable conditions will be formed for coniferous trees, and if soil conditions are also favorable, the boundary of coniferous forest line zone may shift upwards.

Mestia

Mestia climate is relatively continental. Specifically, the climate is less warm as compared to Khaishi, respectively, total precipitation is also lower. In the past climate here was more continental and dry. Testament to this is fragmented remnants of the plantations of Orientalis Quercus Macrocarpa (xerophyte – tolerant to dry habitat) which covered large areas in the past.

In the past, when glaciers still occupied large area in the south of Upper Svaneti, boreal forest varieties (pine-tree and birch) were gradually taking up the space freed up by the retreat of glaciers. As a result of climate change pine and birch tree forest ranges have decreased considerably, but, given climate specificity (continental) pine and birch have not been fully replaced by other, higher shade-loving, and, respectively, stronger edificator (ligneous plants that occupy dominant place in the forest ecosystem) varieties (beech, spruce, and fir-tree).[12] This has also been highly influenced by the types of soil in these areas. They are primarily made up of clayey slates, which is one of the factors conditioning the dryness of the soil. Furthermore, the materials obtained by Mr. Z. Chartolani are provided as the proof that birch forests occupied larger areas in the south of Upper Svaneti. The facts of other changes can also be observed in his photo archive. In particular:

The forests of Kakhuri Ridge near Mestia. The ridge separates Mestia and Mulakhi communities. According to the people representing the generation born in 1900's this ridge was fully composed of birch forest. On the presented photo (Photo 2.6), although vaguely, but still, we can see that the birch trees cover almost the entire ridge. Photo 2.7 was taken in 1969 and the photo 2.8 was taken in 2005. The comparison of these photos shows that a large area of the forest is taken up by spruce trees. It is clear on this section how birch trees have been replaced by coniferous trees, specifically – by spruce trees. At present birch trees are rarely found here.

[11] John Grace,Frank Berninger and Laszlo Nagy, Impacts of Climate Change on the Tree Line, 2002.

[12] Л. Б. Махатадзе М. А. Сванидзе, Сосновые леса и закономерности распределения лесной растительности бассейна р. Ингури, 1970г. (Makhatitdze, L. B., Svanidze, M.A., Coniferous forests and the patterns of the distribution of forest vegetation in the Enguri River basin, 1970)

Photo 2.7 should also be noted for another detail. If we look on the northern slope of the mountain, the tree line of spruce and fir-tree forest flows into the alpine zone forest cover, while on the photo taken in 2005 it can be seen clearly that the northern mountain slope is fully covered by spruce and fir-tree forest (photo 2.8).

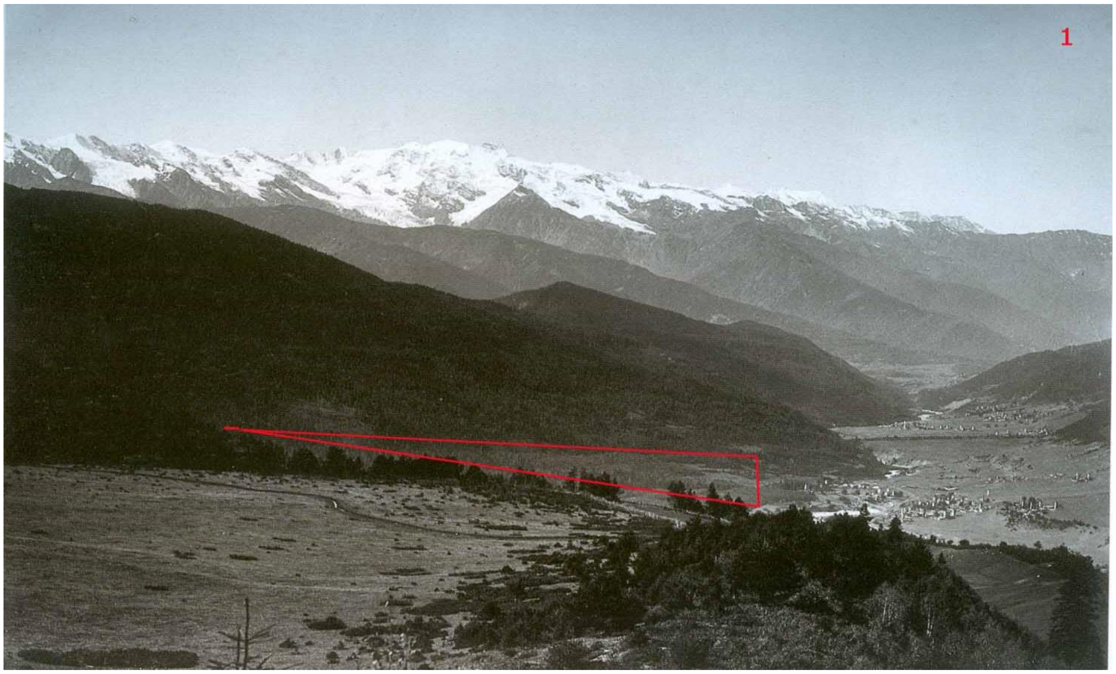


Photo 2.6. View of the Environs of Mestia (Vittorio Sella, 1898-1903).

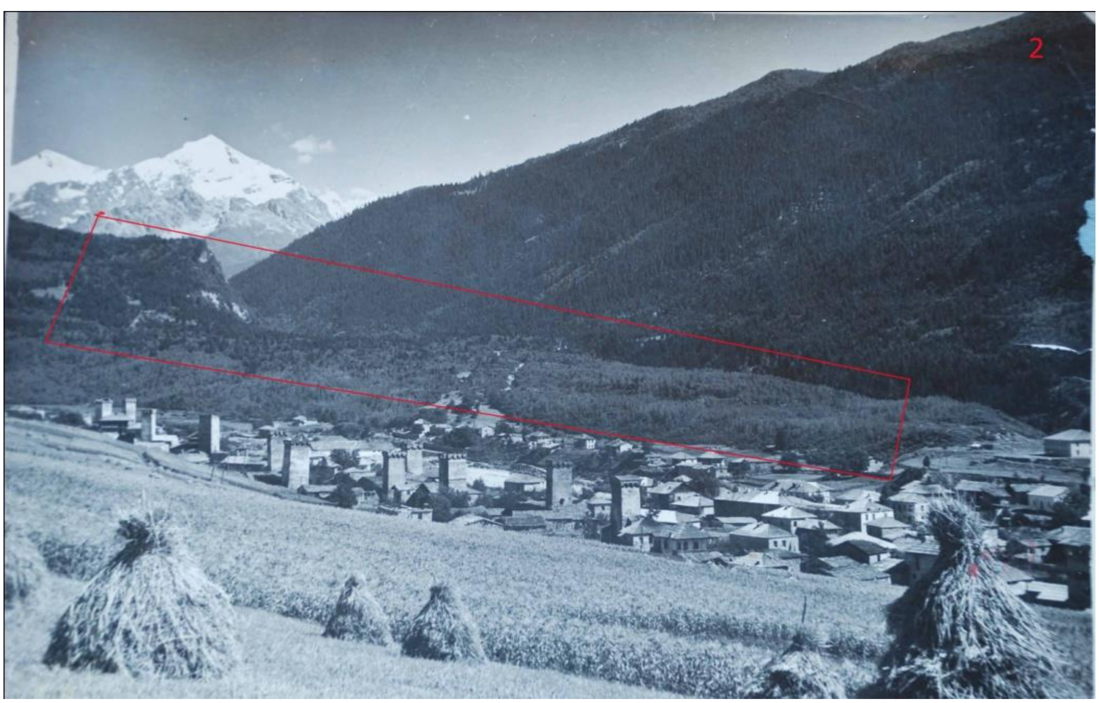


Photo 2.7. View of the Suburb of Mestia (1969)

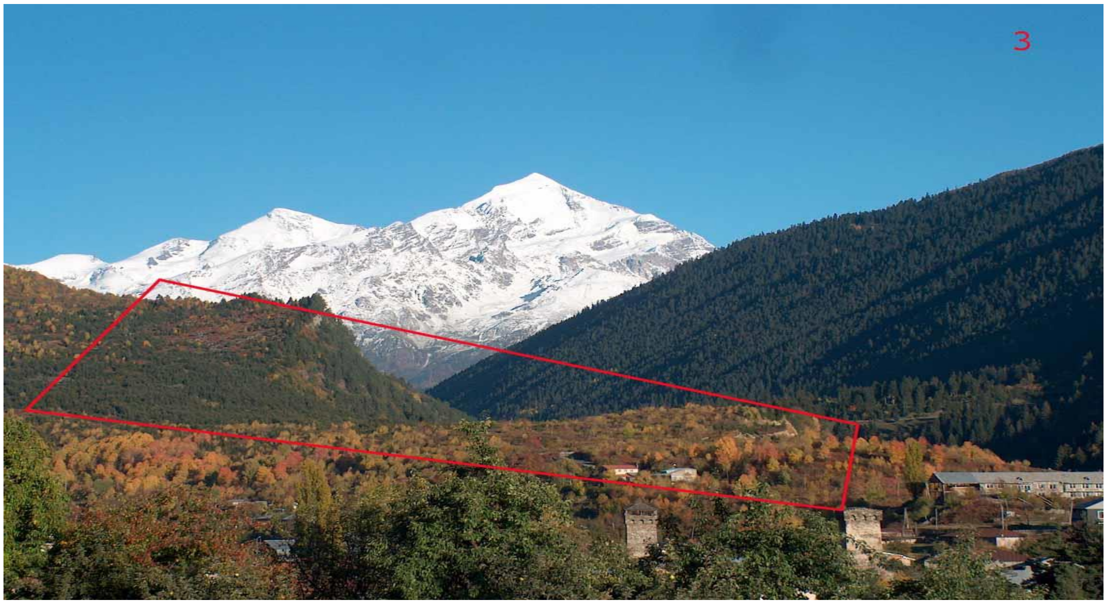


Photo 2.8. View of the same Suburb in 2005.

Borough of Mestia zone includes the Chartolani (Chatvari) forest. The mentioned forest area is located south of Mestia, on the northern slopes a ridge (Photo 2.9). According to the late Mikheil Chartolani (Born in 1898) in early 20th century the above-mentioned slopes were fully covered by broad-leaf forest. Currently, spruce and fir-tree forest is prevalent here. Unfortunately, we were unable to get hold of old photos of this area.


Photo 2.9. Latest view of Mestia environs (2013).

As can be ascertained from the photo materials and various other sources, climate warming has had an impact on the southern forest ranges of Upper Svaneti. Specifically, increased temperatures have had an impact firstly on the habitat of birch forests, since birch tree belongs to boreal forest variety and is characterized by cold, short growing period. Therefore, increased temperature and growing period create stressful conditions for birch tree forests. It should also be noted that there are favorable conditions for birch trees in the alpine zone for shifting its boundary upwards. However, it is necessary to consider impediments as well, such as unfavorable soil conditions and pasturing activity. On the other hand, following warming the favorable conditions will be formed for the forests here, which is expected to facilitate the rise in productivity, density, etc.

In particular, in the sections of alpine zones where the impact of human activity is lower, the forest area will increase, while in the forest ranges located along the alpine pastures, biomass reserves are expected to rise, following the increase of productivity.

The analysis of mutual influence of Upper Svaneti climate change and forest ecosystem has demonstrated that main indicator of impact on forest ranges will be the increase of average temperature and growing period, which will have negative impact in some places, and positive impact in other places of the Upper Svaneti forest ranges.

2.4. The impact of climate change on the intensification of extreme geological processes in Mestia municipality

General overview

A complex of factors -- high energy and geodynamic potential of the highly fragmented relief, complex tectonics and geological makeup, dense hydrographic network, landscape-zonal heterogeneity, local climate-meteorological conditions and human induced impact -- condition extreme development of such hazardous geological processes as landslide, rock avalanche and rock fall, mud flow, water-borne erosion and snow avalanche in Upper Svaneti.

Large part of overall area of the municipality (3 044.5 km^2) is represented by moderately and highly sloping mountainous relief. The range of the variation of absolute heights in the region is 500-5 203, respectively, the difference of the heights is over 4 500 m. With the provided indicator Upper Svaneti is higher than other regions of Georgia, while the summit Shkhara (5 203m) is the highest hypsometric level of Georgia.

Due to small area of the places fit for living, settlements are located in the areas that are not quite safe in terms of geohazard. Majority of settled points are located on the terrace steps and alluvial cones of the Enguri River and its tributaries.

Throughout history, Upper Svaneti has witnessed extreme manifestation of geological processes several times; Such occurrences, unfortunately, were followed by casualties, the ruining of structures, including historical monuments, degradation of the useful lands and consequently – by significant deterioration of living conditions.

In the context of the circumstances provided below the correlation between hazardous geological processes and the demographic situation of the region should be noted – In Upper Svaneti, Eco migration, along with the socio-economic conditions and natural growth, is a significant factor of the demographic situation in the region. Since 1980's to date, due to extreme weather events, up to 1 600 families have left the Mestia municipality. Actually, all settlements of the municipality fall within the zone of hazard of geological processes at varying degrees.

If we look at the statistics of hazardous geological processes (Table 2.13), it is clear that the processes over the past decades have intensified. This cannot be explained by anything else than the global climate change, which is aggravated by human-induced burden on geological environment. The latter is manifested by the intensification of erosion and other geological processes resulting from non-systemic, excessive felling of forests, the use of the slopes for agriculture, cutting off the slopes in the process of construction of motorways and large hydro power facilities, example of which is the Enguri hydroelectric system.

Table 2.13. Statistics of extreme geological events in Upper Svaneti for the period 1960-2013.

Years of observation	Active landslide	Mudflow stream	Rockslide and rockfall	Snow Avalanche	Objects at high risks zone	
					Settlements	Dwelling houses and other buildings
1960-1980	98	NA	NA	>30	>100	NA
1980-1986	12	> 150	NA	მ.ა.ა	>70	NA
1987-1988	148	23	>50	330	>100	>1 100
1989-1991	□49	4	NA	>□0	50	NA
1992-1995	154	>□0	NA	>100	>50	NA
1996□1997	□75	49	47	>50	41	NA
1998	178	>70	51	44	42	>50
1999-2003	NA	NA	NA	NA.	NA	NA
2004	>180	43	41	40	32	180
2005-2006	1□6	>40	>40	NA	27	75
2007	187	>30	NA	NA	2	NA
2008	198	NA	NA	22	31	>50
2009	190	> 30		NA	26	NA
2010	211	46	NA	NA	NA	67
2011-2012	217	>40	14	NA	26	>50
2013	>200	11	14	NA	21	NA

**information source - National Environmental Agency.* *Note:* NA – *Data not available.*

Despite the deficiencies in observations (in certain years no observations – monitoring was conducted), statistics enables to determine trends. Specifically, the cyclical nature of intensity of hazardous geological processes can be observed (1987; 1997-1998; 2004; 2011-2012), which does not contradict with the established general trend – the intensification of the return period of hazardous geological occurrences – the increase in the frequency of such processes. The 1986-1987 winter weather should be mentioned in particular, against the backdrop of which the 1988 situation was more of an aftershock nature. The weather dominated by anomalously high amount of atmospheric precipitation, has virtually totally embraced the Southern slopes of the Greater Caucasus Range. During January –April unprecedented intensity of snow avalanches was observed. According to incomplete data, more than 300 avalanches of various intensity have been observed in settled and adjacent areas, as well as on the roads, causing ruining of residential houses, scores of infrastructure facilities, bridges, etc. Severe weather has also affected historical structures – in Ushguli and Mulakhi Svan towers were destroyed and damaged. The weather has resulted in casualty as well, taking lives of 68 persons. It can be said with absolute credibility, that such an event was unprecedented, which is another argument in favor of climate change process, as of a fact. In Mestia municipality 350 families were evacuated from the disaster zone in 1987-1988.

On Zugdidi-Mestia motorway Khaishi-Mestia section the locations of more or less regular snow avalanches have been identified, numbering between 40-45. The “activity season” of snow avalanches in Upper Svaneti lasts for 4-5 months (December-April) during winter and spring. Before 1987 events, 1976 was also anomalous in terms of extreme snow avalanches, when 360 ha of forest were destroyed by avalanches in Nakra and Nenskra gorges. Relevant climatic data are provided in Table 2.14. Overall, snow avalanches have wrecked and damaged up to 200 buildings in 1976 in Upper Svaneti.

Table 2.14. Seasonal values of 1976 of climatic elements, relative to the 1961-1985 average (Mestia)

1976	Winter	Spring	Summer	Autumn	Annual
Average temperature (^{0}C)	-6.5	4.4	15.0	6.7	5.2
Average temperature of 1961-1985 (^{0}C)	-4.3	5.5	15.2	6.7	5.8
Precipitation sum (mm)	245.7 (198)	211.0 (267)	267.0 (387)	255.0 (202)	978.7 (1 107)
Average precipitation for 1961-1985 (mm)	185.4	235.5	295.7	247.3	961.8

Note: the data in brackets correspond to 1975

Heavy snowfall in the winter of 1986-1987 has stimulated landslide processes in spring and summer; This, in turn, has played significant role in the formation of mudflow currents –the flow of solid material.

The scale of events in 1997-1998 and 2004 was significantly lower. In 1997-1998 atmospheric precipitation was higher than average multi-year value. In 2004 extreme manifestation of geological processes had a local nature and comprised Lenjeri-Mestia, Ipari, Tsvirmi and Mulakhi communities (catchments of the Enguri River tributaries – Mestiachala, Mulkhura and of Enguri) area and it has almost not spread into the "lower zone" of the municipality. In 2004 extreme events (mudflow torrents and landslides) have damaged scores of residential houses, in Ipari community 6 residential houses have practically been fully ruined, extreme weather has claimed the life of 1 person in Village Tsvirmi. In 2006, 2010 and 2011, as a result of heavy rains, powerful mudflow torrents have developed in the gorges of Rivers Nakra and Nenskra. The extreme events of such scale had not been observed over almost 5 decades of the observation, also proven by the survey of local residents and information obtained as a result of visual survey of the territory, dendrochronological dating of the cones of material brought by the mudflow torrents, etc. 2006-2011 climate data are provided in Tables 2.15 and 2.16.

Table Error! No text of specified style in document.**.1. Seasonal values of 2006 climate elements, relative to 1986-2010 average (Mestia)**

2006	Winter	Spring	Summer	Autumn	Annual
Average temperature (^0C)	-4.3	4.5	16.8	6.9	6.0
Average temperature of 1986 - 2010 (^0C)	-4.4	5.6	15.9	7.2	6.1
Precipitation sum (mm)	306	387	221	346	1 278
Average precipitation for 1986-2010 (mm)	241.8	277.6	270.8	271.0	1 058.0

It can be seen from Table 2.15 that in addition to increased precipitation, which has exceeded multi-year average by 220 mm, in summer of 2006 average seasonal temperature, was 0.9 ^0C higher than multi-year average, which would have affected the melting of the glaciers.

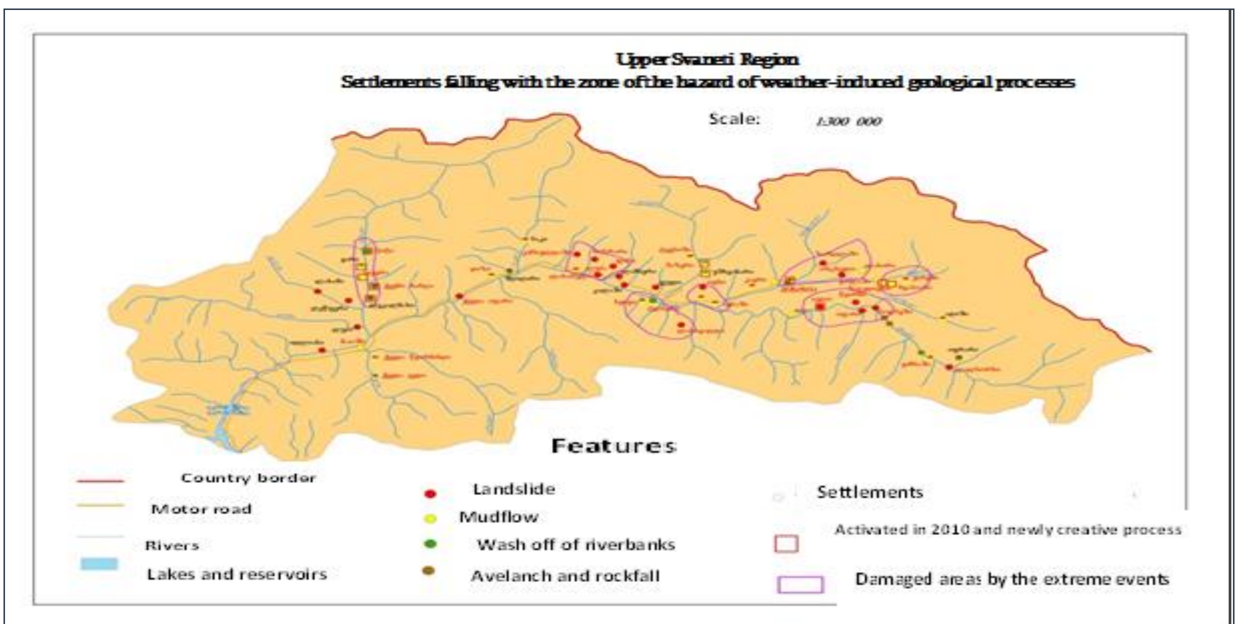
Table Error! No text of specified style in document.**.2. Seasonal values of 2011 climate elements, relative to average of 1986-2010 (Mestia)**

2011	Winter	Spring	Summer	Autumn	Annual
Average temperature (^0C)	-1.5	5.9	17.0	9.4	8.0
Average temperature of 1986 - 2010 period (^0C)	-4.4	5.6	15.9	7.2	6.1
Precipitation sum (mm)	198	337	258	330	1 145
Average precipitation for 1986-2010 (mm)	241.8	277.6	270.8	271.0	1 058.0

Mudflows have developed in River Nakra gorge on the right, western flank of the gorge. The mouths of the tributaries of River Nakri here are located at high levels – above 3 000 meters, and perhaps the melted waters from small glaciers were also involved in the formation of mudflow currents. The mudflows in Nakra and Nenskra gorges have damaged the roads, residential houses and facilities. River Khaishura tributaries are "traditionally" characterized by extreme development of mudflow currents; The same is true especially for the right tributary known as the Black narrow gorge in the mouth of which, in the conditions of tectonic disturbance, the mudflow hotspot of landslide-gravitational genesis made up of grey-blackish clay slates are located – with actually inexhaustible amount of solid material forming debris flows, which is an indication that we should not expect extinguishing of mudflow processes in the near future here. The provided examples can also be considered as extreme manifestation of hazards at the background of climate change, and it indicates to such characteristic as uneven distribution of precipitation and the dominance of torrential rains over other modes of precipitation.

In Mestia municipality, erosive washing off of riverbanks and immediate or indirect damage to motor roads as a result of the above-mentioned is rife. The mentioned geodynamic occurrence was observed in 1982, 1987-1988, 1997-1998 and 2004, as a result of which Zugdidi-Mestia-Ushguli motorway was damaged at 60, 63, 67, 105, 114, 141, 145 and 149-kilometer points.

The map of the settlements falling within the hazard zone of disastrous geological processes in Upper Svaneti gives an idea about the geography of manifestation of extreme weather induced geological processes – the chart as of 2010 (Fig. 2.10). In early 2000's landslide damage coefficient of the Upper Svaneti territory was K_l=0.2, and the coefficient of damage due to mudflow and erosive processes was 0.5-0.6. By 2011 the provided indicators were revised – it appeared that the coefficient of the damage by landslides of the territory shifted above the indicated one and is now in the range of 0.25-0.30.



Source – LEPL - National Environmental Agency.

Fig. 2.10. Settlements in the zone of extreme geological processes (as of 2010)

The list of the sites damaged as a result of weather-induced geological processes in the Mestia municipality is fairly large – it includes residential and economic facilities, agricultural lands, engineering structures, sites of historical importance, etc.

The Municipality does not have accurate register of damages caused by extreme event induced processes over the past 10 years. According to the Municipality Executive office, losses in money terms is about GEL 5 million.

According to the information provided by this office over the past years more than 400 families have been affected as a result of landslides, snow avalanche, mudflows and flash-floods, over 200 residential houses and buildings were damaged, scores of the families have moved to Kakheti and Tsalka municipality.

Table 2.17 provides an indication about the damages and losses caused by extreme geological events observed over the past decades.

Table 2.17. Damaged objects and losses caused by extreme geological events in Upper Svaneti (1987-2013)

Observation period	Extreme events	Damaged objects	Amount of migrant (family)	Approximate direct damage
1987-1988	Snow avalanche, landslide, mudflow, erosion	Dwelling houses - 1 060 Motor road - 70km Bridge - 25	450	120 mln. Rubles
1989 – 1992	Landslide, mudflow, erosion ...	Road - 2.7 Dwelling house -70 Bridge - 6	>300	NA
1992 – 1996	Landslide, mudflow, erosion ...	Motor road - 3.7 Dwelling house >114 Bridge - 9 Arable land >200 ha	>200	NA
1997 -1998	Landslide, mudflow, erosion ...	Road - 4.3km Dwellin house >100 bridge - 8	47	NA 12-15mln. GEL
2004-2005	Landslide, mudflow, Rockfall.	Motor road - 3.6 Dwelling house - 62 Bridge - 8 Arable land -165 ha	>50	
2006 – 2008	Landslide, mudflow, erosion ...	Motor road - 1.7კმ Dwelling house -27 Bridge - 3 Arable land -106 ha	NA	
2009 -2010	Mudflow, landslide	Motor road - 5.2 Dwelling house -26 Bridge - 2	NA	1.0 mln. GEL
2011-2012	Landslide, mudflow, erosion ...	Motor road - 1.5კმ Dwelling house > 20 Bridge - 1	NA	1.0 mln. GEL
2013	Landslide, mudflow, erosion ...	Motor road - 7.3 Dwelling house - 15 Bridge - 7	NA	NA

		Arable land - 120 ha		

** The estimation of the amount of losses resulting from extreme events in the Table is based on various sources of information and the approximation of indicators*

As can be seen from the Table, extreme events in Upper Svaneti region, the intensification of which, against the background of climate change, is becoming more and more evident, is a reality that has to be reckoned with; Therefore, serious efforts are required to minimize impact and to design adaptation activities.

The impact of climate change on exogenic geological processes

Lately alarming changes of natural environment can be observed. Global changes have had its impact on atmosphere, lithosphere, and hydrosphere and, in the opinion of some scientists, the core as well as the mantle of the Earth. These changes have manifested themselves as natural cataclysms, attended by destruction, economic losses and casualties. The rate of global extreme events processes is increasing against the background of anthropogenic loading; This will ultimately have negative impact on the development of the civilization and perhaps it will not be exaggerated to say that at present climate change topic is the most pressing one.

The topic of global warming is being addressed at the local level as well – climate change trends and characteristic values have been identified for Georgia. Climate change forecast covers a 100-year period and principal summarizing conclusion is that by the end of the current century climate in Georgia will be warmer and more arid, but the intensity of atmospheric precipitation will rise and its distribution by seasons will change. Against the background of the above-mentioned, the impact of altered conditions of meteorological elements, especially of atmospheric precipitation, on exogenic geological processes will be more prominent.

Melting of glaciers is the most distinct, obvious indicator of climate change -- warming in Upper Svaneti; Along with natural factors, anthropogenic factor – air pollution is another contributing factor. The trend of the melting of the glaciers – their retreat has been noticeable for at least 100 years, since the period from which observation over the mentioned process has started. Virtually, all glaciers are melting, although in certain years some of them have surged – pulsative dynamics has also been observed.

The glacier's exaration (destruction and removal of rocks) is not only glacial, but also a geological phenomenon. Along with exaration, the so-called glacial mudflows formation is associated with glaciers. The latter phenomena are characterized by unexpectedness and extreme degree of negative manifestation. Glacial mudflows have occurred a number of times in Upper Svaneti and in the context of climate global warming we have to expect "surprises" from those in the future.

The correlation between climate change and the development of exogenic geological processes as well as forecast provided by us below is based on the results of the study performed at the

Hydro meteorological Department of the NEA – "Actual and Projected Values of Mestia Climate Parameters". The mentioned correlation and the forecast of geological processes looks as follows:

In terms of temperature change, the result of the research is explicit – since 1961, average annual temperature has been steadily increasing. The rise in 2010 has amounted 0.3 ^{0}C, which has not had significant impact over the geological processes. According to the forecast, at the end of the 21st century average annual temperature will be 9.8 ^{0}C, which is 4^0 higher than the 1961 value. Temperature rise will drive "continentalization" of climate – the rise of the amplitude of the daily temperatures variation, against the background of which the role of mechanical erosion of the rocks will increase, while the role of waterborne erosion will decrease. The rise of temperature will accelerate the process of glacier melting; Therefore, the formation of glacial mudflows is expected. Mestia climate will become similar to the climate of Eastern Caucasus Range, with relevant characteristic geological processes. The provided scenario of the developments can be anticipated only in case of sharp decline in the amount of atmospheric precipitation (which is not to be expected) and the decline of humidity. However, permanent burst intrusion of humid air masses from the Black Sea may have impact on the retention, and even the rise of humidity.

The observations have shown that the intensity of geological processes observed during 1986-2010 is related to the increase of precipitation in the same period.

Below average annual and seasonal values of temperature and atmospheric precipitation are presented for anomalous years in terms of extreme events (1987, 1988, 1996-1998 and 2004) that were observed within the period of 97 mm (10%) increase of average annual amount of precipitation during 1986-2010.

Table 2.18. Seasonal values of climate elements for the years of eccessive activity of extreme geological processes (Mestia, 1987)

1987					
	Winter	Spring	Summer	Autumn	Year
Average temperature (^{0}C)	-4.1	2.7	15.5	6.2	5.3
Average of 1986-2010 (^{0}C)	-4.4	5.6	15.9	7.2	6.1
Precipitation sum (mm)	461.9	225.2	504.0	187.0	1 378.0
Average of 1986-2010 (mm)	241.8	277.6	270.8	271.1	1 058.0

Daily distribution has shown consecutive 3 days with 22 and more millimeters of precipitation, i.e., at least 66 mm total precipitation and next, further 67 mm precipitation fell in a single day (July 6). This was followed by several consecutive days with daily precipitation of 20-35 mm, which resulted in the events of 1987-1988 (See Table 2.19). 1988 was also quite anomalous in terms of the amount of precipitation.

Table 2.19. Seasonal values of climate elements for the years of eccessive activity of extreme geological processes (Mestia, 1988)

1988					
	Winter	Spring	Summer	Autumn	Year
Average temperature (⁰C)	-4.8	5.2	15.4	5.9	5.4
Average of 1986-2010 (⁰C)	-4.4	5.6	15.9	7.2	6.1
Precipitattion sum (mm)	249.3	193.2	353.2	268.5	1 064.2
Average of 1986-2010 (mm)	241.8	277.6	270.8	271.1	1 058.0

In 1987, as well as in 1988 the abundance of precipitation can be observed, especially during the summer period. In both years, average annual temperature was 0.7 ⁰C lower than average multi-year value and in both years temperature fell in autumn. We have to assume that in this case the melting of glaciers did not have influence on geological processes, unlike 2006, when summer temperature was 0.9 ⁰C higher than average multi-year value. Climate data of Mestia for other years of anomalous intensity of natural geological processes is given in Tables 2.20-2.23.

Table 2.20. Seasonal values of climate elements for the years of eccessive activity of extreme geological processes (Mestia, 1995-1996)

1996 (1995)					
	Winter	Spring	Summer	Autumn	Year
Average temperaturte (⁰C)	-3.4 (-1.50)	7.1 (5.10)	15.5 (14.70)	5.8 (7.97)	6.30
Average of 1986-2010 (⁰C)	-4.4	5.6	15.9	7.2	6.1
Precipitation sum (mm)	136.5 (144)	184.0 (239)	206.0 (276)	246.0 (228)	776.0 (876)
Average of 1986-2010 (mm)	241.8	277.6	270.8	271.1	1 058.0

Table 2.21. Seasonal values of climate elements for the years of eccessive activity of extreme geological processes (1997)

1997					
	Winter	Spring	Summer	Autumn	Year
Average temperature (⁰C)	-3.7	4.5	15.7	NA	NA
Average of 1986-2010 (⁰C)	-4.4	5.6	15.9	7.2	6.1
Precipitation sum (mm)	324.0	248.4	221.0	218.4	1 022.0
Average of 1986-2010 (mm)	241.8	277.6	270.8	271.1	1 058.0

Table Error! No text of specified style in document..**3. Seasonal values of climate elements for the years of eccessive activity of extreme geological processes (1998)**

1998					
	Winter	Spring	Summer	Autumn	Year
Average temperature (⁰C)	NA	7.1	17.8	8.2	NA
Average of 1986-2010 (⁰C)	-4.4	5.6	15.9	7.2	6.1
Precipitation sum (mm)	288	304	138	209	949

Average of 1986-2010 (mm)	241.8	277.6	270.8	271.0	1 058.0

Table 2.23. Seasonal values of climate elements for the years of eccessive activity of extreme geological processes (2004)

2004					
	Winter	**Spring**	**Summer**	**Autumn**	**Year**
Average temperature (^0C)	-2.9	5.3	15.2	7.1	6.2
Average of 1986-2010 (^0C)	-4.4	5.6	15.9	7.2	6.1
Precipitation sum (mm)	191	322	285	258	1 061 (1207)
Average of 1986-2010 (mm)	241.8	277.6	270.8	271.0	1 058.0

Note: 2003 result is given in brackets

Forecast of hazardous geological processes

Based on the forecast data of total annual precipitation and seasonal distribution of precipitation (Table 1.3) it can be said that until 2050, in Upper Svaneti active dynamics of geological processes will continue and the intensification of processes can be projected as a result of impact of various meteorological, as well as non-meteorological, including anthropogenic factors. The scale of negative manifestation of hazardous geological processes in the subsequent period will be consistently large, unless adaptation activities are carried out timely.

In case of frequent, especially in case of mudflow currents and linear erosion, significant condition for the formation of geological processes is peak daily value of atmospheric precipitation that was steadily high during 1986-2010 (Table 2.24).

Table Error! No text of specified style in document.**.4. Actual and projected values of daily maxima of atmospheric precipitation (mm).**

	Winter	Spring	Summer	Autumn	Year
1961 - 1985	38.3	55.0	145.3	71.5	145.3
1986 - 2010	55.3	67.1	67.6	69.9	69.9
2020 - 2050	28.2	76.0	78.3	60.2	78.3
2071 - 2100	39.6	55.7	48.5	68.0	68.0

If we exclude anomalously high value of the 1961-1985 period, the probability of recurrence of which in the nearest decades is fairly high, the scale of manifestation of damages and losses from geological processes during 1961-2010 was adequate to heavy precipitation. According to the forecast, a minor increase of daily maximum is expected until 2050; Based on this we can conclude that meteorological conditions for the formation of hazardous geological processes will be retained and even slightly increased, therefore, considering other “aggravating” factors, escalation of exogenic geological processes is to be expected.

In addition to peak daily precipitation, the number of days with 50mm and more precipitation is important. According to the forecast prepared at the NEA, during the period of up to 2050 this indicator will stay at the level of 1986-2010 – similar occurrence is expected on the average once every 5 years.

Abundant precipitation brings especially grave results in case of torrential rains (According to E. Berg 12 and more mm per hour). Such event took place on July 16, 2004 when during 2-3 hours up to 50 mm precipitation fell on Mestia and Ipari territory, causing formation of landslides, mudflows and erosion processes, destroying of buildings and structures, wiping the plantations on hundreds of hectares and causing casualties.

Based upon actual and estimated data of Upper Svaneti climate characteristics, considering vulnerability of geological environment, nature and trends of exogeodynamic processes, anthropogenic and other factors, we can forecast with high likelihood that over the nearest 4 decades – till 2050 further escalation of hazardous geological processes is to be expected; This, in our opinion, will be evolutionary, unless an unexpected global cataclysm occurs.

Overview of the national legislative framework directed towards the reduction of the risk of geological processes

Over the past period, a number of laws and decrease have been passed in relation to the reduction of the risk of geological hazards. In 1997, Special Ordinance of the President of Georgia (# 66) was issued – "On the Protective Activities against the Development of Hazardous Geological Processes and on the Protection of Lands and Underground Hydrosphere in Georgia. In 1999 the Parliament of Georgia also passed the Law "On the Socio-Economic and Cultural Development of High Mountainous Regions". Furthermore, the Law "On Environment and Soil Protection" was passed where negative role of hazardous processes was mentioned. In 2007, the Parliament of Georgia also passed the Law "On the Protection of Population and Territories from Natural and Technogenic Emergencies".

The problems of managing natural disasters are regarded as a priority direction by the Ministry of Environment and Natural Resources Protection and in the Second National Environment Action Plan (NEAP) Programme.

The above-mentioned legislative documents virtually havea declaratory nature. As for the legislative framework directed at the reduction of risks of extreme events, it seems that here there is a gap.

During natural disaster municipality executive offices, or Regional Administrations of state trustees of the President of Georgia, based on an act prepared by them through the commission rule, provide information about losses to the Prime Minister of Georgia, or to the Regional Affairs Department of Government Chancellery.

Assessment of material damages caused by extreme event depends on the initiative and activeness of local authorities. Information about the amount of estimated losses is sent to the Government that takes the decision whether or not to reimburse losses. There is no normative act regulating the procedures of assessing the losses caused by extreme events in the legislation of Georgia, therefore, response is ad hoc and the implementation of specific activities is delayed.[13]

The role of local self-government bodies in minimizing extreme event and its impact is not adequately regulated by legislation in the Republic.

Any citizen is authorized to defend own life and health from natural disasters and demand from the state guarantee of security, and the state is required to develop relevant legislation and implement it into practice. In Georgia, the protection of population against natural processes is the prerogative of a structural unit of the Ministry of Interior – Emergency Management Department. The indicated Department is required to coordinate the activities of liquidation of emergencies and mitigation of their results, carry out rapid response to emergencies via rescue units.

The Ministry of Environment and Natural Resources Protection is a government body of the Executive Government that is in charge of state governance in the field of environment. Along with other authorities, the scope of the Ministry includes monitoring, forecasting of natural and anthropogenic disasters, and coordination of planning and implementation of preventive activities. National Environmental Agency (NEA) conducts regional, non-instrumental observation – monitoring of hazardous geological processes at the territory of Georgia, and naturally, over the area of Mestia Municipality; The results of monitoring are summarized in annual newsletters and are provided to regional administrations for guidance. NEA is a leading chain among the agencies of the Ministry of Environment and Natural Resources Protection. It is responsible for the development of recommendations for the reduction of risks of natural disasters.

The development of the National Plan for the prevention of natural disasters, including of hazardous geological processes, is the most important, pressing objective across the country.

According to the legislation of Georgia, local self-government bodies are responsible for developing local environmental action programs[14]. Actually, none of administrative-territorial units –municipalities has developed such programs to date.

[13]Government of Georgia under the baking sun", 2006, # 5, (in Georgian).

[14] Institutional strengthening for the reduction of the risk of natural disasters in Georgia. Guidelines for the assessment of risks of geological and hydrometeorological threats and for considering those.

In our opinion, efforts for the reduction of the risk of hazardous geological processes – natural disasters should in the first place be directed at:

1. The development of a monitoring network and orderly early warning system and modification of the existing one, for which the experience of leading countries should be used;
2. It is necessary to prevent and reduce the risk factors causing hazardous geological processes;
3. It is necessary to create the units for effective response over hazardous processes, – rescue teams, staffed from professionals, including at the level of municipalities, and involve volunteers, as of a reserve force in the activities directed at the elimination and minimization of the impact of natural extremes;
4. Georgia, and in particular Mestia Municipality, the most difficult region in terms of manifestation of hazardous geological processes, is so susceptible to natural disasters that it is necessary to increase the level of readiness, therefore it would not redundant if a relevant subject is introduced in the educational system within schools;
5. The process of managing hazardous geological processes in the Republic is distributed among various agencies of the executive government, which, given weak coordination (which is unfortunately the case) complicates the development of a unified vision in the management of hazardous weather processes. Therefore, it is necessary to further improve coordination. The same issue is urgent and should be refined in the relations between the Mestia Municipality and the Government agencies – Ministry of Internal Affairs Emergency Department and the NEA – a structural unit of the Ministry of Environment and Natural Resources Protection.

Since 2000's the transfer from the mode of the Rehabilitation of the results of and Response to Natural Disasters to the mode of Risks Management and Mitigation has come to the forefront in the matters of the reduction of the risks of hazardous processes. The approach according to which the focus was primarily made on hazards, their causes and risk reduction has also been modified. Currently the focus is placed on the reduction of vulnerability of the population to risk and readiness to respond to threats.

International Strategy for Natural Disasters Reduction (ISDR) underlines the necessity to move from the mode of bottom up management of natural disasters and rehabilitation and readiness cycle to such complex approach that envisages the prevention or mitigation of risk prior to a natural disaster and at the same time facilitates raising the level of awareness and responsibility of the public. The latter concept is referred to as Risk Management Cycle, or a Spiral, as part of which, at the example of natural disasters, in our case, of hazardous geological processes, we can not only restore ecosystem and environment to the original condition, but also adapt and modify it.

2.5. Impact of Climate Change on Historical Monuments of Upper Svaneti

General Overview of the Impact of Climate Change on Cultural Heritage

An assessment of the impact of climate change on cultural heritage started in the 90s of the XX century. Climate change related problems and methods of their solution are envisaged in every international World Heritage Convention.

Climate change could lead to:

- Changes in air temperature and humidity;
- Intense rainfall;
- Changes in water levels;
- Changes in the chemical composition of soil;
- Changes in groundwater;
- Changes in humidity cycles;
- Dampness of walls, resulting in a change of porosity of building materials;
- Inorganic and organic erosion increased as a result of the flood;
- Corrosion of metals;
- Daily and seasonal change, strengthened extreme events (heat waves, snow load);
- Increasing winds;
- Desertification.

All of the above will directly affect the cultural heritage. Currently, several World Heritage monuments are under threat. Some of the threatened monuments are the Palace of Westminster in London, Westminster Abbey and the Tower of London. Observations revealed that sea levels are rising and will result in flooding of the River Thames and these monuments. Therefore, it was decided to build a protective barrier. Another endangered World Heritage monument is the Chinguetti Mosque, which is located on the border of the Sahara Desert. Frequent floods, followed by droughts, severely damage the archaeological monument and its surrounding area, as well as the mosque's construction materials. For determining the impact of climate change first of all it is necessary to conduct a complete survey. In Cambodia, a stone diagnose carried out with laser scanner at the Angkor architectural complex determines even a slight stone variability throughout the year. Chan-Chan complex in Peru is included in the list of the endangered World Heritage Sites by UNESCO because of the damage inflicted by heavy rains as a result of climate change. Temporary roofing was arranged at the complex. Past researches demonstrated that a temperature increase by 1^0C endangers more than 150 sites from more than 700 monuments included in the World Heritage List. In Georgia, clear manifestations of damages caused by climate change could be seen on the Holy Cross Cathedral in Mtskheta. The temple is adorned with several relief images. Almost all of the reliefs are well-preserved on the photographs taken in the beginning of the XX century. Frequent winds and acid, increased rains led to the collapse and deflation of the reliefs. Conservation works on the eastern facade of the relief was going on for few years and were completed last year.

Upper Svaneti Cultural Heritage: General Characterization from XX Century to the Present

The study of the cultural heritage in Upper Svaneti started from 40-50s of the last century. There are also old, XIX century photos taken by Georgian and foreign travellers, which provide important information about the condition of the monuments at that time. On Vittorio Sella's photographs, which he took in 1889-90, towers, churches and conditions of houses are seen very clearly. Most of the tower roofs were not repaired. The houses had better roofing and they were in good condition. The churches were covered with damaged shingle. A photo of the northern facade of Lashtkhveri church is interesting. It depicts Amirani's battle with giants. The western facade depicts the prayer composition. It should be noted that compared with the present situation, the color of the painting was relatively sharp. Today, figures of the west facade are also almost invisible. It should be noted that most of the machubis (first floors of old Svanetian houses) and other buildings depicted on the photographs taken by Sella no longer exist today. They were sacrificed to the construction of new apartments in the communist period. The local population abandoned machubis and old housing complexes, as a result of which they slowly fell apart. Today it is possible to see a lot of ruins of these old houses even in Mestia.

We do not have information about the monuments restored in Svaneti in the second half of the communist era. Taking care of the cultural heritage in Svaneti only started in 1970-80s of the last century. Of course, the population was probably repairing their towers and machubis on individual basis.

In the abovementioned period, mainly the churches and the towers were restored by the state. Mainly roofs were replaced and shingle was replaced with tin.

Geographical and Cultural Conditions

Peculiarities of the terrain in Upper Svaneti created special conditions for the development of culture and the preservation of cultural heritage in this region since ancient times. Upper Svaneti is surrounded by high ridges. The height of these mountains reaches 4 000-5 000 meters. The ridges are covered with permanent snow and glaciers and non-transportation passes on them are located at the height of 2 600-3 100 meters. They operate for less than 5 months per year. The only road that connects the region to the outside world runs along steep rocky slopes of Enguri Gorge and its length from Zugdidi to Mestia is 138 km. Recently, the second road - Tsageri-Lentekhi-Ushguli-Mestia was built via Lower Svaneti. It passes Svaneti Ridge at the height of 2 623 meters and is open only from June to October.

The region covers an area of 3 044 km^2. An average elevation is 300 m^2 above sea level. 135 villages or 17 communities are located in the region. The height of the villages changes from 510 meters (Idliani) to 2 200 meters (Ushguli) and most of them are located in the 1 500-1 800 m altitude zone. The regional center – the borough of Mestia is located at an altitude of 1 440 m in the hollow of the upper part of Enguri Gorge.

The climatic conditions in Upper Svaneti are quite severe. Winter continues for 6 months in the most part of the territory, the minimum temperature drops down to -35 ^{0}C and the average thickness of the snow cover is 1 meter. Another fact demonstrates severity of the climate, namely, glaciers in Upper Svaneti hang down to 1 900 m in some places. On average, they are located at the height of 2 400-2 600 meters. The height of the upper boundary is changing within 3 900 - 4 300 m in most cases.

The data indicates that the natural conditions contribute to the isolation of Upper Svaneti from other regions of Georgia and the neighbours bordering from the north. This has laid the groundwork to create a unique local culture that, at the same time, developed under the influence of processes taking place in Kolkheti. From V-VI centuries, following the establishment of Christianity in Svaneti, the construction of churches and other religious buildings started actively, which lasted until the late Middle Ages. Temples built in Upper Svaneti, because of the region's difficult access, was used for storing and protecting Georgia's national treasure from enemies threatening other regions of Georgia. This led to the accumulation of a large number of treasures of the national culture in the region, which along with its original architectural monuments in fact determines a status of historical and architectural reserve of Upper Svaneti.

As in the other regions with rich historical past (Egypt, Greece, Italy, India, China, etc.), the climatic factors and the extreme weather events in Upper Svaneti (avalanches, landslides, mudslides and abundant precipitation) have negative impact on the historical monuments, they cause their collapse and dissolution. The process is accompanied by an anthropogenic pressure (increase in the rain acidity, the construction of reservoirs, deforestation, road construction, increasing numbers of tourists and etc.) and the condition of the monuments are deteriorating. Along with the religious (cult) facilities, Upper Svaneti is also rich with secular architectural monuments characteristic for this region of Georgia (towers), which, because of their identity have a great ethnographic value. Naturally, the climatic factors are also negatively influencing these monuments.

Historic Monuments

The populated areas of Upper Svaneti are characterized by different climatic features because of the great diversity of the terrain. In terms of the climate change and its impact on historic monuments of the region, Mestia Municipality is currently divided into 3 zones that are located at different heights above the sea level and at different distances from the sea and the Enguri HPP reservoir.

The first, the highest zone, is located at the altitude of 1 500-2 180 m and is 165-210 km away from the seashore. It includes 4 communities - Ushguli, Kala, Iphari and Tsvirmi. 385 monuments are registered in the zone, including 42 religious, 330 secular and defense and 13 archeological monuments. The villages in the zone are characterized by dry and relatively warm climate, which are determined by their well-chosen locations. Except for the monuments ruined because of antiquity and neglect, their condition in the zone is assessed as medium, although a lack of roofing had its impact on many of the monuments and for this reason many of them are falling down and collapsing. This does not apply to the churches, which are kept in good condition and mural paintings in most of them are well preserved. A lack of care had the most significant impact on the serious condition of these towers, which was determined by a shortage of timber because of its remote location and distance from the alpine zone.

The second, the zone of the average height is located at an altitude of 1 350-2 020 m, 150-180 km away from the seashore. This zone is the most densely populated and it includes 8 communities: Mulakhi, Mestia, Lenjeri, Latali, Tskhumari, Becho, Eceri and Fari. 573 monuments are registered in the zone, including 153 - religious, 404 defense and secular and 16 archeological sites. The condition of historic monuments in different communities differs from each other. Namely, the majority of the churches in Mulakhi, Mestia, Lenjeri and Latali communities has roofs and is well preserved. Towers in Mestia and Lenjeri communities are also in good conditions, although it is necessary to restore and preserve Svanetian hall-type houses on the territories surrounding the towers for ensuring integrity and improvement of the Svanetian complexes.

Churches in Tskhumari and Becho communities are less taken care. The majority of the towers does not have roofs and is damaged. Churches in Eceri and Fari communities are in more severe conditions, a lot of churches in Fari Community are already in ruins. The same situation is regarding the towers, the majority of which require restoration.

The third, the low zone, is located at the 500-1 500 m above sea level and is the closest from the sea shore (80-150 km) and is 0-55 km away from Jvari Hydro Reservoir.

It includes 5 communities: Lakhamuli, Nakri, Chuberi, Khaishi and Idliani. The zone is the least rich in the heritage: In all, 62 monuments are registered here, from which 18 are religious, 19 defensive and secular and 25 archaeological monuments. The main part of the material monuments on the territory is turned into ruins or archaeological monuments. The examples of tower architecture survived in relatively high area of the zone. The churches are preserved without frescoes. The existing situation in the zone seems to be determined by 2 factors: It was the most accessible for invaders and enemies who did not spare historical monuments. In addition, its proximity to the sea and over the past decade to the reservoir determined high air humidity, which accelerated deterioration of their conditions. The majority of the historical monuments in the third zone include remnants of the fortifications facilities and metallurgical enterprises of the antique period.

Thus, a total of 1 020 material cultural monuments are registered in Upper Svaneti, from which 213 are religious and 753 are defense and secular monuments.

A large part of the churches in the high and middle zones are kept well, but the towers require restoration. The latter can be explained by the fact that in recent decades the population mostly moved to more comfortable homes, the towers lost their basic functions and attention towards them faded. Roofing is the main problem of the monuments - rain and snow are damaging interiors of the churches, as well as the tower walls.

It is also noteworthy that only a small part of the monuments are damaged by natural disasters (snow avalanches, landslides, mudslides, snow) as the population selected the areas for them, where risks of natural calamities were minimal. The construction of the monuments and especially the Svanetian towers can withstand the devastating impact of the big snow and avalanches.

Influence of Exogenous Geological Processes on Upper Svaneti Historical Heritage Facilities

The area of the influence of natural geological processes covers the territory of Upper Svaneti. Obviously, natural processes developed in the historical period to some extent affected cultural monuments, namely, the Svanetian towers and living houses - machvibis (machubis).

The Svanetian towers are distinguished by their original design - the foundation is a layer of large stones pulled out horizontally to tower walls by a few dozen centimeters that are deepened in the ground from the surface at the maximum of 1.0-1.5 meters so that the center of gravity of the building is located in the lower point of the symmetry axis.

The tower is monolithic from the foundation to the height of 4-5 m and represents a layer of the large unprocessed and poorly treated, preferably naturally smooth solid rock boulders connected with lime mortar.

The tower height as usual is equivalent to the quadruple size of the wall length on the level of the surface and varies in the range of 16-24 meters.

After the monolithic part of the tower wall, the wall width is approximately 1.0 m. The wall thickness is reduced with the height. Traditional houses-machvibis are 2, rarely 3-storied capital structures, which also served as an animal shelter. The Svanetian tower is attached to the machvibi or is away from it by just a few meters.

From the geological processes, in terms of the scale of the negative impact on Upper Svaneti's historical heritage monuments, the earth's interior and endogenous expression of power in the form of seismic earthquakes is distinguished by its scale.

In the past, Svaneti many times was at the epicenter of earthquakes. Transit earthquakes had an impact on the historic monuments of cultural heritage. In Upper Svaneti they were manifested with an intensity of 5-6 magnitude.

Despite the fact that the epicenters of the latter, as it was the case with the earthquake that took place in Racha in 1991, was the adjacent regions of Upper Svaneti, they left significant footstep on the historical monuments of Svaneti. Except for the direct damage, the buildings damaged by seismic strikes became vulnerable towards exogenous geological and geological-hydrometeorological processes – snow avalanches.

Crack extensions emerging on the Svanetian towers and walls of houses as a consequence of the seismic strikes and further weakening of the building walls until their collapse is a result of the weathering, the exogenous geological process.

Many examples of damaging the Svanetian towers and the residential buildings as a result of the natural geological processes can be brought - in fact there is no historic settlement, which does not have the damaged tower or traditional house. Often towers on the slope were constructed in such a way as to prevent frontal blow of snow avalanches.

The most often reason for the damage of the towers is erosive processes produced by water flows emerging as a result of rain and melting snow on steep slopes. Often flows during heavy rains turn into streams. We can mention Chartolani ancestral tower in Lekhtagi District in the borough of Mestia as an example. In 2008, the studies conducted within the framework of "Mestia Towers Rehabilitation Project" identified that during the centuries-long existence period, as a result of the influence of erosive and accumulative processes going on the slopes, the tower walls, 3 meters from the foundation are covered by gravel-clay soil brought down by erosive-mudflow processes from the slopes. This fact indicates the pace of accumulation in anthropogenically altered environments. On the basis of artifacts found in the cultural layer, the layer was dated and more than half of the total capacity of the layer was considered as the 20th century formation.

The events similar to the above-mentioned processes took place on the territories of Akvsdaba, Mestia, Lanchvali and Laghami. With high probability, mudflows should be considered as the reason for the damage-the destruction of one of towers in Laghami. The processes similar to the developments in the borough of Mestia are also takin place in Latali, Eceri, Lenjeri, Mulakhi, Kala-Ushguli and other settlements.

Intensification of disastrous geological processes caused by climate changes in recent decades, manifested by natural calamities taking place in 1987, 1997-98 and 2004, increased the risk of the damage to the historical monuments.

In winter of 1987, the area was covered with incredible amounts of snow. Snowslips virtually flew down from slopes in all gorges. They along with other buildings also damaged the Svanetian towers and the old traditional houses-machvibis. Ushguli and Mulakhi communities were especially hit - almost no house remained intact in these communities. The towers were damaged or destroyed in Murkmeli and Jamushi and houses were massively damaged throughout all valleys.

In the conditions of global climate change, which in Upper Svaneti, according to the forecast will be characterized by the increase in the average annual and the amount of daily maximum precipitation until 2050, an increase in the scale of mudflows and negative influences of erosive processes on slopes is expected. Because of this, the risk of the damage to the towers and other historical buildings will be increased, which determines the necessity to approach the issue with more responsibility and the actuality of developing the plan of preventive measures.

Impact of Climatic Conditions on Architectural Monuments

Harsh weather conditions in Upper Svaneti forced local architects to maximally take into account the impact of climatic factors on architectural monuments. The fact that IX-X century churches have been preserved in the region indicates that the architects managed well their tasks. It should be also noted that for the last 12 centuries the climate of the Northern Hemisphere has experienced major changes: Warming in X-XIII century (so-called "Viking Era") was followed by chilling XIV-XVII centuries (so-called "Little Ice Age"), which then, from the XIX century has been replaced by a gradual warming. However, beginning of the 1970s, the pace of global warming significantly exceeds the previously estimated all warming rates.

Churches

In the Upper Svaneti churches, as well as in other buildings, walls are built with well-hewed bladder stone quadros, as well hewn stones trimmed and bound with lime mortar. Climate variability, frequent winds and rains in the first place affects the lime mortar, leading to its dissolution and collapse due to increased exposure to moisture.

Humidity greatly affects internal church frescos, so attention during the repair or the restoration of the monuments should be mainly paid to the enrichment of the lime solution with modern admixture that increases its sustainability, to applying modern technologies for roofing in a way that they do not violate the monument's authenticity and to arranging drainage systems around the monuments for reducing moisture of the wall from the ground.

It should also be noted that shingle is used for roofing the churches and the machubis in Svaneti, however, slate is also widely used in Ushguli Community. Both shingle, as well as slate is one of the oldest materials used for the roof cover arrangement in the mountainous areas of Georgia. Such cover is also very practical during snowfalls - its surface is flat and slippery and the snow hardly stalls on it. If tiles commonly used in the plains were used here, it would substantially harden the construction and snow would not slip on it nor would its cleaning be possible.

The examples of the churches and their interiors are given on the Photo 2.10.

Nezguni Church in Lenjeri community (IX c.), Chvabianis "Savior" in Mulakhi Community (IX-X cc.) and Matskhvarishi "Savior" (X c.) are some of the earliest churches in Svaneti. The churches were built with well-hewn pumice quadros.

The construction of the churches is quite strong, so they almost invariably survived. Only the roofs were changed. In recent years Chvabianis Church underwent restoration - new floor was made and the drainage system was built around the church which removed water from the walls of the temple.


Photo 2.10. Church Monuments of Upper Svaneti

The analyses of the existing churches demonstrated that the functioning churches in the region do not require any major structural reinforcement. Restoration works carried out in 70-80s of the last century and also during the last few years included the roof replacement and the repair and the construction of the drainage system for protecting the building from moisture.

Matskhvarishi, Laghami, Lashtkveri, Ifrali, Fuzdi and other churches were restored in this period. These measures have significantly contributed to the preservation of the churches, but the weather conditions and the climate change still had a noticeable impact on the temples, on their wall paintings and religious objects and icons stored in the churches. Namely, Ifrali façade painting was much better preserved in 1940-1950 than it is today. The situation is the same regarding the Laghami Church facade.

Interior paintings are significantly damaged in Chvabiani Savior and Taringzeli churches in Ienashi, Ifkhi and Chvabiani communities. Paintings blackened from moisture and moved from wall surface.

It is also noteworthy that a lot of medieval easel or embossed icons are stored in the churches of Svaneti. Due to the absence of microclimate control devices, metal corrosion is frequent in the churches. Sharp climate variability damages both the metal and also the paint of the pictorial icons. During cooling-warming paint is compressed-expanded, as a result of which paint can be removed from the surface and collapse.

Thus, it can be said that the condition of the artworks in Svaneti has worsened in comparison with the previous century. Although an increasing number of restoration works going on in recent years are directed at stopping these processes and preserving the cultural heritage.

Conservation of historic monuments and related works shall be even more enhanced in this century, as effects of the global warming and extreme events caused by the climate change are becoming more frequent. The experience gained by other countries in similar geographical conditions should be also taken into account.

Towers

Svanetian towers are playing an important role in creating an artistic and architectural face of Svanetian housing. Currently, there are about 250 towers in the region, many of which are located in zones I and II.

The Svanetian towers are square, powerful, vertically developed monumental buildings, narrowing in the upper part. The tower has mainly 4-5 floors. In most cases the last floor is completed with crown hat-arched hems (Photo 2.11).

Photo 2.11. Svanetian Towers

Despite the obvious defensive function, in case of the danger, the tower sometimes even combined the functions of the house and the stall. Now it is mainly used for household purposes, but still has not lost its symbolic value and represents pride for each family.

As explained above, the tower walls are built with smooth solid rock boulders connected with lime mortar and with mixed large-sized boulders, sand and cobble-stone quadros in the lower part.

This construction material is very resistant to the climate changes. The tower bottom is a single monolithic volume of about 3-4 meters in height and ensures its seismic resistance, as well as resistance against avalanches.

Two-force tower roofing is arranged on timber beams. Traditionally, birch plaits and then roofing cover (slate or shingle) was coated on a wooden structure. Now, under this roof, which preserves authenticity of the tower, tin coating is built. In case of shingle damage, this latter protects the structure from leaking water and significantly increases the exploitation term for the roof. Nevertheless, the recent renovation and restoration methods give preference to the authenticity of the monument and the use of traditional materials.

Because of a lack of maintenance and frequent rains, shingle and wooden beams are frequently rotting, walls are damped and collapsed. There are cases when the tower is damaged not from above, but as a result of damping the foundation. Studies conducted in recent years demonstrated that many of the tower foundations are quite damped. In this case it becomes necessary to study the geology of the tower and the remove water with the help of the drainage or other methods.

Machubi and Castle-House

Matchubi is the stone-built, two-floor building, rectangular in most of the cases, which was used for living, as well as the cattle shed in the winter. The castle-house or turret Svanetian house is only found in Ushguli. The castle-house is the three or four story building, usually larger than tower. The first floor is the ordinary machubi with the hearth and the cattle shed. The middle floors are halls, while the last floor has the defensive function. The castle-house combines the functions of the defensive fortress and the residence and is a highly compact and efficient structure. As in the case of the tower, also on this type of buildings, the impact of climate is reflected on damping of the walls and the collapse in case of roof damage, which accompanies the foundation moistening.

Conclusions

The brief review above gives a possibility to make the following conclusions:

- A major reason of the damages of the churches in Upper Svaneti is moisture affecting both the building materials-stone and its bonding lime mortar, as well as the church paintings. Dampness primarily affects the wall-painting, leads to the removal of plaster from the wall and the collapse of the painting. The color of the painting is also tarnished and blackened. In addition to the interior, the climatic factors destroy decorations of the exterior walls and painted sculptural elements, with which Svaneti's historic facades are rich.
- Moisture and snow are mainly threatening the facade paintings. Observations revealed that the physical condition of the Laghami Church façade painting deteriorated in the 80s of the last century: After filling the Jvari Hydro reservoir, humidity sharply increased in Svaneti. The same thing happened in case of the paintings of Lashtkhveri and Ifrali churches.
- During the heavy snowfall in the region in 1980s snow reached 2 meters. Snow covered the walls of many churches and heavily moistened them. In order to prevent such accidents, it is recommended to construct the protruded roof in the churches with the façade paintings so rain and snow damage less their decorative elements.
- It is recommended to construct the drainage system for reducing moistening of the walls from the ground surface;
- Also in case of the Svanetian towers, precipitation and humidity pose a major threat to these structures. In case of damaging the roof, the tower walls damp and collapse. The result is the same in case of moistening the tower from the ground surface. In this case too, constructing the drainage system gives the best outcome.
- In order to prevent/minimize climatic elements and the harmful effects of the climate change on the Upper Svaneti cultural heritage monuments, it is recommended to prepare an adaptation project proposal with an aim to introduce new technologies along with traditional methods, which shall include the experience of cultural conservation of the country with similar geographic conditions and the rich historical past.

In general it can be concluded that currently the large part of Svaneti's cultural and historical heritage monuments is in poor condition. Systematic and qualified restoration, conservation, scientific research, fixing and certification do not take place. In order to solve this problem it is necessary to:

- Register the movable and immovable cultural heritage sites, as well as the intangible cultural heritage monuments on the territory of Mestia Municipality and determine their historical, scientific and artistic values and archive the obtained results;

- Train the local staff in the field of cultural heritage;
- Develop research and rehabilitation projects for the cultural heritage monuments and programs for the protection and conservation of monuments;
- Develop cultural, educational and tourist programs;
- Prepare proposals for granting the status of the cultural heritage monument and submit them to the relevant competent authority;
- Support small businesses producing authentic local materials necessary for the restoration (lime, slate, shingle and other materials);
- Establish the on-site restoration and research laboratories that will cooperate with analogous laboratories functioning in the developed countries with extensive similar experience in this area.
- Establish the Svaneti Cultural Heritage Development Fund, which will attract donors for implementing specific projects.
- Establish the constant/continuous monitoring system of the cultural heritage facilities;
- Systematically organize national and international scientific conferences in Mestia.

2.6. Impact of Climate Change on the Health Sector

Climate Change Specificities in Mestia District

Results of the study conducted within Georgia's Third National Communication to the UNFCCC revealed that the frequency of climate-dependent diseases, such as injuries, pathologies of the cardiovascular and the respiratory systems, mental disorders increases in Upper Svaneti and specifically in Mestia Municipality. The reason of such changes may be the change in climate parameters, namely: The average annual air temperature at the beginning of the current century in comparison with the previous century (the average values of the years of 1986-2010 are compared with the same figures of 1961-1985 period) increased by 0.3 ^{0}C, the annual amount of precipitation increased by 10%, while the total number of hot days during the 25-year period, when the air temperature exceeded 25 °C, increased by 178.

In addition to the change of specific climate parameters observed in Mestia Municipality, the increase in intensity of natural disasters-extreme geological processes was also observed.[15] One of the main reasons for this is melting of glaciers due to the high temperature, which stimulates geological hazards, such as floods and landslides. The increase in the intensity of natural disasters, in turn, adversely affects the health sector: The medical infrastructure is disintegrated, the increasing number of natural disasters increases the frequency of disease incidences, the number of ecological migrants also grows, which lies as a heavy burden on the healthcare system.

[15] Report: "Natural Geological Processes in Upper Svaneti," Ilya Chkheidze, 2013

Another indicator that has been identified within the project and allows to assess an importance of a comfortable climate for health is the Tourism Climate Index (TCI). It is a complex indicator and includes 7 climate parameters.[16]

The TCI for Mestia municipality varies slightly. According to the analysis conducted for the period of 1961-2010, the maximum TCI in Mestia is observed in August, September and October, when it reaches 80. A potential of tourism and recreational resources is "very good" in this period. The lowest index - 31 is observed in December, which is consistent to "unfavorable" conditions. Nevertheless, experts agree that the potential of tourist and recreational resources in Mestia is sufficiently high at all seasons and there are conditions for developing the mountain tourism in winter.

Impact of Climate Change on the Health Sector in Mestia

The World Health Organization (WHO) designed a list of diseases that are particularly related to climate change. These diseases are called the climate-dependent diseases, namely: Infections transmitted by water, food and insects/animals; diarrheal, cardiovascular and respiratory diseases, diseases caused by extreme events are listed as a separate group of diseases (including trauma, post-traumatic mental disorders and infection outbreaks), abnormal conditions caused by extremely high temperatures and heat waves.

The climate change already observed in Upper Svaneti during the recent decades allows to evaluate with a first approximation the impact of the change of individual climate elements on the spread and the frequency of diseases listed above, as well as their projected trends in relation to the expected climate change in the current century. The obtained results should be considered in the future healthcare plans of two priority sectors for Upper Svaneti - tourism and the development of the health sector.

Vulnerability Assessment Methodology

In order to assess vulnerability of the health sector to climate change in Upper Svaneti, the following areas were reviewed:

- Assessing the level of climate-dependent diseases;
- Assessing the potential of the healthcare sector (infrastructure, as well as the medical staff);
- Risk assessment – highlighting risk factors that increase the region's vulnerability to climate change.

[16] The index contains a combination of seven parameters, three are independent components, while the other two is a combination of bio-climate components. TCI = 8•Cld + 2•Cla + 4•R + 4•S + 2•W, where Cld is a daily comfort index, which contains the average maximum air temperature - Tmax (°C) and relative low humidity - Fmin (%), Cla - is the daily comfort index, which contains the average air T (°C) and relative average humidity f (%), R - is precipitation (mm), S - sunshine duration and W- is the average wind speed (m/sec). Unlike other climate indices, TCI is graded.

1) Medical statistics[17] (2002-2011), 2) the meteorological observation data[18], 3) special questionnaires were developed for physicians and 4) verbal autopsy (interviews) were used to assess the vulnerability of the sector.

Climate-Dependent Diseases in Upper Svaneti

By taking into account the survey conducted within Georgia's Third National Communication to the UNFCCC, non-communicable diseases, including injuries should be mainly considered relevant for Upper Svaneti from the climate-dependent diseases. From the chronic pathologies - mental disorders, cardiovascular diseases (especially hypertension), respiratory diseases and the number of death caused by them should be mainly considered relevant. The incidence and the prevalence[19] of these pathologies in Upper Svaneti region exceed the same data from other regions of Georgia. Among morbid conditions listed above, traumas are among the most common and troublesome and therefore, will be discussed in a separate section.

The prevalence of transmitted diseases (infections) is high in Upper Svaneti, the dynamics of the increased frequency is also observed, although the rate still cannot be considered as alarming at this stage.

Prevalence of Non-Communicable Diseases in Upper Svaneti

Trauma Prevalence Rate

The injury prevalence analysis (calculated per 100 000 persons) was conducted based on the statistical data for 2009, 2010 and 2011.[20] The frequency of injuries in Upper Svaneti region is significantly higher than the data observed in Samegrelo-Upper Svaneti and other regions of Georgia both in terms of the incidence, as well as the prevalence (Fig. 2.11).

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[17] Healthcare, Statistical Yearbook, 2010; The data of the Statistics dpartament of the National Center for Disease Control and Public Health.
[18] Mestia Meteorological Station.
[19] Incidence - the primary infection; Prevalence - the total incidence;
[20] Healthcare, Statistical Yearbook, 2010.

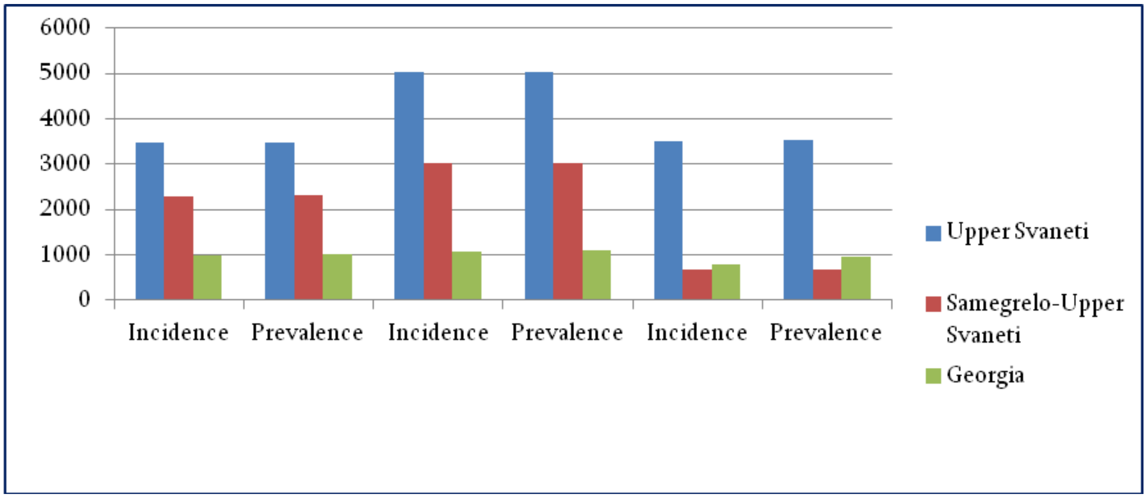

Fig. 2.11. Indicators of Trauma Incidence and Prevalence in Samegrelo-Upper Svaneti Region, 2009-2011

High incidence of injuries can be caused by natural disasters (landslides, mudslides, snow avalanche), to which Upper Svaneti region is highly susceptible. Meanwhile, the high rate of injuries and the increased annual rate may also be related to the melting of the snow cover on mountains, which creates inappropriate and risky conditions for mountaineering. According to the local experts[21], the high rate of injuries is related to the difficult terrain of the region, a low level of awareness of persons employed in the tourism sector about the risks that may be associated with injuries, to the lack of the state control over certain types of tourism, such as mountaineering and trekking. If the frequency of natural disasters caused by climate change continues to increase or the snow cover is significantly weaker[22] because of the sharp rise in temperature and also, if the relevant sectors (mainly tourism, healthcare) are not mobilized, a dramatic increase in the threat of injuries and medical problems caused by injuries (disability) is anticipated.

Prevalence of Other Non-Communicable Diseases in Upper Svaneti

From other non-communicable diseases, the frequency of which is the highest in Upper Svaneti (after the injuries), the first to note are the cardiovascular diseases and the mental disorders.

Upper Svaneti, compared to other regions of Georgia, is characterized by high rates of cardiovascular diseases. In comparison to the cardiovascular diseases, hypertension is the most common in Upper Svaneti, which is at the same time characterized by an annual prevalence increase (Fig. 2.12). According to the local experts[23], the cardiovascular diseases and in particular, the high incidence rate of hypertension, along with a prevailed unhealthy life style, may be also linked with the location of region, namely to the high altitude above sea level. The latter is characterized by the relative lack of oxygen, which prevents proper functioning of the cardiovascular system.

[21] The questionnaire for physicians: "Assessment of the Health sector Vulnerability to Climate Change in Upper Svaneti."
[22] http://www.grinningplanet.com/articles/global-warming-climate-change/global-warming-melting-ice.htm
[23] The questionnaire for physicians: "Assessment of the Health sector Vulnerability to Climate Change in Upper Svaneti."

Already detected climate change, primarily the increase in the annual average temperature, as well as the risk of increasing the frequency of natural disasters, which is observed in Upper Svaneti, increases the threats related to the mountain tourism. Climbing to high altitude above sea level increases the risk of adequate functioning of the respiratory and cardiovascular systems in the oxygen rarefied atmosphere. Preliminary assessment of such risks, their prevention and introducing an efficient response system is essential for the development of safe and attractive mountaineering.

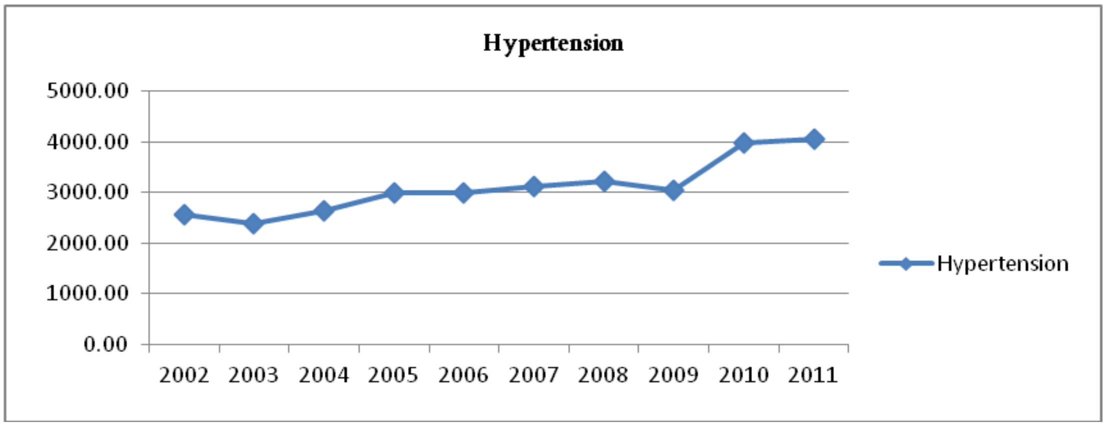

Fig. 2.12. Dynamics of Hypertension Prevalence in Upper Svaneti, 2002-2011.

The incidence and the prevalence of the mental disorders is quite high in Upper Svaneti (Samegrelo-Upper Svaneti ranks second in Georgia after Imereti) (Fig. 2.13).

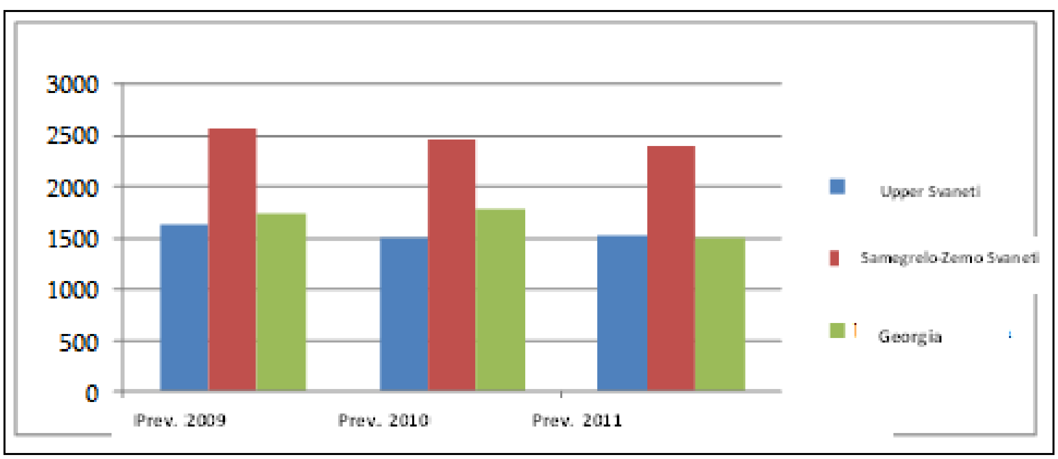

Fig. 2.13. Prevalence of Mental Disorders in Upper Svaneti, in the whole Samegrelo-Upper Svaneti Region and Georgia, 2009-2011.

As the diagram demonstrates, the incidence of mental disorders in Svaneti is lower than the data for Samegrelo-Upper Svaneti. In general, it is not high in comparison to other regions. At the same time, a sharp increase in the frequency of this group of pathologies has been observed since 2008 in Upper Svaneti (Fig. 2.14).

The high rate of mental disorders could be explained by the following reasons: Geographical location made Upper Svaneti more susceptible to natural disaster (See Section: Disaster Risk Assessment in Upper Svaneti). One of the pathologies emerging after the natural disaster is a post-traumatic mental disorder syndrome (PTSD). The pathology may be formed independently, although it also could become a cause of the severe mental disorder relapse (recurrence). Based on the international data, prolonged heat and cold may cause psychological stress and further worsen the mental state of those who are prone to psychological disorders or are chronically ill with this type of pathology. [24]

Thus, the high rate of mental disorders may be caused by the high exacerbation numbers of existing mental health problems and at the same time, by the high PTSD rate.

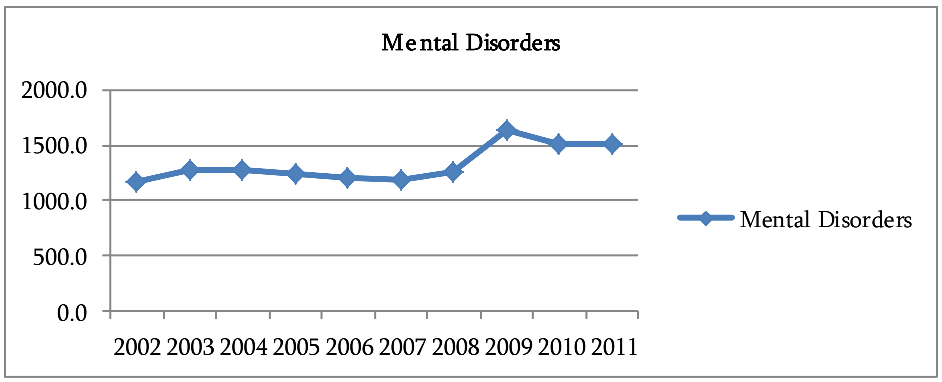

Fig. 2.14. Dynamics of the Prevalence of Mental Disorders in Upper Svaneti, 2002-2011

Another group of diseases that is also considered as the climate-dependent pathology, are the diseases of the respiratory system. According to the statistics of the recent years, their frequency is not very high in Upper Svaneti in comparison to other regions. However, the sharp increase in the annual prevalence rate is observed (Fig. 2.15).

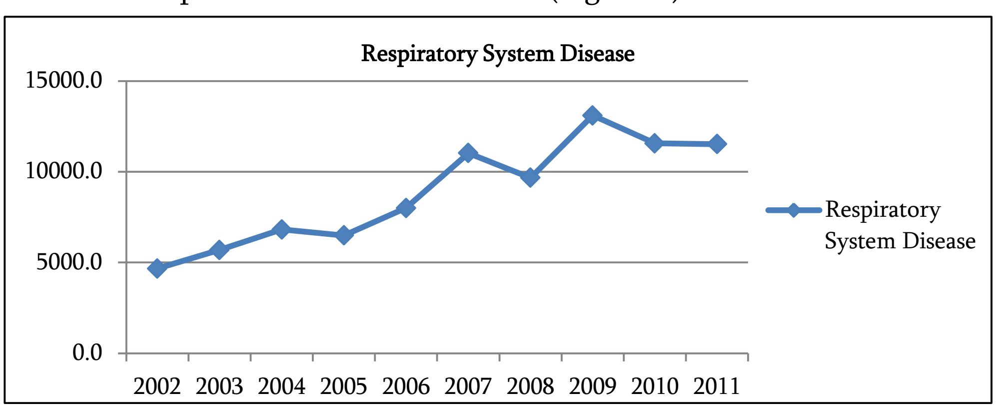

Fig. 2.15. Dynamics of the Respiratory System Disease Prevalence in Upper Svaneti, 2002-2011

[24] A Human Health Perspective on Climate Change; A Report Outlining the Research Needs on the Human Health Effects of Climate Change; April 22, 2010; www. niehs.nih.gov/climatereport

The respiratory system, as well as the cardiovascular system, is quite sensitive to climate change. The WHO estimates[25] that the change in the air composition as the result of climate change adversely affects the functioning of the respiratory system: The concentration of suspended particulate matter in the air, as well as ground-level ozone increases as a result of climate change, which interferes with the adequate functioning of the respiratory system: Ozone damages a lung tissue and makes it easier to develop asthma; also, the infections easily penetrate into the tissue and cause infectious inflammatory changes. [26]

Prevalence of Communicable Diseases in Upper Svaneti

From communicable diseases, the incidence of which is higher in Upper Svaneti in comparison with other regions of Georgia, the infectious and the parasitic diseases should be mentioned at the first place. Their prevalence rate (prevalence and incidence) does not exceed the data from the other regions of Georgia. This region holds one of the high positions in terms of the mortality rates (in 2008-2009 it ranked 4th after Adjara, Tbilisi and Imereti and in 2010, it ranked first).

According to the 2010 data, the mortality rate in Samegrelo-Upper Svaneti determined by the infectious and the parasitic diseases was twice higher than the average indicator for Georgia: The mortality rate for Georgia was 1.0 and 2.0 for Samegrelo-Upper Svaneti. At the same time, a sharp increase in the mortality rate has been observed in recent years (2008 - 0.4, 2009 - 0.7, 2010 - 2.0).

The high mortality rate caused by the infectious and the parasitic diseases may be determined by several reasons: The infectious disease is acute and this is why it is difficult to manage; the infectious pathology emerged during the period when the disease management becomes difficult (natural disaster and post-disaster situation, sudden epidemiological explosion); the infectious and the parasitic disease management is complicated by the lack or the absence of appropriate specialists in the region. In order to determine the specific cause, as well as for revealing links with climate change, it is necessary to conduct a more detailed analysis – a small-scale research.

Samegrelo-Upper Svaneti is characterized by high rate of the viral hepatitis A ("Botkin's disease"), (Fig. 2.16), especially in children. Other types of hepatitis are not so frequent. Although the frequency of this type of hepatitis decreased, the overall figure remains high.

Hepatitis A belongs to the pathologies, which are easily transmitted, especially in children, by a fecal-oral route. An outbreak of viral hepatitis is primarily associated with the violations of the sanitary norms, which in turn may be related to the disruption of the sewerage system. It is also possible that the outbreak of this type of infection is linked to the dense settlement of the

[25] http://www.who.int/globalchange/en/

[26] http://www.epa.gov/climatechange/impacts-adaptation/health.html#impactsreducedair

population (temporarily, as a result of forced migration), which is accompanied with the disregarded hygienic norms.

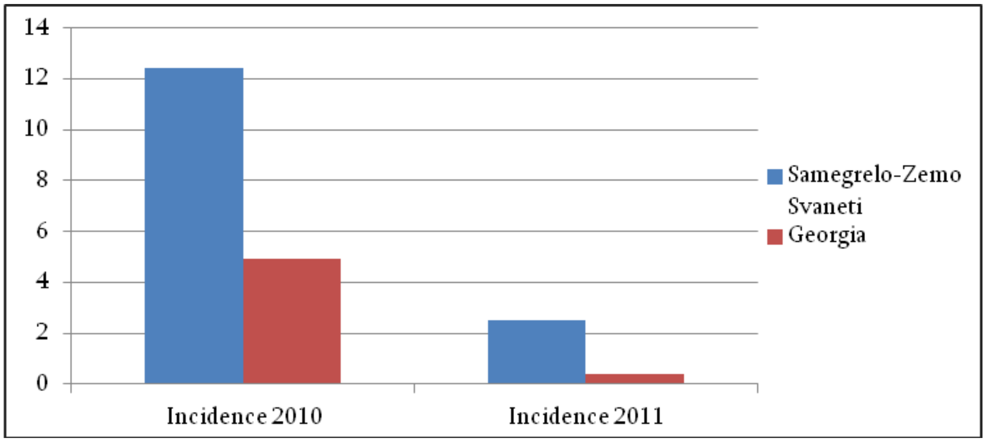

Fig. 2.16. Hepatitis A Prevalence Rate in Samegrelo-Upper Svaneti region, 2010-2011

Another acute disease with the high prevalence rate that is observed in Samegrelo-Upper Svaneti, is influenza.[27]

Compared with other regions, the highest incidence of influenza morbidity is observed in Upper Svaneti. This phenomenon can be explained as follows: flu is the acute infectious disease of the upper respiratory tract, which is managed and controlled by the properly organized health system. When there is a lack of appropriate infrastructure or the medical staff shortage or the outbreak is observed (which makes it difficult to control the disease), the frequency of the disease may increase. In this case too, as well as in case of the infectious and parasitic diseases, it is necessary to conduct the enhanced analysis and the research to link them with the climate change trend in Upper Svaneti.

The prevalence of tuberculosis is high. The incidence and the prevalence rates have been steadily high over the recent years. After Adjara and Tbilisi, Upper Svaneti has the highest rates.[28] TB very sensitively reflects the efficiency of the healthcare system: The high level of the tuberculosis indicates the malfunctioning of the system (both infrastructure and qualified medical personnel) that determines the poor pathology management. Thus, the sudden increase in the frequency of infections pathologies (water, food and air-borne) occurs after the natural disasters, when the population is temporarily forced to change their place of residence and live in the densely populated temporary shelters or with relatives. In such circumstances, the infection prevalence risk (the risk of water and food, as well as air-borne infections) increases, which is accompanied by the failure of the sewage system after the natural disasters (which is possibly mixed with drinking water), determines the epidemic outbreak caused by infectious diseases transmitted through water and food. Another reason, which may cause the increase in

[27]According to the statistical handbook: "Influenza-like illnesses".
[28] Healthcare, Statistical Yearbook, 2011.

the incidence of the infectious and the parasitic diseases is unusually high temperatures, which create the favorable conditions for easy breeding of the infectious agents.

Health Sector Capacity Assessment

Assessing the potential of the healthcare system in Upper Svaneti entails the evaluation of the medical facilities and the medical staff, as well as the access to medical services. Since the frequency of natural disasters is considered as one of the associated events to climate change, it is necessary to focus on the climate-dependent disease management and the risk reduction. First of all, it is necessary to assess whether the medical network is provided with professionals who are necessary to reduce the risks of the climate-dependent diseases.

The assessment of Upper Svaneti health sector revealed that Mestia municipality is experiencing an acute shortage of medical personnel, such as: a cardiologist, a traumatologist, an infectious disease specialist, a psychotherapist, a neonatologist, an allergist, an angiologist and others.
It is necessary to have a majority of the medical personnel listed above for reducing the risks of climate-related diseases. The shortage of this type of the medical personnel might be one of the factors that contributed to the increase in the climate-dependent disease incidence rate during the recent years.

A district-level hospital operates in Mestia, Upper Svaneti, where the population receives emergency inpatient and outpatient services. The region is divided into 13 health sections and a doctor and a nurse serve the population in each section. Not only are the medical facilities in the sections ill-equipped with basic medical supplies (there is only a medical bag and the doctor is responsible for filling it with necessary medical supplies at his/her own expense), their part is located in places that are difficult to reach for the doctors, as well as for the population.

When there is a need for a medical assistance, the patient from the section-level medical facility is sent to the district hospital and in the absence of the relevant specialist – to Zugdidi district hospital, which is located 137 km away from Mestia. The patient is transferred with an ambulance.

The primary analysis of the situation demonstrates that the indicator of the access to medical services and the medical infrastructure in Upper Svaneti is low due to the inefficiency of the appropriate infrastructure and the medical personnel. As a result, the control and the reduction of the risks of the climate-dependent diseases, such as physical and psychological injuries, cardiovascular and respiratory diseases are inadequate. The number of the private insurance beneficiaries is very small in Samegrelo-Upper Svaneti region. This service is typically used in the urban settlements, mostly in Zugdidi, where the number of hired employees is greater. Access to finance health services and medication is problematic is the region. The universal insurance program has been functioning since 2013 and provides the basic medical insurance through the state medical insurance scheme. However, it does not ensure the full eradication of the problem.[29]

The weak and insufficient operation of the medical insurance system deepens the existing medical problems in the region. If the medical insurance includes prevention of the series of diseases, among them the climate-dependent diseases, treatment costs are significantly reduced.

Assessing the Existing Risks

For assessing the vulnerability of the region's inhabitants and the healthcare sector to climate change, it is essential to highlight the risks that increase the vulnerability to climate change. Such risks include the geographic location of the region to be assessed, its socio-economic background, the level of infrastructure development, etc.

The primary risk determined by the geographical location of Upper Svaneti is the prevalence of natural disasters. Based on the survey, which was conducted by the Caucasus Environmental NGO Network (CENN) and Twente University Faculty of Geo-Information Science and Earth Observation (ITC), among 9 regions of Georgia, Samegrelo-Upper Svaneti is at the second place according to the identified risk data.[30] Analyses of the overall threat and risk level (the highest risk rate - 12, the smallest risk level - 1), which was produced using a multi-spatial analysis, Samegrelo- Upper Svaneti scored a total point - 11, which indicates a very high risk. The population under the risk of the natural disasters was awarded 10 points, buildings at risk of 11 points, GDP - 10, and agriculture - 10 points.[31] The absolute risk indicators were represented with the following figures: The number of the population, who are at risk of natural disasters is 76 000, the number of buildings - 2 506, the gross domestic product (GEL) - 117 799, the road length (km) - 27 602. This data are very important for the healthcare sector, as the number of buildings and the road extent is important to assess the access to the medical services. The GDP refers to the region's economic development, which in turn is also related to the access to the medical services (in terms of the ability of the population to pay for the medical services). The number of vulnerable population is the most powerful indicator that directly reflects the quantity that needs special attention from the healthcare system.

The increase in the incidence of diseases that may be related to the natural disasters were observed in Upper Svaneti. For example, the high incidence and prevalence rates of injuries may be a result of the natural disasters. The rate of chronic pathologies is also high, which may as well be associated with the natural disasters. For example, the high incidence and the prevalence of mental disorders may be caused by the increase in post-traumatic syndrome of

[29] Samegrelo-Upper Svaneti Regional Development Strategy for the years of 2014-2021.

[30] The Atlas of the hazards and risks of natural disasters characterizing the territory of Georgia. CENN, ITC; 2012

[31] The overall vulnerability parameters were calculated by estimating components, such as the vulnerability of the population, buildings, GDP and agriculture. The component related to the population provides the most relevant information on the assessment of the vulnerability of the healthcare system and the public health. The assessment was undertaken by using the following indicator groups: Population density (weight indicator - 0.50), healthcare (0.2), education (0.15) and vulnerable groups (0.15).

mental disorders. Also, natural disaster-induced stress may facilitate the initiation or the exacerbation of the pre-existing mental disorder, which is another reason for the high rate of mental disorders.

The region, which is highly prone to natural disasters, the role of the healthcare system is particularly important. It is necessary to introduce the medical management of natural disasters, which is a complex measure: It has several stages and requires the involvement of different sectors. The involvement of the mobilization of the health sector (readiness) begins before the start of the natural disaster and continues after it (the fourth phase is the longest, which includes the post-catastrophic medical management).

Connecting the climate-dependent diseases with natural disasters is quite difficult as there is no accurate registration system of the natural disasters. In addition, there is a lack of the medical statistics in Mestia Municipality for the long-term period - the accurate registration only started in 2000. In general, for the assessment of the impact of natural disasters on the climate-dependent diseases, it is necessary to evaluate how the frequency of certain types of climate-dependent diseases change after the natural disaster.

The following types of connection were revealed based on the statistical data available to us: During the last 12 years, the maximum number of injuries in Upper Svaneti was recorded in 2004 (the prevalence and the incidence rates exceed 6 000, when about 3 000 cases were registered in other years). Particular activity of mudflows and landslides was observed exactly that year, as a result of which 180 buildings were destroyed (including residential houses) and more than 50 families became ecological migrants.[32]

The active attack of landslides and mudflows was also observed in 2010, when the landslide destroyed 67 buildings. Unfortunately, the number of ecological migrants for this year is unknown. As for the injury statistics, the increase in the prevalence and the incidence was observed in 2010 (the prevalence and the incidence rates was about 5 000).

Linking other climate-dependent diseases with the natural disasters is complicated, as their formation, unlike the injuries, does not take place instantly, but it needs time. In order to reveal the existence of such linkages, it is necessary to conduct the more detailed, deeper research.

Future Climate Change in Mestia Municipality and its Impact on the Health Sector

Based on the result of the research conducted within Georgia's Third National Communication to the UNFCCC, it was derived that the parameters climate change in future may proceed as follows: The average annual air temperature is expected to rise by 1.5 ^{0}C (the average values of 1986-2010 are compared to the data of 2021-2050), the annual amount of precipitation may

[32] Report: "Natural Geological Processes in Upper Svaneti," Ilya Chkheidze, 2013

increase by 12%, while the annual number of hot days when the air temperature is higher than 25 °C is expected to increase by 28%.

According to the even more distant forecast (compared to the data of 1986-2010), the average annual air temperature increment for the years of 2071-2100 is 4.0 °C. The annual number of hot days, when the temperature exceeds 25 ^{0}C will increase by 64 and precipitation will grow by 3%. Based on the forecast we can say that in parallel with the temperature increase, melting of the snow cover is expected, which would prevent safe alpinism, as well as skiing.

As for the activation of disastrous geological processes, as in the future, until 2050, there is the slight increase in daily precipitation expected in Mestia municipality. Experts suggest that the meteorological conditions for the formation of the hazardous geological processes will be maintained and even increased slightly. For this reason, by taking other "aggravating" factors in mind, the escalation of geological processes is anticipated.

Such forecast indicates that unless the adaptation measures are developed, the frequency of injuries may even further increase.

As for the health sector's adaption ability, without providing relevant information to the local physicians, as well increasing the access to the medical facilities, the number of climate-dependent disasters will increase.

The World Health Organization provided a sample chart that is used to assess the vulnerability[33] and also gives a general idea of the type of changes we can expect in the future and in which direction the adaptation measures should be undertaken (See Table 2.25)

Table 2.25. The Chart to Evaluate the Trend of Climate Parameters and Climate-Dependent Diseases Change

Climate change			**Trend of dissemination of climate related diseases**		
Changes in temperature	Changes of amount of days	Changes in precipitation	Cardio-vascular diseases	Phycological disorders	Diseases in breathing systems
↑	↑	↑	↑	↑	↑

The Table demonstrates that in light of the changes in certain climate parameters, the trend of the prevalence of climate-dependent diseases would be observed. The increase in the future climate parameters may contribute to increasing the frequency of these types of diseases. This is only an assumption, but it could be said that if the number of hot days and the average annual temperature is increased, it results in the reduction of the snow cover on mountain peaks and in general, in melting snow on mountains. This will create unfavorable conditions for

[33]Protecting Health from Climate Change; A Seven-country Initiative, WHO Regional office for Europe, 2013. www.euro.who.int/en/what-we-publish/abstracts/methods-of-assessing-human-health-vulnerability-and-public-health-adaptation-to-climate-change.

mountaineering, as well as for skiing. This may pose a threat to some sport categories and will undermine the development of tourism in the region. It may be accompanied by the increase in accidents, which will primarily result in the creation of unfavorable conditions for mountaineering and skiing.

According to the abovementioned results, the Tourism Climate Index (TCI) for future indicators (2071-2100) revealed a number of changes, which may be unfavorable for the development of tourism and, in general, be less comfortable for health. For example, the Index value changed significantly in July, and became "unfavorable", when currently it is "very good." If December is now "unfavorable", in the future, January becomes "unfavorable". In general, it should be said that Mestia Municipality is characterized by the worsening trend of its tourist-recreational potential by the end of this century. It seems that if the deterioration of the TCI is added to the unfavorable change of the climate parameters in the future, it might negatively affect human health, as well as a number of the sectors (health, tourism) and will hamper the country's economic growth.

Recommendations

In order to minimize the vulnerability of Upper Svaneti's health sector to climate change, it is desirable to implement the following measures:

- Supporting the healthcare system in Upper Svaneti with the relevant infrastructure (rehabilitation/establishment of medical facilities) and the appropriate medical personnel (the traumatologist, the psychotherapist, the infectious disease specialist, the cardiologist, the neonatologist, etc.), who will be specifically oriented towards the management of the climate-dependent diseases;
- Sharing an international experience, which includes provision of information and sharing of the so-called Best Practices, which are directly related to the medical management of the climate-dependent diseases in a mountainous region similar to Svaneti;
- Development of the Natural Disaster Medical Management Plan (NDMMP) by involving other sectors. The post-traumatic rehabilitation is one of key components, which mainly involves the management of the post-traumatic nervous breakdown syndrome;
- Developments of the early warning system, which will make it easier for the healthcare sector and the local community to prevent and manage the climate-dependent diseases as a result of timely preparedness;
- Raising awareness on the climate-dependent diseases among representatives of the healthcare and the tourism sectors in Upper Svaneti.

2.7. Climate Change and Tourism in Mestia

According to the established classification, by 1980s Upper Svaneti was divided into 4 tourist and recreational zones. Figure 2.17 demonstrates the distribution of these zones.

The high mountain alpinism and ski sport tourism zone holds an important place among these zones and includes famous peaks such as Shkhara, Ushba, Shkhelda, Tetnuldi, Laila, etc. An abundance of glaciers and peaks in Upper Svaneti that are difficult to access attracts many tourists from different countries. The fourth zone, recognized as the historical reservation is no less popular. It includes Europe's highest mountain settlement Ushguli with its communities, namely: Jibiani, Chajashi and others. The resort zone located at the terraces of the Enguri Gorge and mountain slopes, includes the settlements with the rich historical past (Mestia, Lemsia, Ushkhvanari, Svifi, Tkvebishi, Lakhamula, etc.), as well as the resort areas of unique beauty that are covered with forests. More than 30 mineral springs, including Lakhamula, Etseri, Svifi, Lasili, Khalde, Adishi and others are registered here. Due to lack of the proper infrastructure, these areas are still not adequately developed. A brief rest zone #3 covers steep slopes and places with dense forests.

The climate description of Upper Svaneti is today possible with the data from Mestia and Khaishi meteorological stations. Mestia Weather Station was selected for calculating the TCI, which is more representative for the region's territory. The peculiarity of this station is that it is located in the Mestia Hollow surrounded by high mountains, where the microclimate typical for the basin is formed by winter frosts and summer heat.

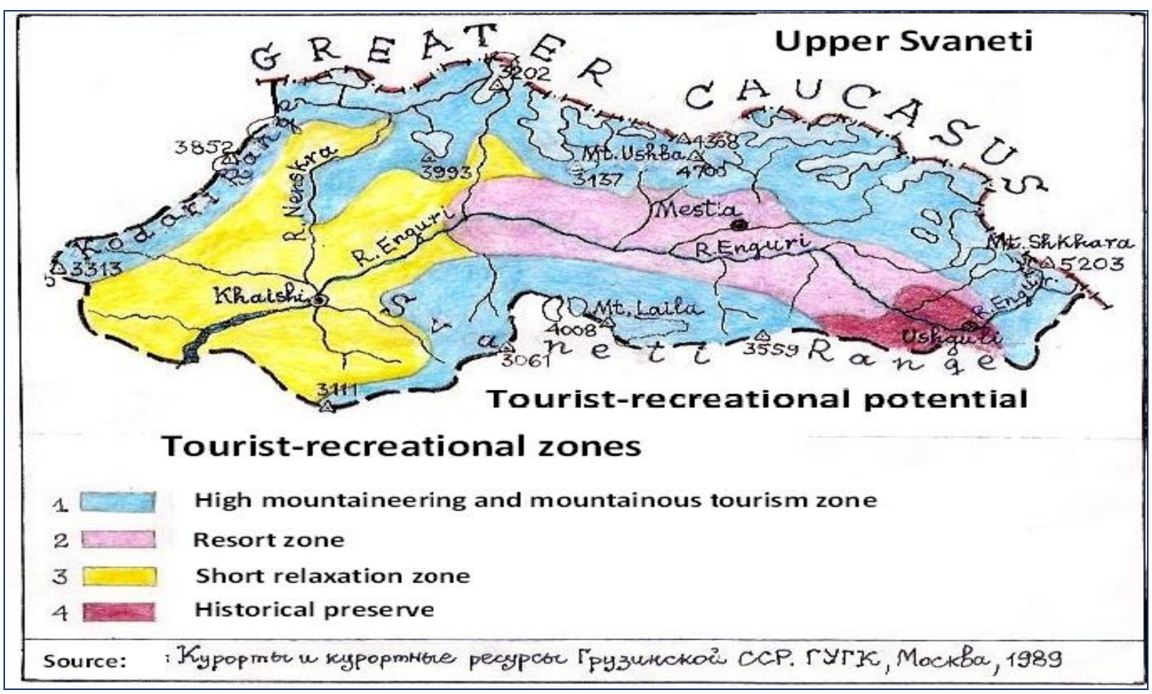

Fig. 2.17. Distribution of Tourist-Recreational Zones on the Territory of Upper Svaneti in 1980s.

The TCI calculated according to the average monthly climate data for the period of 1961-2010 is presented in Table 2.26. Here, the TCI categories are represented with 5 rankings, starting from "a very good" (70-79 points) and ending with "unfavorable" (30-39 points). The same Table includes predicted TCI indicatores for the period of the 2071-2100. It is possible to make the following conclusions from the Table:

- Unfavorable climate conditions for the tourism currently exist in Mestia in the winter months (December-February) and "acceptable" or better conditions are observed from March through November;
- The climate is described as the best or "very good" from June through September;
- By the end of the current century, the climate conditions that facilitate tourism are expected to improve in February, March, May, October, November and December, but these conditions will worsen in all three summer months. This process should take place particularly sharply in July, when the TCI index may be decreased by 2 categories and may move only to the "acceptable" level. This phenomenon should be related to the abovementioned features of Mestia's terrain. Therefore, the spread of the obtained result should be considered inappropriate for the entire territory of Upper Svaneti.

Table 2.26. Distribution of the Tourism Climate Index categories in Upper Svaneti according to months in the past period of 1961-2010 (Δ) and the forecasted period of 2013-2100 (●) (Mestia Weather Station data).

TCI category / Month	1	2	3	4	5
January					Δ ●
February				●	Δ
March			●	Δ	
April			Δ ●		
May	●	Δ			
June	Δ	●			
July	Δ				
August	Δ	●			
September	Δ ●				
October	●		Δ		
November			●	Δ	
December				●	Δ

TCI categories: 1- very good; 2 - good; 3 - pleasant; 4 - acceptable; 5 - unfavorable.

3. Production of Renewable Resources (Biogas) and Organic Fertilizer in Mestia Municipality

3.1. Energy Consumption

Upper Svaneti is the highest mountainous region of Georgia. Its average altitude reaches 2 300 m above sea level. The territory of the region, which includes Mestia Municipality is 3 044 km2, and the population, as of 2012, amounted to 13 679, of whom 2 881 persons live in the administrative center of the unit - Mestia Borough. The rest of the population is distributed in 134 villages, which are united in 16 communities (Annex 2, Table 3.1). The population density in the municipality is about 5 people/km^2, which is 13 times less than the national average. Some villages consist of about 5-10 families, that is why they were unified into the larger communities..

Agriculture and particularly livestock raising are the leading sectors of the economy in Upper Svaneti, natural grassland-pastures are their food base. Animal husbandry, particularly cattle breeding is the mainly developed sector due to the harsh climate and the mountainous terrain in Upper Svaneti. Information about the state of the sector in the municipality is given in Annex 2, Table 3.2. Except animal husbandry, cereal crops and potatoes are cultivated here in small quantities.

As noted above, Upper Svaneti is the high mountainous region and the significant part of the settlements here are located pretty height, where the climate is cold. In particular, the majority of the population is concentrated on the right banks of Enguri River between the gorges of Nakra and Mulkhra rivers, in the range of 1 200-1 500 m ASL. This zone is characterized by the data of Mestia Meteorological Station (1 441 m), according to which, the average annual temperature is 5.8 ^{0}C here, while the average minimum temperature is negative for the duration of 6 months from November through April. The higher settlements are located in Ushguli Zone, in the direction of Enguri River source, at the altitude of 1 800-2 100 m ASL. According to the climate data of Koruldashi Meteorological Station (1 943 m ASL), which is located nearby (the average annual temperature - 3.2 ^{0}C), winter here also continues for 6 months. The minimum temperature at both of these meteorological stations falls below to -35 ^{0}C.

These figures reflect the climate conditions existing in Upper Svaneti half a century ago. The ongoing warming taking place in the recent decades somewhat shortened the duration of the winter and limited it to even 5.5 months; however, even this period, compared to other regions of Georgia, is remarkably long.

The given data shows that the population of Upper Svaneti lives in harsh climate circumstances, which requires major energy expenditures for meeting household heating and other consuming needs. The total energy consumption in Mestia Municipality according to the communities for 2012 are listed in the Table 3.1.

Table 3.1. Energy consumption in Mestia Municipality (2012)

Community	Population	Annual energy consumption		
		El.energy thousands of KWT	Wood m³/year total	Liquid petroleum, m³ liquid petroleum
Ushguli	267	102.2	1 260	1 050
Kala	107	4.2	486	405
Ifari	261	131.4	1 620	1 800
Tsvirmi	484	183.9	2 260	1 890
Mulakhi	1 007	456.9	5 634	9 390
D. Mestia	2 881	1 192.8	9 804	65 360
Lengeri	1 066	325.5	4 014	11 150
Latali	1 104	569.4	7 020	19 500
Tskhumari	633	353.3	3 872	7 260
Becho	1 003	537.2	5 888	9 200
Etseri	813	329.9	3 616	5 650
Fari	316	153.3	1 680	2 625
Lakhamula	337	108.0	1 184	1 480
Nakra	332	185.4	2 032	3 810
Chuberi	1 304	559.2	6 028	11 490
Khaishi	1 281	614.7	6 736	12 630
Idliani	443	167.9	1 840	3 450
Total	**13 679**	**5 975.2**	**64 974**	**168 140**

We consider that despite the current climate warming, these energy consumption indicators in Upper Svaneti will grow in the near future, as the promotion of agritourism and a network of guesthouses requires to satisfy tourists, including foreigners, with higher comfort than it was before. These include more energy consumption for heating rooms, having hot water, electricity, air conditioning and other service areas, which makes it relevant to search for alternative energy sources. Biogas is one of such source of renewable energy. Dung that is not in a shortage for this livestock district is necessary for biogas production.

From the energy resources listed in Table 3.1, until 2014, Mestia Municipality was supplied with free electricity from Enguri the HPP. However, in the conditions of harsh winter, heavy snow and glaze ice, power supply is often disrupted for 2-3 weeks due to damage of electricity transmission lines. According to the data provided in the Table, the average annual per capita electricity consumption in Upper Svaneti is 437 kWh., which equals 36.4 kWh per month. This figure is the same as the similar figure in Tbilisi (40-50 kWh per month) and confirms that the population in Mestia consumes electricity mainly for illumination. Firewood and liquefied natural gas LNG) is mostly used for heating and cooking. In 2012, the average per capita ponthly energy consumption was 0.39 m³ firewood and 1.0 m³ liquid petroleum gas. It should be also noted that in the high alpine villages of Upper Svaneti, for instance, in Ushguli Community, firewood has to be transported from the lower, forested zones, while liquefied gas is supplied with cars from Zugdidi. All this complicates and increases the cost of energy consumption in the region, while the renewable energy source - cattle manure - is abundant in the region.

3.2. Potential to Produce and Use Biogas

The use of manure for biogas production has a lot of economic, social and environmental benefits. The economic advantage is expressed in saving liquefied gas, because biogas can successfully replace liquid gas in cooking. Social and environmental advantages are related to the fact that dung reservoirs in Upper Svaneti are not properly arranged. Manure is piled near barns in an open-air, which pollutes the environment - strong smell of manure, flies, rodents and contaminated water causes resentment among tourists. Therefore, the low level and the poor sanitation conditions in guesthouses, despite the impressive historic sites and natural beauty of the region does not contribute to the attraction of tourists. Producing biogas from manure can contribute to cleaning of the surrounding areas, will stop the emission of the active greenhouse gas - methane to the atmosphere and thus will contribute to attracting tourists, which in turn will lead to increasing the living standards of the local population.

The main constituent biogas components are: Methane CH_4 (50-70%), carbon dioxide CO_2 (50-25%) and hydrogen sulfide H_2S (0.1-3%).

According to various sources, the biogas calorific value, depending on the quantity of methane, varies in the range of 5 000 5 500 kcal/m^3, which corresponds to energy content expressed in mega Joule (1 cal = 4.19 J) in the interval of 21.0÷23.0 MJ/m^3. Below, we bring some of the examples of the energy contents of other energy sources for the comparison: Petrol - 44.8 MJ/kg, diesel - 43.3 MJ/kg, liquefied gas - 47.3 MJ/kg, natural gas - 33.6 MJ/m^3 and firewood - 7.5 MJ/m^3.

Installations used for producing biogas (bioreactors) are divided into 3 types according to the temperature of the process (Table. 3.2).

Table. 3.2. Installations used for biogas production

Regime of equipment	Diapazone of temperature, ^{0}C	Processing time,day	Biogas production m^3/m^3
Phsychopilic	15-18	>100	0.25
Mezopilic	28-33	50-60	0.4-0.5
Thermopilic	50-60	10-15	3.5-4.0

Taking into account rigorous climate conditions and rocky soil of Upper Svaneti, it is necessary to build a moderate-size thermophilic unit for producing sufficient quantities of biogas (5-10 m^3), which ensures the daily 15-20 m^3 biogas production. Technical-economic feasibility study and technical documentation for the installation of this capacity family-type digester was assessed by "Bio-Energy" Ltd. in 2012.

According to the theoretical data, the quantity of biogas produced from 1 t. of different types of animal dung varies in quite a large range: This figure is 25-30 m^3 for cattle, 50-70 m^3 for swine, 20-25 m^3 for goats and sheep and 50-60 m^3 for chicken. As for the amount of manure generated each day, it is 20 kg for cattle on the average, 5.1 kg for pigs, 1.6 kg - for goats and sheep and 0.16 kg for poultry.

In order to correctly assess the potential of biogas recovery in the digester, it is necessary to take into account that the abovementioned values correspond to the winter period, when the cattle is in the stall during the whole day and it is possible to fully collect droppings. In summer, when cattle is on pasture during the day, manure is collected only at night and its taking is on the average 10 kg/day per head. One cattle head can produce the average of 20 kgx180 days=3 600 kg (winter) and 10 kgx180 days=1 800 kg (summer) manure annually or a total of 5.4 tons of manure per year. Thus, taking into account various losses, the annual amount of manure for each cattle head could be 5 tons. Based on the similar approach and by using the abovementioned initial data, 1.3 tons of manure per pig and 0.4 t. manure per goat/sheep head is obtained annually.

Due to its small amounts, the collection of poultry manure for biogas production is profitable only in conditions of having a large poultry factory. As there is no large-scale poultry farm in Mestia Municipality at this stage, it does not make a sense to assess the contribution of the poultry sector in the biogas production.

Based on the values obtained above and the case of the year 2013, as well as by using the data given in Annex 3, it is possible to assess the potential of Mestia Municipality to produce biogas from the livestock sector (Table. 3.3).

Table 3.3. Potential for Biogas Generation from Livestock Manure in Mestia Municipality and Total Energy Capacity (2013).

Animal Speices	Amount /Head/	Annual amount of manure /t/ head/	Biogaz from the manure m^3/t	Annual amounr of biogaz, m^3/sec	Total energy capacity** GJ/yr
Cattle	7 962*	5.0	25	995 250	20 900
Swine	2 133	1.3	50	138 645	2 912
Goats/sheep	1 792	0.4	20	14 336	301
Total				1 148 231	24 113

*Notes: *Cows in Family/household farms*
***Biogas energy content Equals to 21 MJ/m^3*

The annual amount of recovered biogas demonstrates that theoretically, on the average, it is possible to produce monthly 7 m^3 per capita biogas in Mestia.

The most conservative assumptions were made when compiling this Table. In particular, only cows, that are actually wintering in the stall were included in the number of cattle. Therefore, it is realistic to collect their manure. The biogas emissions from manure are estimated in minimum quantities. A minimum heating value cited in the literature is considered as biogas energy content (5 000 kcal/m3 transferred in J).

The significant results are obtained when comparing the data given in Table 3.3 to the total energy content of firewood and liquefied natural gas (LNG) consumed in Mestia in 2013 (Table. 3.4).

Table 3.4. Energy cpacity of firewood and LNG consumed in Mestia Municipality and theoretical potential of Bbogas (2013).

Population	Consumed wood		Consumed LNG		Theoretical potential of biogas	
	Amount, m^3	Produced Energy, GJ	Amount m^3	Produced Energy, Gj	Amount m^3	Produced Energy, GJ
13 679	64 974	487.3	168 140	7 953	1 148 231	24 113

As the Table shows, in 2013, the population of Upper Svaneti spent 8 440 GJ or 8.44 TJ energy on main heating and cooking. At the same time, more than 1 148 000 m^3 biogas was emitted into the atmosphere from the livestock sector, the gross calorific capacity/energy content of which was 24.1 TJ or it is almost three times higher than the heating value of consumed firewood and liquefied natural gas. This does not mean that biogas emitted in Mestia Municipality from the livestock sector is able to cover the demands of the energy consumption in the household sector. The issues related to the technical exploitation of digesters, natural and technical losses, ensuring bioreactors with warmth and other issues need to be discussed separately. These losses might halve the estimated biogas energy potential, but, in any case, the results of the conducted assessment make it clear that the local population in Mestia owns a powerful technical resource of this renewable energy and its utilization might double or triple the energy consumption in the household sector and the hotel service industry.

Another big advantage of using biogas in the household sector is related to the conversion of methane produced as a result of the combustion into the carbon dioxide, the global warming potential (GWP) of which is 21 times less than the methane GWP. In particular, as Table 3.6. demonstrates, only in 2013 more than 1 million m^3 of biogas was emitted into the atmosphere from Mestia Municipality's livestock sector, from which approximately half, i.e. 500 thousand m^3 was methane. The cut in methane emissions will be of course beneficial for activities impelemented by Georgia for mitigating the global warming.

3.3. Bio-Fertilizer

After processing a manure solution in the digester and discharging biogas, a natural bio-fertilizer is produced (Fig. 3.1), which, unlike conventional manure and mineral fertilizers, contains biologically active substances and microelements.

Photo Error! No text of specified style in document..**1. Bio-Fertilizer**

From the features of the bio-fertilizer, the following properties should be underlined:

- Storage and use of nitrogen containing in the organic materials processed in the bioreaktor to the maximum extent. Manure loses 50% of nitrogen during the long-term storage (composting). Due to the anaerobic transformations in the digester, nitrogen N is stored in its entirety in the bio-fertilizer. In addition, the concentration of soluble nitrogen NH4-N increases by 10-15%;
- Lack of weed seeds. 1 ton of manure contains up to 10 thousand weed seeds. They do not lose their ability to crop up even after passing through the cattle stomach. After processing in the bio-plant, 99% of these seeds lose their ability to spring up.
- Human and animal manure may contain a microflora causing dangerous diseases (salmonella, ascariasis, intestinal infections). Bio-fertilizer does not have the pathogenic microflora. On the contrary, it has the active microflora. The high humification level of organic materials activates soil micro-organisms, resulting in the fixation of nitrogen. Other microbiological processes are also accelerated. Bio-fertilizer is effective right after its application in the soil, and unlike manure, does not require a one-year delay;
- Bio-fertilizer is resistant to washing out of nutrients. 80% of mineral fertilizers are washed out from the soil in one season. This is why it is necessary to add them annually. Only 15% of the bio-fertilizer is washed out from soil in the same period. It works 3-5 years longer in the soil than the conventional fertilizer;
- Soil drought durability growth. Unlike mineral fertilizers, the bio-fertilizer enriches the soil with organic substances, which increase the soil drought resistance by accumulating rain water;
- Environmental impact on the soil. Mineral fertilizers pollute the soil and ground water with nitrates and other harmful substances. The biofertilizer is an absolutely pure ecological fertilizer;

- Productivity growth. The use of the bio-fertilizer will increase yield by 10-20%;
- It could be used as the supplement to the cattle forage. After processing in the digester, the pathogenic microflora in the bio-fertilizer becomes safe, especially by processing with the thermophilic regime. Its protein concentration is increasing, it is enriched with Vitamin B12 and other useful substances. Protein-vitamin-enriched food supplements processed on the basis of the bio-fertilizer, because of their quality and low cost, are widely used in the United States, Israel, Canada and elsewhere.

Bio-fertilizer production and marketing can become a significant source of income for the population in such leading animal husbandry districts, as is Mestia Municipality.

3.4. Existing Situation and Problems for Using the Biogas Potential of Mestia Municipality

As already mentioned above, the harsh climate determines the high energy demand in Mestia Municipality. At the same time, animal husbandry is well developed in the region and determines the high potential for biogas production. Despite these two preconditions, the utilization of this potential is still slow, in part due to the lack of the high quality technology in this sector. In particular, in 2013, 2 biogas units were installed in Ushguli Community, one of which is the device with 10 m^3 volume operating in the mesophillous mode, while the other is the device with 5 m^3 volume and works in the thermophilic mode.

The mezophilic unit productivity is sufficiently high according to theoretical calculations (12-15 m^3 per day). The installing family has a guesthouse, produced gas quantity is sufficient, the family uses it for cooking and water heating. Other family living nearby is also linked up in the system.

The thermophilic plant has 5 m^3 capacity. Its productivity, like of the mezophilic device is 12-15 m^3 per day. Produced biogas is used only for covering family needs, for cooking and having hot water in the kitchen. The device is covered with high quality insulation material that maintains the temperature in the reactor during 2 weeks after turning off the heating.

Both biogas units are designed by local entrepreneurs, who are unable to ensure appropriate quality at this stage. In addition, the systems are difficult to control and require a lot of effort from the residents. Because of these reasons, a number of problems were encountered during the operation of both digesters. The family-type installations acceptable in the cold climate are still underdeveloped even at the international level.

3.5. Existing Legal Framework for the Development of Renewable Energy Sector

The biogas technology is widespread in the world. Many countries declared its introduction as a national priority. The USA, Germany, Sweden, Denmark, Holland, England, France, China, India and others serve as good examples for this. The success of the biogas sector in these countries is determined by the applicable laws. They have short and long-term biogas programs. The laws regulate raw biogas generation, processing and use. These countries have set the biogas utilization levels according to its use in the energy sector and environmental protection.

EU countries, including Germany, which is leading in the production of biogas, have laws in place encouraging the introduction of biogas.[34] In order to strengthen the sector, the state provides certain subsidies for electricity produced with biogas.

In order to mitigate climate change, ensure environmental protection, store energy entails of the earth and reduce expenditure of energy supplies, Germany adopted the following schedule for increasing the share of renewable energy in the total industrial production: 35% by 2020; 50% by 2030; 65% by 2040 and 80% by 2050.[35]

Denmark is one of the leading countries in Europe in terms of the developed biogas technology. The legislation of this country sets a requirement to process 50% of produced manure in biogas installations until 2020. Before 2011, 60 small mesophillous biogas plants operated in the country. They processed 10-20 thousand tons of manure per year. In addition, there were 22 large-scale biogas plants processing up to 400 thousand tons of manure per year (1 095 t/day). The addition provided by the state on 1 kWh electricity produced by biogas is 10.2 cents. The state subsidy for the construction of the bio-facilities is 20% and the state guarantees the credit. Biogas owner companies use raw materials collected in a 20-30 km radius.

The EU countries have introduced the Law on nitrogen, which defines the rules for the application of the nitrogen-rich bio-fertilizer produced by the biogas plant.[36]

The existing Georgian legislation does not contain a similar requirement for the use of biogas. Only Decree #315 of the Government of Georgia adopted on 12 August 2011 on "Amendments to the Decree of the Government of Georgia #57 of March 24, 2009, on Rules for the Issuance of Construction Permit and Permit Conditions" regulated construction permit terms in case of the complete absence of the documents for Class V facilities - e) Electric hydro power stations under the category V (HPPs, solar and biogas installations up to 50 kW). The country has not developed a biogas development program.

The Renewable Energy Development Program has been funded from the state budget for already the fourth year (KfW code 25 03 02). 10 127 million GEL was spent on this program in 2011. 15 341 million GEL was envisaged in the budget for 2012. Unfortunately, the money attracted from grants is only directed towards the utilization of water energy. Not a single Tetri has been spent for developing the biogas technology program. The state should allocate funds

[34] http://www.gesetze-im-internet.de/eeg_2009/index.html
[35] http://www.gesetze-im-internet.de/eeg_2009/index.html
[36] (http://www.fluid-biogas.com)

for biogas at least in the future. The biogas technology provides energy for heating and cooking to rural residents. But the state gets even more benefits from the introduction of the biogas technology. This leads to the need for the allocation of funds from the state.

3.6. Recommendations for the Development of Biogas Production in Georgia and Specifically in Mestia

It is necessary to implement the following actions for stimulating the biogas technologies in Georgia:

1. **A Renewable Energy Development Fund** in Agriculture should be established, which will promote the improvement and the development of the biogas plant quality;
2. The state should encourage energy companies if they at different facilities substitute energy produced by the traditional way with biogas energy (On the example of Sweden, where large companies operate the city's heating system with biogas).
3. The State Biogas Development Program should be developed (particularly for the mountain regions, where there is a lack of energy resources) and set out an action plan that should outline the biogas utilization stages scheduled by years. The enabling legal framework required to solve this problem needs to be developed.
4. The Nitrogen Program should be developed, which will determine the rules for using fertilizers in agriculture;
5. By taking into account the existing reality, the Decree of the President of Georgia #120 of 3 March 1998 should be updated and the updated version of the Decree should be re-issued.

In order to fully utilize the (cold climate) biogas potential that exists in Mestia District, the installations operating in the thermophilic and the mesophillous modes should be selected for the improvement. The following recommendations should be considered in the process of developing biogas technology in Mestia District:

1. A state program should be developed that will specifically promote the development and the introduction of the biogas installations operating in the thermophilic and the mesophillous modes;
2. Depending on local conditions, it is recommended to give a preference to the thermophilic digester with 3 m^3 volume that has a production capacity of approximately 10 m^3 per day, which is quite enough for one family. The thermophilic installations require less space, a factor that is very important for Upper Svaneti’s land-poor villages. The volume of the mezophilic biogas facility is 6 m^3, the production capacity is about 8-10 m^3 per day, which will be also enough for one family. The latter is able to maintain a relatively low temperature in the digester process. The volumes are in line with the resources existing in Mestia on the average in one family;

3. For the successful implementation of the program, it is very important to raise awareness of the local population about this technology and its management principles, as well as the positive aspects of biogas production and use. Intensive training must be conducted for the recipient households and the video instructions should be prepared;
4. The donors should support the implementation as many pilot projects as possible by offering the best existing technologies.

4. Mestia Municipality Climate Change Adaptation Strategy

The present strategy was drafted in the process of developing Georgia's Third National Communication on Climate Change. The strategy mainly discusses measures for assessing and mitigating the expected risks caused by climate change.

The strategy is accompanied by 7 project proposals the implementation of which will significantly reduce the risks reviewed in this strategy.

The assessment of changes in the climate parameters of Mestia District and adjacent territories (Khaishi, Zugdidi) demonstrated (Chapter 1) that during the last half-a-century (1961-2010), the global warming in Upper Svaneti caused the most significant temperature increase in fall in Khaishi (+0.8 ^{0}C) and in summer in Mestia (+0.7 ^{0}C). The seasonal temperatures at both meteorological stations have not changed in winter and spring (in the range of ≥0.1 ^{0}C). Precipitation at both stations increased on every season by 10-15% in the annual context. Mestia was an exception, where summer precipitation decreased by 8%. It is important to note for the vulnerability assessment process that the maximum daily precipitation in Mestia in winter increased by 45% and by 22% in spring that generally increases the risk of landslides and floods. In addition, relative air humidity increased by 3% in winter, which also increases the risk of avalanches, because the snow cover becomes less stable as a result of increased water content. According to the data of Khaishi meteorological station, the slight increase in humidity was observed (only by 2.5%) in the winter months; almost the 5% increase in winter is observed according to the data of Zugdidi meteorological station. From extreme events, in the second 25-year period, the recurrence of abundant precipitation was halved in the summer season in Mestia (≥50 mm), but extreme precipitation was observed twice in fall in Khaishi (≥90 mm), which did not take place in the previous period.

Summer (+0.9 ^{0}C) and fall (+0.6 ^{0}C) became considerably warmer in Zugdidi Municipality, but winter became harsher (-0.3 ^{0}C). Precipitation decreased by 14%, the recurrence of abundant precipitation also decreased. The frequency of droughts decreased in Upper Svaneti and increased slightly in Zugdidi (by 10-15%).

4.1. Vulnerable Systems

The assessment of different systems demonstrated that the greatest risk for Mestia Municipality is the impact of climate change on **the tourism sector**. Tourism, after the energy sector is one of the leading industries of the district's economy. With its capacity, it can maximize the realization of the potential of natural resources and cultural heritage in Upper Svaneti. The vulnerability of the tourism sector is mainly determined by the overall vulnerability of the Upper Svaneti Region, as the mountainous ecosystem is vulnerable to climate change. Sensitivity of historical and cultural heritage monuments to the intensity of climate parameters, such as the amount of daily precipitation and the increase in average air humidity also plays a significant role.

As mentioned above, the development of the tourism sector in Upper Svaneti is based on two main factors: A wide range of possibilities for the development of the mountain tourism (winter and summer) and the existence of the rich cultural heritage of the region, which along with its fantastically beautiful nature makes this region particularly attractive for tourists.

However, it should be noted that the process of transforming the tourism resources into the tourist product does not proceed with a desired pace. The state policy is not directed at these issues and the private sector still lacks the necessary experience. Moreover, there are no approaches discussed even at the conceptual level.

As it is well-known, the mountain winter and especially, the summer tourism is in itself associated with natural dangers and even more so, when threats become widespread. It is very important to accurately assess hazards anticipated at tourist routes and to take appropriate preventive measures, as well as to inform and instruct tourists.

Tourists (including sportsmen) should be given instructions not only about the dangers on the tourist routes, but in general, about all kinds of dangers existing in the Caucasus Mountains and what to do during such threats.

For example, one can consider the possibility of rockfall, which is directly related to the climate conditions and represents a serious threat even in the calm weather, as it starts with the rising temperatures. Experienced alpinists know very well when to start the movement to prevent this type of threat, but these actions too change with the climate changes. The average temperature in summer increased by 0.7 ^{0}C in Mestia, which is likely to lead to the change of the daily temperatures (but this parameter was not studied when drafting this report).

Thus, the measures for reducing climate change risks in the tourism sector and the sector's adaptation should be implemented in two directions: Capacity building of the tourism service sector and the maximum consideration of the risks of climate change in the preparation of the strategy, as well as the rehabilitation of the historic monuments and the implementation of the preventive measures to minimize the risk of further damage.

The following actions for the adaptation of **the tourism sector** to climate change are considered in the strategy of Mestia Municipality:

- A local weather forecast service should be established, which will collect information from NEA (National Environment Agency) and will have the potential to provide recommendations based on received information to fully secure tourist movements. Desirably, the local office should have access to several sources of information for the case, if information could not be obtained in a timely manner from one of the sources;
- Risks on existing and new tourist routes that are determined by climate change must be examined to the maximum extent (frequent rockfall, starting rockfall earlier than it was previously known, mudflow or landslide hazard areas, sunstroke, mountain diseases and other impacts);
- Knowledge of the local residents and mountain climbers, which may not always be scientifically justified and supported, should be used to the maximum extent in the risk assessment process;
- Safety rules for the movement on the tourist routes must be developed. They should be available for tourists upon the arrival in hotels and the tourism service centers;
- The local meteorological department should have information about risks faced by the winter tourism (e.g.: On snow cover, anticipated avalanches, increasing temperature and humidity, etc.);
- Establishment of the special medical service and equipping it with the modern equipment in order to enable the arrival to the place of scene of accident in the shortest time and the provision of the assistance if necessary;
- It would be desirable to establish the local service that will be in colaboration with the national rescue service and will combine meteorology, certain categories of healthcare, rescue services and other areas. The agency should work on the prevention, as well as needs to provide assistance.

The extreme development of dangerous geological processes in Upper Svaneti, such as landslides, rock avalanches, rockfall, mudflows, erosion by water and snow avalanches is determined by a set of the factors - high energy of the very fragmented landscape and geo-dynamical potential, complex tectonics and the geological structure, the dense hydrographic network, landscape-zonal heterogeneity, local climate and meteorological conditions and anthropogenic loadings.

From the 1980s of the last century to present, up to 1 600 families have left Mestia Municipality due to the disaster. Almost all settlements of the municipality to some extent are located in the hazardous zone of natural geological processes.

On the background of the climate change, the following actions are considered for mitigating the increasing of the impact **of extreme geological processes** in Mestia Municipality Strategy:

- Establishment of the of coherent system of the monitoring and early warning network through a modification of the existing ones (for which the experience of the developed countries will be used):
  - For the population in the high-risk areas;
  - In the areas containing dangers to the significant infrastructural facilities (mainly on roads);
- Implementation of the preventive measures for the reduction of the anthropogenic risk factors causing natural geological processes. It is necessary to include the local population to the maximum possible extent in the planning and mitigation of the anthropogenic risk factors through awareness raising campaigns;
- Implementation of the systematic preventive measures on the facilities containing the geological risks that threaten infrastructure and tourist facilities;
- In order to effectively respond to the natural processes, it is necessary to establish, equip and train several units–rescue teams in the district. The teams should unite professionals. It is also necessary to include volunteers as the reserve force in the measures directed to the elimination and mitigation of the effects of the natural extremes;
- Georgia and Mestia Municipality as one of the most complex districts in terms of manifesting disastrous geological processes, is so much vulnerable to the natural disasters that in general it is necessary to raise the level of the readiness of the district population, for which it is recommended to add a school subject in the educational system.
- Currently, the task of managing disastrous geological processes is distributed among different executive branches which in case of weak coordination (which unfortunately takes place presently) complicates the development of the unified approach to the management of hazardous geological processes;
- This circumstance determines the necessity to improve and enhance the coordination mechanism. The coordination should be improved among the Mestia Municipality and other governmental agencies, namely, the Disaster Management Department of the Ministry of Internal Affairs of Georgia and National Environmental Agency, which is the structural unit of the Ministry of Environment and Natural Resources Protection of Georgia.
- Large scale campaign to inform the population about the practice of providing prompt aid.
- It is well known that geological and glacial research institutions were destroyed in the post-Soviet period. The population heard at the level of the rumors about the existence of sources of radiation in places freed from glaciers, which could cause radioactive pollution of water. These rumours may seriously influence psychological condition of the population, as well as the further development of the tourism industry. It is necessary to study this issue thoroughly, inform the population about it and take adequate measures;
- To prepare the action plan for the implementation of the abovementioned measures.

As mentioned above, Upper Svaneti together with its natural beauty is rich with **historical monuments,** which makes it even more attractive to tourists. Protection of these monuments from the negative impact of climate change is necessary not only for the development of the tourism sector, but also for preserving the distinctive identity of the local population and , in general, for the history of Georgia. These monuments are the important richness at the national, as well as the local and international levels. One of the villages in Ushguli Community, Chajashi, is the UNESCO World Heritage Monument.

In churches of Upper Svaneti, as well as other buildings, walls were built with well-trimmed pumice quadras, as well as with broken stones bound with lime mortar.

Climate variability, frequent winds and rains primarily influence lime mortar, cause its deflation and collapse under the influence of the increased exposure to moisture.

Humidity strongly affects the inner frescos of the churches, this is why when repairing and restoring the monuments, the main attention should be paid to the enrichment of lime solution with various modern admixtures for increasing its resistance/sustainability to humidity, the application of modern technologies in roofing in a way that does not violate the monument's authenticity and the construction of the drainage system around the monuments for reducing soil moistening from the walls.

It should also be mentioned that shingle was used in the region for roofing of the churches or Machubis, but slate was also widely used in Ushguli Community.

Shingle, as well as slate is one of the oldest roofing materials used in the mountainous areas of Georgia. The cover is also very practical at times of heavy snow- its surface is flat and slippery and snow hardly stalls on it.

If they used tiles widespread in lowlands of Georgia, along with the increasing weight of the construction; it would have made impossible slipping of snow or its cleaning. At the same time, shingle is the least stable construction material and this is why, it is necessary to use more sustainable modern roofing material that has the same features in the reconstruction process (lightweight material on which snow slips easily).

A major reason for damaging churches in Upper Svaneti is moisture, which affects both the building’s construction materials (stone and lime mortar), as well as paintings inside the churches. Dampness primarily affects the wall painting, causing the removal of plaster from the wall and its collapse. Color of the painting is also compromised and tarnished. In addition to the interior, the climate factors also destroy sculptural and painted decoration elements of the external walls of the churches, by which the temples in Svaneti are rich.

The following actions are considered for mitigating the growth of the risks **for historic monuments** at the background of climate changes:

- More thorough study of the impact of climate and its change on the Historical monuments by taking international experience into account, for which the inventory of the historical monuments located in Mestia should be conducted aiming at scrutinizing the impact of climate change on them and developing adaptation recommendations. This should be done by including already experienced international experts in these issues;
- Training national experts (Heritage specialists and restorers) in the modern methods of assessing the vulnerability of the monuments to climate change and their adaptation, which should be considered during the restoration. While working on these issues, we revealed a shortage of expertise and experts in Georgia;
- Developing the action plan for the rehabilitation of historic monuments and the adaptation to the climate change in Mestia District, which, along with traditional methods should incorporate the introduction of new technologies that are already used in the process of conserving cultural heritage in countries with similar geographic and climate conditions;
- Developing the strategy and the action plan for restoring historical monuments by taking climate change risks into account;
- The amount of the monuments in Mestia municipality and their conditions necessitates the establishment of the dual subordination organization (Mestia self-government body, Monument Protection Department of Georgia) for ensuring protection of the heritage in Mestia Municipality.

The healthcare sector is one of the most important sectors in terms of the vulnerability to climate change in Mestia Municipality. From the climate-dependent diseases in Upper Svaneti, the injuries, including psychological trauma should be considered the most widespread, from chronic pathologies - cardiovascular diseases (especially hypertension), respiratory diseases and deaths caused by them. The incidence and prevalence of these pathologies in the Upper Svaneti Region exceeds the same data from other regions. Among the morbid conditions listed above, traumas are the most common and troublesome. Their significant part are caused by the unorganized tourism.

The primary analysis of the situation demonstrates that the accessibility index to the medical services in Upper Svaneti Region is very low due to the lack of the medical infrastructure and the qualified medical personnel. In particular, the healthcare facilities, in addition to the fact that they are ill-equipped with basic medical supplies, their part is also located in places which are difficult to access and reach not only for the medical personnel, but also for the population.

Namely, the part of the medical outpatient centers located in the districts, in addition to being inadequately equipped with basic medical stuff, are located in the remote places that are difficult for access for the population. In case the patient requires medical assistance, s/he is sent from the medical outpatient center to the district hospital and in case of the absence of the specialist in the district level hospital, s/he is further referred to Zugdidi District Hospital, which is 137 km away from Mestia.

By taking all of this into account, the control of climate-dependent diseases and risk reduction, namely, physical and psychological traumas, cardiovascular and respiratory diseases is inadequate.

The Mestia **health sector** adaptation strategy to the negative impact of climate change considers the following actions:

- Establishment of the emergency medical service that will coordinate the rural primary health care/outpatient facilities, as well as district-level hospital-type institutions and will ensure their efficient operation, will equip them with the essential and other medical equipment for the primary emergency medical aid, including vehicles, as well as will provide the system with qualified/certified personnel, will develop the optimal employment and compensation schemes for the local medical personnel;
- Providing support to the provision of the health care system of Mestia Municipality with relevant infrastructure (setting up hospitals) and the appropriate medical personnel (orthopedist, psychotherapist, infectious disease specialist, cardiologist, neonatologists and others), who will be focused on specific climate-related disease management (prevention, treatment, post-traumatic rehabilitation);
- Promote the development of the healthcare system of the mountainous regions;
- Sharing international experience, which includes sharing and providing information about so-called Best Practices, which is directly related to the climate-dependent disease medical management in the mountainous region similar to Upper Svaneti;
- The development of the disaster medical management plan (DMMP) with the engagement of other sectors. One of its key components is the post-traumatic rehabilitation, which mainly involves the management of the post-traumatic nervous disorder syndrome;
- Monitoring and risk management of climate-sensitive diseases;
- Establishment of the early warning system that will enable and make easy the prevention and management of the climate-dependent diseases in the local healthcare sector for the local community as a result of the timely preparedness;
- Raising awareness of the representatives of the healthcare and tourism sectors in Upper Svaneti on climate-sensitive diseases;
- Improving health services in the tourism sector, for which it is necessary to mitigate the risks of climate change and especially, to prepare the action plan for the prevention of injuries.

In the process of assessing **forest massifs** of Upper Svaneti to climate change, two main zones should be distinguished. Their existence is determined by different climate conditions and soils existing on the territory of the municipality.

In particular, lower zone is situated in the downstream of Enguri Gorge (former Khaishi forestry), where the climate is temperate and humid and the higher zone is located above the middle part of Enguri Gorge (former Mestia forestry), which is characterized by dry continental climate. The impact of climate change on these zones is different. If for the time being, any specific impact of climate change on the territory of Khaishi Forestry has not yet been identified, the impact is clearly explicit on the territory of Mestia Forestry, where boreal forest species (pine and birch) were mostly dominant in the period following the retreat of the glaciers. Currently, pine is prevalent on the southern slopes and the boundaries of birch groves moved upper. They were gradually replaced by warm and humid climate loving species, such as beech, spruce and fir. This substitution is likely to be caused by the fact that these woody plants can better endure high temperatures than pine and birch. As birch tree belongs to the boreal forest species and is featured by cold and short vegetation period, this is why the increased temperature and the vegetation period stresses the birch groves. It should be also noted that the temporary favorable conditions are created for the alpine birch tree for lifting up its boundary, but it encounters hindering factors, such as unfavorable soil conditions, thin rocky soils, on which the birch plantation is not distinguished by good productivity.

It should be noted that the negative symptoms associated with climate change are not observed in Upper Svaneti forests, namely: The increase in fire incidences, spread of dangerous diseases, which has an expressed tendency toward the increase in other regions of Georgia. However, surface freshets and mudslides cause soil erosion in the forest groves and pastures.

Mestia's sustainable **forest** development strategy considers the following actions in the adaptation process to the negative impact of climate change:

In order to strengthen soil-protection functions and restore the degraded forests:

- Reforestation as the soil protective measure for stopping erosion on degraded pastures and wash offs, with the purpose of their further prevention;
- Enhancing the capacity/potential of forests as a CO_2 sink source, which implies a reduction of its age and improving its quality (increasing the thikness) to the level of the quality forest;
- Examining alternatives to the forest privatization (community forests, tourism sector forests, etc.);
- Preparing the action plan for the sustainable development of the forest sector.

Mestia District and especially its alpine villages are deprived of energy resources despite the fact that there is a serious hydropower potential. Thermal energy is especially in shortage here. Due to lack of forests in the alpine zones, the residents need to buy firewood in lowland districts and transport it to long distances. At the same time, there is a great potential for the development of the biogas systems in the municipalities, as the population is mainly engaged in animal husbandry and almost every family has 10 and more cattle heads here. Technologies existing and available in Georgia are difficult to use in the mountainous and cold regions. It is necessary to thoroughly study the international practice and import and introduce the biogas technologies that are acceptable for Mestia's cold climate. This on the one hand will reduce the emission of methane in ambient air and on the other hand will promote production of high-quality organic fertilizer. At the same time it will improve energy sustainability of the region and will also significantly promote the development of the tourism sector.

The following actions are considered in the strategy for the development of **renewable energy resource** in Mestia:

- Conducting the survey of the technical and economic feasibility of energy resources (biogas, solar power) in Mestia Municipality;
- Searching for the modern technologies of renewable energy (biogas, solar power) and assessing the potential of their application with the help of international experts;
- Implementation of pilot projects in order to dully identify barriers;
- Training of volunteer groups interested in these issues;
- In general, raising public awareness about the benefits of the utilization of renewable resources to the maximum possible extent;
- Developing the action plan for the efficient use of renewable resources in Mestia Municipality.

Climate and Agro-Climate Zones. As a result of the terrain diversity and the large difference in elevation, the territory of Upper Svaneti is characterized by the diversity of climate zones. The lowest point of the region is Jvari Reservoir (500 m ASL), while the highest point is – Shkhara, the highest peak in Georgia (5 232 m ASL).

According to the 1980 year data, 5 climate zones are in Upper Svaneti, from which the lowest (Khaishi Meteorological Station) directly borders the marine subtropical climate zone (the closest typical station - Zugdidi). The nival zone covered by permanent snow and glaciers occupies quite large area in the northern part of the Region.

According to the study conducted within Georgia's Third National Communication on Climate Change, it is expected that the average annual temperature for the period of 1986-2010 will increase by 4.0^{0}C in Mestia, while the sums of annual precipitation will remain virtually the same (as in the period of 1961-1990).

If this last amount is within the variation of annual precipitation and does not contain a major threat, the predicted temperature increment is very alarming and will be able to bring far-reaching changes in the natural ecosystems, as well as in the economy.

In particular, this temperature increase will be followed by the transformation of the climate zones of Upper Svaneti, which most likely will lead to their following redistribution:

The humid warm zone typical for Zugdidi invades the neighboring Khaishi climate zone, other climate zones are lifted up by about 700 meters and the lower boundary covered with permanent snow and glaciers, which in the beginning of the XXI century was at approximately 3 200 m ASL will be lifted to the altitude of 4 000 ± 200 m ASL.

These results were obtained based on the climate data of the meteorological stations located in the region and its nearby areas (Mestia, Khaishi and Zugdidi). For example, the average annual temperature increase in Khaishi for 2100 will bring closer its thermal regime to Zugdidi's current thermal regime with approximately 14.5 ^{0}C, while Mestia's thermal regime (T mean = 9.8 ^{0}C) will become almost similar to the current regime in Lentekhi (9.4 ^{0}C).

The change of the climate zone thermal regime will bring relevant changes to the region's climate and agroclimate zones. Therefore, it will be necessary to make some changes to the traditional activity of the population. Probably, the current climate warming in general will benefit the development of agriculture in Upper Svaneti, if the sudden drop in atmospheric precipitation does not prevent it and the reduction of river runoff as a result of the glacier degradation, as well the micro-climate change as the result of the complete meltdown and other issues related to the transformation of landscapes do not hinder this development.

Agriculture occupies an important place in the economy of Upper Svaneti. Almost 90% of the local population is employed in this sector.

At this point, the leading agricultural activities in the municipality are animal husbandry, potato production, production of cattle forage (hay), apiculture and pomiculture. More than 99% of the municipality inhabitants are small farmers. Peasant farms produce most of the agricultural products. At present, potato production is one of the leading sources of income for the local population. As mentioned above, geological disasters as a result of global warming are significantly activated in Mestia Municipality.

The increase in the frequency and intensity of these events (floods, landslides and mudslides), the changes of the temperature regime and the precipitation amount caused strong erosion of the agricultural lands and resulted in significantly reducing the humus layer of brown soil that was followed by the decline in soil fertility and the sharp drop of the productivity levels. The irrigation systems of the agriculture sector virtually were completely broken. As the result of the negative impact of climate change (frequent precipitation and hard frosts in the spring period), a massive drying up of the walnut trees are observed throughout the region, which negatively impacts the income of the Upper Svaneti population.

Natural disasters destroyed secondary roads and bridges connecting to agricultural and vital meadows and pastures, 10 ha arable and hay lands are washed off, which is a great loss for the land-poor Svaneti. The population has problems in the period of harvesting and storing hay, beans and corn.

The adaptation strategy to the expected climate change in the climate and agro-climate zones of Mestia Municipality considers the following actions:

- Systematic monitoring of the impact of climate change on the ecosystems and the economic sectors and the assessment of the expected risks;
- More attention should be paid to the agricultural sector, because this sector is the main sustenance of the local population. Along with raising awareness on the shifting of the zones related to climate change, it is necessary to provide the sector with new agricultural technologies and the recommended agro-crops;
- Developing the risk prevention and adaptation strategy and action plans;
- Systematic monitoring of the impact of climate change on the ecosystems and the economic sectors and the correct assessment of the use of these changes;
- Developing the strategy and action plan to utilize the positive impact of climate change to the maximum extent;
- Raising awareness of the population regarding the current and expected changes in climate in order to utilize the positive changes and minimize the risks to the maximum extent.

4.2. Mestia Municipality Adaptation Strategy to Climate Change

(The strategy reviews the period until 2025)

The strategic action plan of adaptation measures to climate change in Mestia Municipality was developed at the workshop held on 24 June 2014 in the hotel "Tetnuldi"/Mestia Borough.

Main Strategic Goal	Target Group	Action	Potential Leading Organization	Expected Results	Potential Donors
1. Tourism					
1.1. A local weather forecast service should be established, which will collect information from NEA (National Environmental Agency) and will have the potential to provide recommendations based on received information in order to fully secure tourist movements.	Leadership of Mestia District The local tourism agency The local branch of the Ministry of Health and Social Welfare NEA Flight Safety Department of Mestia Airport Quick Response Department of the Ministry of Internal Affairs	A special service in the Mestia Municipality or at the Flight Safety Department of Mestia Airport should be established in Mestia Municipality (e.g., Tourism Security Service), which will be responsible for constantly being aware of the climate risks; The Tourism Safety Service must be equipped with necessary modern appliances, which will enable the agency to always have information about the processes occurring in the atmosphere and the possible risks; The climate parameters that cause geological and other types of hazards in Mestia District should be determined. The action plan	Most probably, there is a need to establish the Tourism Security Service in the municipality or at the Flight Safety Department of the Airport. This function may be carried out by the Municipality or any existing service.	The Tourism Security Service regularly prepares information about the potential risks for the tourists (not just for tourists traveling on the tourist routes); Organized and unorganized traveling tourists have access to information about the potential threats and the security measures in all types of travel agencies and hotels; The group that was trained and equipped appropriately will be mobilized and activated	Ministry of Regional Development and Infrastructure Aviation Service of Georgia Department of Tourism Local self-government Climate change adaptation funds ENVSEC

		should be prepared for the timely submission of information and ensuring security; This Service shall be provided with a reliable communication system and should have an access to several sources of information on the weather forecast for cases if information could not be obtained from one of the sources in a timely manner.		in case of special hazards.	
1.2. Risks on existing and new tourist routes that are determined by climate change must be examined to the maximum extent (frequent rockfall, starting rockfall earlier than it was previously known, mudflow or landslide hazard areas);	Leadership of Mestia District; NEA Mestian Mountaineering Association	Employees of the Tourism Security Service shall be constantly provided with the theoretical and practical training in modern methods of risk prediction; This service should be staffed mainly by geologists and mountaineers who are well familiar with the local environment and possible hazards. In other cases, they should receive intensive trainings on issues related to the geological events and issues related to the specifics of the mountain; Knowledge possessed by the local population and climbers, which may not always be scientifically justified and supported, should be reviewed and applied to the	Tourism Security Service	A potential has been developed in Mestia to regularly (daily) assess risks related to climate change; Information is regularly supplied to the relevant and trained stakeholders (travel agencies, hotels) for further dissemination;	Ministry of Environment and Natural Resources Protection of Georgia GEF; EU; USAID; UNDP.

		maximum extent in the risk assessment process.			
1.3. Safety rules for the movement on the tourist routes must be developed. They should be available for tourists upon arrival in hotels and tourism service centers;	NEA/Ministry of Environment and Natural Resources Protection of Georgia Leadership of Mestia District Local mountaineering and alpinism associations Mountain Affairs Institute	Based on local knowledge and materials related to the mountain tourism that is available at the international level, materials regarding potential risks and safety rules should be prepared; Flyers/leaflets, illustration materials and various types of references, which will benefit and be used by tourists and tourism services should be prepared and printed based on these materials.	Tourism Security Service	Reference materials are prepared for tourists (this is especially important for tourists traveling in an unorganized manner)	UNEP; GEF; NEA Various financial mechanisms operating at the UNFCCC; Non-governmental sector.
1.4. Tourism Safety Department should have information about risks faced by the winter tourism (e.g., on snow cover, anticipated avalanches, increasing temperature and humidity, etc.);	NEA/Ministry of Environment and Natural Resources Protection of Georgia Leadership of Mestia District Local mountaineering and alpinism associations Mountain Affairs Institute	Based on the materials related to the winter tourism that is available at the international level, as well as on the basis of information available at NES that are related to the climate risks in the winter period, the materials on expected risks and safety rules should be prepared; Flyers/leaflets, illustration materials and various types of references, which will benefit and be used by tourists and tourism services should be prepared and printed based on these materials.	Tourism Security Service	Reference materials are prepared regarding the winter tourism and the risk mitigation (this is especially important for tourists traveling in an unorganized manner)	UNEP; GEF; NEA Various financial mechanisms operating at the UNFCCC Non-governmental sector
1.5. Establishment of the special	Ministry of Labour,	Establishment of a special division	Mestia Public	The Service operates and	Ministry of

medical service and equipping it with the modern equipment in order to enable its prompt arrival to the scene of accident and provision of the assistance if necessary;	Health and Social Affairs of Georgia; Insurance companies; Leadership of Mestia District; Local tourism agency.	at the Healthcare Department of Mestia Municipality, which will serve the tourists in case of a need; The Service must be equipped with modern technologies and knowledge of the risks and the rehabilitation of the negative consequences of the mountain tourism (on winter, as well as the mountain tourism in general) Medical personnel must at least speak English and Russian.	Health Service	functions effectively during the year; Service is equipped with modern technologies and knowledge; In case of a need, it will serve the local population.	Labour, Health and Social Affairs of Georgi; Insurance companies
2. Mitigation of Geological Risks Caused by Extreme Weather Events					
2.1. Establishment of the coherent system of the monitoring and early warning network based on a modification of the existing ones (for which the experience of the advanced countries will be used):	Leadership of Mestia District NEA Ministry of Regional Development and Infrastructure; Emergency Situation Management Center	The monitoring and early warning system of particularly dangerous geological processes (on the basis of the existing one) should be established on the ground; The system must be equipped with modern technologies and knowledge; Regular monitoring should be carried out in the high-risk for the population areas; Regular monitoring should be carried out in places containing threats to major infrastructure facilities (mainly roads);	Leadership of Mestia District NEA	A permanent monitoring system of geological extreme is established locally in Mestia; The system is equipped with modern knowledge and risk assessment methodologies; The system is provided with a continuous weather forecasts;	Adaptation funds operating within UNFCCC GEF ENVSEC UNDP
2.2. Implementation of	Leadership of Mestia	In cooperation with NEA, the	Local geological	The existence of	Adaptation Fund of

preventive measures for the reduction of anthropogenic risk factors causing natural geological processes. Mainly in the hazardous for the population zones;	District NEA Ministry of Regional Development and Infrastructure; Emergency Situations Management Center Local population	locally established agency should plan and carry out preventive measures by reducing anthropogenic factors; It is necessary to involve to the maximum extent the population in the process of reducing the anthropogenic risk factors by raising awareness of the population and through its direct involvement in the planning process; It is necessary to inform the population and make mandatory the practical training in renderingmedical first aid in case of injury. The long-term action plan for the implemention of preventive measures should be developed. Monitoring of the results and the improvement of the measures by taking into account identified errors and barriers should be implemented within these preventive measures; International good practice involving insurance companies should be explored.	service established in Mestia	anthropogenic factors in particularly hazardous geological zones are examined and in case revealing such zones, the mitigation measures are designed; The population is well aware of the current processes and the possible consequences and where possible, is actively involved in the implementation of preventive measures; The population has minimum medical education required for providing the initial assistance in case of injuries; The local government has a plan and a vision of how to act in case of the threat-enhancement;	the Framework Convention on Climate Change Ministry of Regional Development and Infrastructure of Georgia (MRDI) Mestia Municipality GCF[37]

[37] Green Climate Fund, which among others funds the implementation of adaptation projects

				The possibilities and conditions for the inclusion of insurance institutions in the preventive measures are examined.	
2.3. Implementation of the systematic preventive measures at the facilities containing the geological risks that threaten infrastructure and tourist stablishments;	Leadership of Mestia District NEA Ministry of Regional Development and Infrastructure; Emergency Situation Management Center	In cooperation with NEA, the locally established agency should plan and carry out preventive measures by reducing anthropogenic factors; The long-term action plan for implementing preventive measures should be developed. Monitoring of the results and the improvement of the measures by taking into account identified errors and barriers should be implemented within these preventive measures; It is necessary to prepare project proposals for the implementation of the preventive measures and discuss the various mechanisms and schemes to attract funds for these projects.	Local Geological Agency/Service	The existence of anthropogenic factors for infrastructural facilities in particularly hazardous geological zones are examined and in case of revealing such zones, the mitigation measures are designed; Local authorities and the national government are aware of the current situation and the possible consequences and are actively involved in the implementation of the preventive measures where possible; The local government has a plan and a vision of how to act	Adaptation Fund of the Framework Convention on Climate Change Ministry of Regional Development and Infrastructure of Georgia (MRDI) Mestia Municipality GCF Other donor organizations

				in case of the threat-enhancement.	
2.4. In order to effectively react to the natural processes, it is necessary to establish, equip and train several units-rescue teams in the district. The teams should unite professionals. It is also necessary to include volunteers as the reserve force in the measures directed to the elimination and mitigation of the effects of natural disasters;	NEA Local Mountaineering Association Local Medical Service Mestia Municipality and Council (Sakrebulo)	A professional rescue team(s) should be established in Mestia, which will be well equipped with modern methods and technologies. These units will serve the local population, as well as the tourism sector; Professional group must consist of at least a mountain-climber, geologist and physician-orthopedist. It is also possible to include a mountaineer-doctor/alpinist-geologist and others in the team. Volunteer rescue units should be established in Mestia that will systematically be trained in modern techniques and will be used mainly by principal/professional groups; A precise mobilization plan should be developed, which will calculate and will be adapted to a variety of threats.	Tourism Security Service	Care on the population, infrastructure facilities and security of tourists is improved in Mestia; Permanent monitoring systems are operating; Professionals and volunteer rescue units are trained; The emergency action plan is developed and its implementing agency is established.	Adaptation Fund of the UNFCCC Ministry of Regional Development and Infrastructure of Georgia (MDF) Mestia Municipality GCF Other donor organizations
2.5. Raising the level of preparedness of the population by taking high vulnerability of Mestia District to natural disasters into account. It is desirable to raise the general	Ministry of Education and Science of Georgia NEA Mountaineers and	Manuals and illustrative materials at different levels should be prepared to be submitted to the students at different levels; Local teachers should be	Education Resource Center in Mestia Municipality Non-	Special textbooks and visual materials for local schools about the dangers and hazards existing in Mestia District and	Non-governmental sector Ministry of Education and

level of the readiness of the district population, for which it is recommended to add a school subject in the educational system.	Alpinists Association/Union Mestia Municipality	continuously trained in climate change, hazardous geological events and preventive or rescue activities; Senior students should undergo additional special trainings in rescue work and first aid;	governmental sector	the preventive measures that need to be implemented are prepared; Groups of the school teachers are trained; Senior students are systematically trained in skills that are necessary to participate in rescue operations.	Science NES UNEP UNDP Other donor organizations
2.6. Management of natural geological processes is distributed among various agencies of the executive branch, which in conditions of the weak coordination (which unfortunately is the case in Georgia at present) complicates the management of natural disasters. It is necessary to further elaborate-improve the coordination mechanism and to review this issue in the relations of the Mestia municipality and government agencies (Emergency Department of the Ministry of Internal Affairs, Ministry of Environment and Natural Resources Protection and its structural unit - National Environmental Agency)	Leadership of Mestia District Emergency Department of the Ministry of Internal Affairs The Ministry of Environment and Natural Resources Protection and its structural unit - the National Environmental Agency.	Coordination should be strengthened not only among the various ministries and agencies at the national level, but also among the state agencies and the local authorities that are dealing with the ecosystems in Mestia, in ensuring the population and the municipality with security of the economic sectors; Rights and responsibilities of the central government and local agencies should be delineated; The central government should encourage the development of local resources and potential to the maximum extent.	Leadership of Mestia District	Coordination among the various ministries and agencies responsible for effective disaster risk prevention is established at the national level; Coordination is effective among the national government and Mestia Municipality. The local potential to instantly respond to the threats and the systematic preventive measures is established in Mestia	The Government of Georgia UNDP USAID ENVSEC Other donor organizations

				Municipality.	
2.7 Development of the action plan for the implementation of listed measures.	Leadership of Mestia Municipality Emergency Department of the Ministry of Internal Affairs; Ministry of Environment and Natural Resources Protection and its structural unit - the National Environment Agency; Ministry of Education and Science of Georgia; Mountaineers and Alpinists Association/Union; Mestia Tourism Information Center; Education Resource Center in Mestia District;	Roles and responsibilities of all stakeholders should be assessed; shortcomings and barriers to the implementation of the strategy should be identified; Risk zones and degree of threats should be assessed, the minimum potential necessary for the development of Mestia Municipality should be clearly identified; The action plan should include real options for developing the existing potential and the coordinated mechanism of the action in case of a threat.	Mestia Municipality	The action plan on how to react to dangerous geological situations is developed in Mestia District	Mestia Municipality UNDP USAID
3. Adaptation of Historic Monuments (Reducing Vulnerability)					
3.1. A detailed examination of the impact of climate and its change on historical monuments of Mestia by taking the international experience into account, for which it is necessary	Local agency responsible for the protection of cultural heritage; Ministry of Culture and Monument Protection of	Inventory of the monuments in Mestia municipality to assess the impact of climate change by using modern methodologies and technologies	National Agency for the Protection of Cultural Heritage of	A report on the historical monuments in Mestia upon which the negative impact of climate change is observed (mainly,	UNFCCC adaptation funds UNESCO Various donors

to conduct a complete inventory of the historical monuments in Mestia District considering their vulnerability to climate change.	Georgia;		Georgia;	moisture and precipitation increase) is prepared.	from countries having solid experience in the field (Italy, Britain)
3.2. Training national experts (monument protection specialists and restorers) in modern methods of assessing the vulnerability of monuments to climate change and their adaptation, which should be considered during the restoration. The lack of the appropriate local expertise and experts in Georgia was identified during the work on these issues;	National Agency for the Protection of Cultural Heritage of Georgia; Ministry of Education and Science; Tbilisi State Academy of Arts (Restorers); Georgian Technical University (Strength of Materials)	Manuals and illustrative materials should be prepared that will be used for teaching the restorers of historical monuments about the impact of climate change on historical monuments, as well as various risk mitigation measures; Knowledge on climate parameters, the impact of climate change on the historical monuments and modern methodologies of risk prevention should be provided to the students at the faculties of the Restoration and Strength of Materials (in relevant higher education institutions).	National Agency for the Protection of Cultural Heritage of Georgia;	Manuals and illustrative materials are prepared that will be used for teaching the restorers of historical monuments the impact of climate change on relics of the past, as well as various risk mitigation measures; Expert-restorers are trained in Georgia who are able to assess the impact of climate change on historical monuments and plan their restoration by taking these risks into account; Restoration and adaptation projects are developed for the most important historical and attractive to tourists monuments potential that take into account the threat posed by	UNEP UNESCO EU

				climate change and their mitigation and elimination.	
3.3. Detailed examination of the impact of climate change on historical monuments and development of adaptation recommendations (project proposals)	National Agency for the Protection of Cultural Heritage of Georgia; NEA Mestia Municipality	Based on the dangers/threats revealed in the process of conducting the inventory, the monuments should be prioritized and project proposals should be developed for raising funding. For the development of the project proposals it will be necessary to utilize the international practice, for which experienced international experts should be invited to the project. Along with the traditional methods, adaptation projects should take into account the introduction of new technologies, which are already used for the conservation of cultural monuments in countries with similar geographic and climate conditions.	National Agency for the Protection of Cultural Heritage of Georgia;	Restoration and adaptation projects are developed for the most important historical and attractive to tourists monuments potential that take into account the threat posed by climate change and their mitigation and elimination.	Adaptation Fund of the Framework Convention on Climate Change CDM CGF UNEP UNESCO EU
3.4. Development of the Action Plan for the rehabilitation of historical monuments in Mestia District and the adaptation to climate change.	National Agency for the Protection of Cultural Heritage of Georgia; National Tourism Administration of Georgia	Relevant ministries, local authorities in Mestia and other stakeholders should participate in the development of the Action Plan that will envisage the rehabilitation of the historical monuments and their protection from the risks caused by climate	National Agency for the Protection of Cultural Heritage of Georgia;	The Action Plan for rehabilitation of the historical monuments in Mestia District and their protection from the risks caused by climate change is developed.	National Communications on Climate Change UNEP EU

	Ministry of Culture and Monument Protection of Georgia; Administration of Mestia Municipality	change.			Various donors
4. Developing Potential of the Local Healthcare Sector					
4.1. Supporting the provision of the health care system in Mestia Municipality with relevant infrastructure (the establishment of medical facilities) and personnel (orthopedist, psychotherapist, infectious disease specialist, cardiologist, neonatologists and others) who will be oriented towards the management of the climate-dependent diseases (prevention, medical treatment, post-traumatic rehabilitation)	Public Healthcare Service of Mestia Medical personnel Ministry of Health and Social Welfare Leadership of Mestia Municipality	A detailed needs assessment of Mestia's healthcare system should be conducted (the number of the medical facilities, their location, also the number of the medical staff) Development of the medical facilities equipped with modern technologies. Raising qualification of the local medical personnel/their training for the better management of the climate-dependent diseases.	Public Healthcare Service of Mestia	Medical facilities with qualified medical personnel are established in Mestia District and serve the local population, as well as tourists. Medical facilities are equipped with modern equipment and are located in places that are easily accessible.	Adaptation Fund of the Framework Convention on Climate Change WHO USAID Other donors
4.2. Sharing the international experience, which includes receiving information and sharing the so-called Best Practices that directly relate to the management of the climate-dependent diseases in the mountainous regions similar to Svaneti;	Public Healthcare Service of Mestia Medical personnel Leadership of Mestia Municipality	Searching examples by the international expert(s) on the existing Best Practice in the regions having the similar complexity, conducting the comparative analysis and informing the stakeholders (primarily Mestia Public Health Service) about the recommendations through organizing workshops and seminars.	Ministry of Health and Social Welfare	A document is drafted, which provides the comprehensive comparative analysis of the international experience and the situation in Mestia in terms of the medical management of the climate-dependent diseases;	Ministry of Health and Social Welfare International donors

				Illustrative materials are prepared; Stakeholders (healthcare professionals) have comprehensive information about the necessity to implement the medical management of climate-related diseases.	
4.3. The development of the Disaster medical management plan (DMMP) with the engagement of other sectors. One of its key components is the post-traumatic rehabilitation, which mainly involves the management of the post-traumatic nervous disorder syndrome;	Emergency Department of the Ministry of Internal Affairs; Ministry of Health and Social Welfare Public Healthcare Service of Mestia Medical personnel Administration of Mestia Municipality	DMMP development by international and local experts; Discussing the plan with the stakeholder participation through trainings and workshops; Facilitating the establishment of the post-traumatic rehabilitation center in Mestia Municipality.	Public Healthcare Service of Mestia	The medical management plan of natural disasters is developed for Mestia Municipality; The post-traumatic rehabilitation center is operating, the medical personnel has relevant qualifications.	WHO UNEP ENVSEC Other international donors Adaptation mechanisms and funds to the Convention on Climate Change
4.4. Monitoring and risk management of climate-sensitive diseases;	Ministry of Health and Social Welfare Public Healthcare Service of Mestia	The development of the monitoring and management plan of the climate-dependent diseases; Training of the primary healthcare staff in Mestia on issues related to the monitoring and management	Ministry of Health and Social Welfare	The monitoring and management plan of the climate-dependent diseases is developed. The local primary	Ministry of Health and Social Welfare of Georgia Various

		of the climate-dependent diseases.		healthcare staff in Mestia has information on the results of the monitoring and management.	international donor agencies
4.5. Establishment of the early warning system that will enable and make easy the prevention and management of the climate-dependent diseases by the health care sector for the local community as a result of the timely preparedness;	Ministry of Health and Social Welfare Public Healthcare Service of Mestia Local population Mestia Municipality Emergency Department of the Ministry of Internal Affairs; LEPL NEA of the Ministry of Environment and Natural Resources Protection of Georgia	Development of the structure of the early warning system, adapting it to the local conditions of Mestia with the inclusion of international and/or national experts in the process. Raising awareness of the agencies involved in the early warning system on the management of climate-dependent diseases and on the importance of the early warning system.	LEPL NEA of the Ministry of Environment and Natural Resources Protection of Georgia Public Healthcare Service of Mestia	The early warning system is established and informs responsible structures about the expected threats in a timely manner. Agencies involved in the early warning system have information about the risk prevention and the management	Adaptation funds of the Framework Convention on Climate Change
4.6. Raising awareness of the representatives of the healthcare and tourism sectors in Upper Svaneti on the climate-sensitive diseases;	Public Healthcare Service of Mestia Tourism Security Service of Mestia National Tourism Agency	Development of the training modules (training materials) on the management of the climate-dependent diseases; Raising awareness of the representatives of the healthcare and tourism sectors about the climate-sensitive diseases in Upper Svaneti through trainings, risks	Tourism Security Service of Mestia Ministry of Health and Social Welfare of Georgia	Training materials are developed for trainings; Representatives of the Upper Svaneti healthcare and tourism sectors have information about climate-dependent	International agencies Non-governmental sector Georgia's National Communications on Climate Change

		caused by them and the modern methods of their modern management.		diseases. Coordination between the tourism and healthcare sectors is enhanced, as well as their coordination with other parties (e.g., NEA).	UNEP
4.7. Improving health services in the tourism sector, for which it is necessary to mitigate the risks of climate change and especially, to prepare the Action Plan for the prevention of injuries.	National Tourism Agency Tourism Security Service of Mestia Ministry of Health and Social Welfare of Georgia Public Healthcare Service of Mestia NEA Local Mountaineering Association	Development of the Action Plan to mitigate risks caused by climate change with the special focus on the prevention of injuries;	Public Healthcare Service of Mestia	The Action Plan for the prevention of risks associated to climate change and in particular, the prevention of injuries is developed; The medical staff working in the tourism sector is aware on the issues related to the climate change risk reduction and especially, the prevention of injuries.	WHO UNEP ENVSEC Other international donors Adaptation mechanisms and funds to the UNFCCC
5. The Forestry Sector Adaptation Strategy of Mestia District					
5.1 Afforestation and reforestation as a soil protection measure on degraded pastures for stopping erosion and preventing wash offs;	National Forestry Agency Service (Samegrelo-Upper Svaneti Regional Forestry Department); Local self-government.	Planning the identification and rehabilitation of degraded, washed off and eroded areas; Preparation of proposals; Palnting of the soil protection forests.	Samegrelo-Upper Svaneti Regional Forestry Department);	Areas in need of rehabilitation are specified; Pilot projects are developed; Further degradation	National Forestry Service GIZ ADA

				of soil is suspended as a result of the afforestation; Degradation of pastures adjacent to the rehabilitated areas is stopped; The local potential for conducting the monitoring of the forests is developed/enhanced. This is necessary not to reduce the soil protection potential of forests.	UNDP USAID Various adaptation mechanisms operating in the forest sector of the UNFCCC
5.2 Enhancing the capacity/potential of forests as the CO2 sink, which implies the reduction of its age and imrpoving its quality (increasing the thickness) to the level of the quality forest;	National Forestry Agency (Samegrelo-Upper Svaneti Regional Forestry Department); Local self-government. Local population/rural communities.	Cut forest areas around the settlements should be mainly restored; Planting of new mixed forests (coniferous, deciduous and fruit bearing species, e.g., pear, apples, etc.).	Samegrelo-Upper Svaneti Regional Forestry Department	Capacity of the forests as the CO2 sink is increased; Diversity of the forest ecosystem is increased; Consumption of the non-woody forest resource by the population is increased.	National Forest Service GIZ ADA UNDP USAID Various adaptation mechanisms operating in the UNFCCC forestry sector of the UNFCCC

5.3 Examining alternatives to the forest privatization (community forests, tourism sector forests, etc.);	National Forestry Agency (Samegrelo-Upper Svaneti Regional Forestry Department); Local self-government. Local population/rural communities. Private sector (including the tourism service sector).	Alternative ways to forest privatization should be developed through active consultations with all stakeholders; Development of the action plan to assess the barriers existing in the forest privatization process and the ways to overcome them.	Ministry of Environment and Natural Resources Protection of Georgia	Alternative ways to the sustainable forest management are searched for and assessed in terms of their implementation; The population, rural communities and local administration are informed about the prospects for the sustainable forest management.	Mestia Municipality; National Forestry Agency; Ministry of Environment and Natural Resources Protection of Georgia GIZ ADA UNDP USAID Various adaptation mechanisms operating in the forest sector of the Convention to Climate Change.
5.4 Preparing the Action Plan for the sustainable development of the forest sector	National Forestry Agency (Samegrelo-Upper Svaneti Regional Forestry Department); Ministry of Environment and Natural Resources Protection of Georgia	Preparation the sustainable forest management Action Plan with active consultations of all stakeholders and by taking climate change risks into account (Development of the forest utilization plan by taking climate change risks into account, cultivation of soil protective forests, efficient use of the excess/surplus biomass received from forest)	Ministry of Environment and Natural Resources Protection of Georgia	The Action Plan for the sustainable management of forests in Upper Svaneti by taking climate change risks into account is developed (restoration of the cut down soil protection forests, effective management of forest use)	Ministry of Environment and Natural Resources Protection of Georgia National Forest Service Mestia Municipality GIZ ADA Non-governmental sector
6. Promotion of the Development of the Renewable Energy (Biogas, Solar) Development					
6.1 Conducting the inventory of the technical and economic	Administration of Mestia Municipality	A non-governmental organization that will work in the renewable	The NGO sector established	There is the potential for the	Mechanisms of the UNFCCC, which

feasibility of the use of renewable energy resources (biogas, solar) in Mestia Municipality;	Local population Non-governmental sector working on the renewable energy resources Ministry of Environment and Natural Resources Protection of Georgia Ministry of Energy of Georgia	energy and energy efficiency sector should be established in Mestia District; This non-governmental organization should conduct the inventory of the renewable resources (biogas, solar) in the municipality in terms of their technical and economic applicability; Climate conditions in Mestia should be considered during the evaluation process (in particular, long winters and very low winter temperatures) and modern technologies related to the renewable energy (biogas, solar) should be searched for by taking these factors taking into consideration and the potential of using them in Mestia should be assessed by the international experts;	specially for this purpose (for working on the issue of renewable energy).	implementation of the renewable energy and energy efficiency projects in Mestia District; Local renewable energy is registered; Technologies acceptable to the climate conditions of Mestia District are searched for.	fund the greenhouse gases reduction (CDM, NAMA, GCF, GEF) GIZ USAID; EU
6.2 Implementation of a variety of many pilot projects in order to dully identify barriers;	Non-governmental organization, which will be established in Mestia; Energy Efficiency Center (EEC); Other non-governmental organizations that are working on renewable energies.	Promising project proposals should be prepared for utilizing the new technologies of the renewable energy in harsh climate conditions; The local community should be involved in the project identification and preparation process as much as possible.	Non-governmental organization, which will be established in Mestia and will work on renewable energy	Promising project proposals that promote utilization of the new technologies in Mestia is developed; The local community is involved in the project identification and preparation process.	Mechanisms of the UNFCCC, which fund the greenhouse gases reduction (CDM, NAMA, GCF, GEF) GIZ USAID EU CTCN

6.3 Training of local volunteer technical groups interested in these issues;	Non-governmental organization, which will be established in Mestia; Energy Efficiency Center (EEC); Other non-governmental organizations that are working on renewable energies.	It is necessary to train the technical team locally that will serve to renewable technologies; The group must undergo through the intensive training in renewable technologies and should be equipped with the proper equipment.	Non-governmental organization, which will be established in Mestia;	The technical team who serves to renewable technologies is trained locally;	Mechanisms of the UNFCCC, which fund the greenhouse gases reduction (CDM, NAMA, GCF, GEF) GIZ USAID EU CTCN
6.4 In general, raising public awareness about the benefits of the utilization of renewable resources to the maximum possible extent;	Non-governmental organization, which will be established in Mestia; Mestia self-government; Local population.	A large part of the renewable technologies is not yet brought to a commercial level. Their operation requires a great deal of work and is not very comfortable (e.g., the biogas digester requires certain knowledge and is difficult to operate in the harsh climate conditions). Therefore, it is necessary to train the population in advance for overcoming expected difficulties.	Non-governmental organization, which will be established in Mestia;	Local residents are well aware of renewable technologies and have sufficient knowledge on the proper operation of these technologies in the sever climate.	UNEP GIZ USAID EU CTCN Non-governmental sector
6.5 Developing the Action Plan for the efficient use of renewable resources in Mestia Municipality.	Non-governmental organization, which will be established in Mestia; Other non-governmental organizations that are working on renewable energies.	The renewable energy development Action Plan in Mestia shall be prepared, where the harsh climate in Mestia and its mountainous villages as well as the technologies available at the international market and inGeorgia will be considered; The potential for the implementation of the Action Plan should be developed locally.	Non-governmental organization, which will be established in Mestia;	The renewable energy development action plan in Mestia is prepared. The potential for the implementation of this action plan in Mestia District is developed.	Georgia's National Communications on Climate Change UNEP GIZ USAID EU CTCN Non-governmental sector

7. Long-Term Adaptation Strategy to Climate Change for Mestia District (after 2025) Adaptation to the Changes in Climate Zones					
7.1 Systematic monitoring of the impact of climate change on the ecosystems and the economic sectors and the assessment of the expected risks;	Climate Change Division of the Ministry of Environment and Natural Resources Protection of Georgia Mestia self-government;	Development of the risk prevention and adaptation strategy and action plan to the changes expected in the climate and agro climate zones that are associated to climate change; Informing the population and the local leadership regularly regarding the current and expected changes in order to minimize the risks.	Climate Change Division of the Ministry of Environment and Natural Resources Protection of Georgia	The risk prevention and adaptation strategy and Action Plan to the changes expected in the climate and agro climate zones that are associated with climate change is developed. The population and the local leadership are regularly informed regarding the current and expected changes and implementation measures.	Georgia's National Communications on Climate Change Adaptation funds within the Convention that work on strategies GEF UNEP
7.2 Systematic monitoring of climate change impact on climate change, the ecosystems and the economic sectors and the correct assessment of the potential use for the use of these changes;	Climate Change Division of the Ministry of Environment and Natural Resources Protection of Georgia	Preparing the strategy and action plan to maximize the use of the positive impacts of climate change. Informing the population and local leadership regularly regarding the current and expected changes in order to maximize the use of the positive impacts of climate change.	Climate Change Division of the Ministry of Environment and Natural Resources Protection of Georgia	The strategy and Action Plan to maximize the use of the positive impacts of climate change in the climate and agro-climate zones are prepared. The population and local leadership are regularly informed regarding the current and expected changes that need to be implemented to maximize the benefits from these changes.	Georgia's National Communications on Climate Change Adaptation funds within the Convention that work on strategeis GEF UNEP

5. Project Proposals

5.1. Planting of Soil Protection Forests on Eroded Slopes and Establishment of Forest Nurseries in Upper Svaneti

5.1.1. Problem Description

Forest massifs in Upper Svaneti are located in the basins of Inguri River and its major tributaries - Adishi, Mulkhura, Dolra, Nenskra and Nakra. The areas that are covered by forests lie mostly on steep slopes and deep gorges. The distribution in Upper Svaneti of areas covered by forests according to the slope inclination is as follows:less inclined (up to 10%) are covered with 6% of forests; batter slopes (11-20 °) - 19%; steep slopes (21-35 °) - 49%, while strongly steep slopes (36° or more) are covered by 26% of total amount of forests.

The main part of forests in Upper Svaneti are of special environmental importance. Only 35% of the total area falls within the industrial forestland, where it is quite difficult to conduct forest utilization works due to the lack of the forest roads. Very steep slopes and sparse forest that have lost self-replicating function and slopes at some places that are completely devoid of forest cover increase the risk of frequent extreme events as a result of climate change, as floods may wash off slopes and create gullies. While in others places a precondition for establishing landslides may be created. As the result, not only the soil protection forest ecosystem is endangered, but also the settlements, agricultural lands and roads, which in reality is observed in many forest sections of Upper Svaneti.

Several problematic plots were identified in Upper Svaneti for working on these problems, for which the restoration works, namely the planting of the soil protection forests were designed.
Up to 8 independent territories in the deplorable state, where the reforestation works were planned, were identified during the implementation of the project. On various areas selected for the project proposals, the forest cover existed in the past, but because of the illegal and also, irregular forest cuts, these slopes currently almost totally lack the plantations. These areas are located in the zones of Mestia Borough and Mulakhi Community (some of the selected areas of given on Photos 1, 2, 3 and 4), a part of which are in the ownership of the municipality and some are managed by the Forestry Agency. The forests will be mainly cultivated on washed off, eroded slopes of these territories, which in total amounts to 23.3 ha.


Photo 5.1. Area selected around Fusti Church adjacent to Mestia Borough (0.8 ha – the territory of the Forestry Agency)


Photo 5.2. Landslip in Village Artskheli, 2 ha (at this section, which is managed by the Forestry Agency, the forest covered the larger area. Afforestation may not fully change the existing situation, but will stop the emergence of new gully erosion areas and wash offs)

Photo 5.3. Area selected at the territory belonging to the Zardlashi Village and Ghobri Village (4 ha)

Photo 5.4. Jamushi, Lakhiri, Tscholashi: Washed off and eroded slopes (the territory of the forestry agency) – 10 ha

5.1.2. Project Goal

The goal of the project is to rehabilitate the degraded territory in Upper Svaneti aimed at planting the forests and increasing the CO_2 sinks. The project proposal first of all envisages the restoration of the damaged forest ecosystem, which implies the reforestation on degraded and eroded areas. This on the one hand will prevent further wash offs of the slopes and on the other hand will enhance the areas of forest massifs in Upper Svaneti and consequently, the carbon accumulation potential.

In order to ensure the self-reproduction and sustainable development of forests, the establishment of the forest nursery is planned in the region that will promote the enhancement of the scale of cultivating the soil protective forests and will enable planting of all slopes that currently are in the deplorable situation.

In the past, the afforestation of the slopes in Upper Svaneti was mainly done by using a single species, that subsequently gave poor results and hence, such groves were unstable.

In our case, the planting of the slopes in Upper Svaneti will be carried out by using different species. The action could be also considered as the adaptation measure. In particular, forest groves planted with mixed forest species stands out for their relatively good sustainability in comparison with the forest groves consisting of a single species of threes. The description of the sustainability approach and the development scheme/methodology are given in the following section.

5.1.3. Project Implementation

Methodology

As mentioned above, the methodology envisaged by the project involves planting of mixed forest groves on degraded areas, which are distinguished by their resilience to climate change, in particular, the planted forest groves have a relatively good ability of self-renewal and they will not be sensitive to diseases and rapid spread of fires. When selecting the species to be planted on the project territory, many factors should be considered, namely: Soil protection ability, adaptation ability to expected climate change (deciduous species selected for the cultivation need to be characterized by relatively good adaptation ability to climate change, but the potential of the coniferous species that represent one of the biodiversity components of the forest ecosystems in Upper Svaneti also must be taken into account.

During the planting, the percentage ratio of their use could be lowered and the coniferous species may be planted only in areas that have the best conditions for them and where they will have an acceptable growth rate. One of the main principles that should be considered in planning the development is that the restored forests should be adapted to the maximum extent to the natural conditions of the local forest ecosystem. For ensuring the annual growth scale of planting the soil protection forests on the eroded slopes, the construction of the new forestry nurseries are planned, where planting materials adapted to the local climate conditions will be produced. It is planned to transplant two-year seedlings characterized by high percentage of survivability to the nurseries organized separately for coniferous and deciduous trees. For the deciduous nursery, the former territory of the forest nursery in Khubery Forestry at the 650 ASL was selected (0.3 ha), while for the coniferous trees - also the former forest nursery area in Ifari Forestry at the 1 350 ASL (0.3 ha).

Planned Activities

The project provides the reforestation of degraded slopes and the establishment of forest nurseries. The planned activities include the following basic stages:

I. Reforestation of the degraded areas (23.3 ha)

- Preparing the selected planting area: Cleaning, clearing and fencing;
- Preparing platforms and pits on the slopes;
- Removing seedlings from the nurseries and planting them on selected areas.

The location of selected areas is shown on the map below (Figure 5.1).

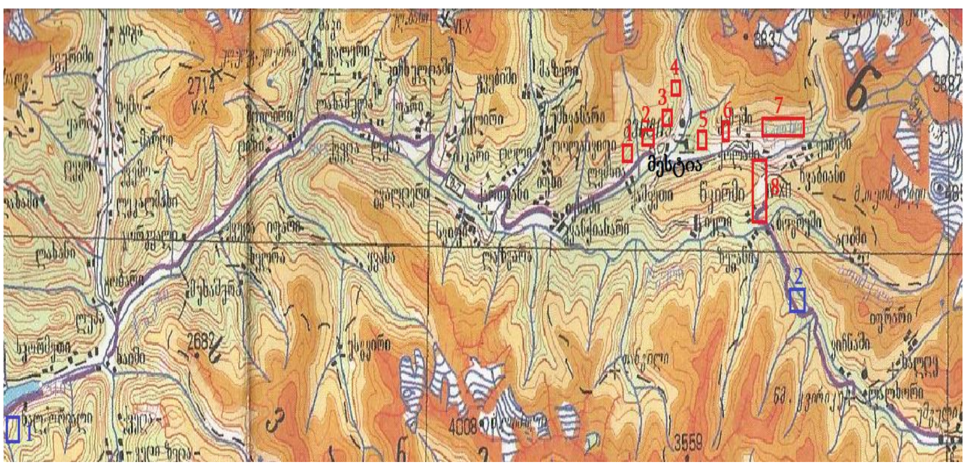

Figure 5.1. Identified degraded, washed off and eroded areas.

Mestia Borough: On the top of Lekhtagi - 0.8 hectares (the territory of the Forestry); on the top of Lanchvari, Fusti Church - 1 ha (the territory of the Forestry); the territory of Laghami Gully - 1 ha (the territory of the forestry); the territory of Lalaidi Gully - 1.5 hectares (the territory of the Municipality).

Mulakhi Community: The territory of Zardlashi and Ghobri - 4 ha (the territory of the Municipality); landslip in Artskheli Village - 2 ha (the territory of the Forestry); In Zhamushi, Lakhiri and Cholashi: Washed off and eroded mountainous areas - 10 ha (the territory of the Forestry); The section along the road in the process of the construction; the 6th km-section of Kherashi Gully and Ughviri Pass - 3 ha (the territory of the Forestry). The total amount of the area to be planted in Mestia Borough and Mulakhi Community equals to 23.3 ha.

A total of 50 800 pieces of coniferous and deciduous trees will be planted on the territories selected for the project, from which the woody plants will be planted on the southern exposure slopes with the following percentage proportions: Pine - 35%, high mountain oak - 22%, ash - 14%, high mountain maple - 13%, pear - 7%, Caucasian crabapple (Malus orientalis Uglitz) - 5%, acacia - 4%, while the following percentage of the woody plants will be built on the northern exposure slopes, namely: Fir-tree - 30%, beech -17%, ash -15%, high mountain maple -14%, pear -10% , Caucasian crabapple (Malus orientalis Uglitz) -9%, acacia - 5%. One of the examples of the afforestation scheme on the slopes is given in Figure 5.2.

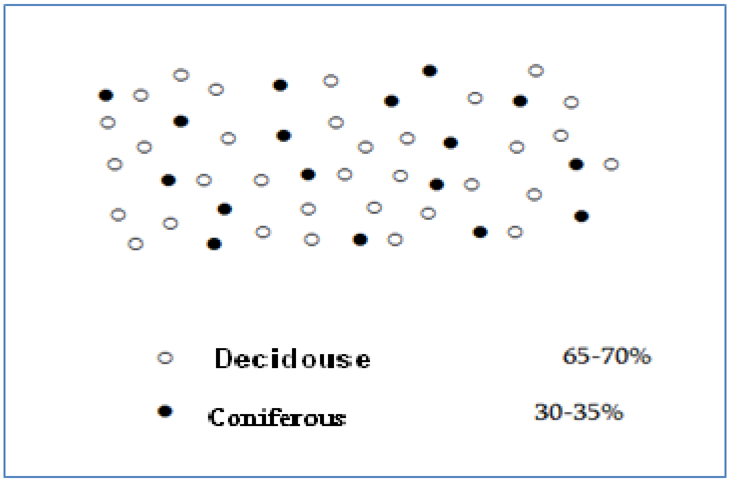

Figure 5.2. Example of the forest planting scheme for the slope areas

II. Establishment of the Nursery of Woody and Coniferous Trees (0.3 ha)

- Preparing the sowing area: Cleaning, fencing, plowing, harrowing and doing sowing furrows;
- Purchasing category 1 seed material and its subsequent spraying (with anti-fungal drug);
- Spraying the furrows prepared for sowing (with anti-fungal drug) and afterwards, seeding;
- Applying herbicides into the areas, shading germs/sprouts, watering and thinning of the annual seedling.

Here it should be noted that shading is necessary for only coniferous seedlings, because direct solar rays represent a threat for the fresh seedling. It can scorch and damage the sprout.

III. Establishment of the Nursery of Woody Deciduous Plants (0.3 ha)

- Preparing the sowing area: Cleaning, fencing, plowing, harrowing and doing sowing furrows;
- Purchasing category 1 seed material and its subsequent spraying (with anti-fungal drug);
- Applying herbicides into the areas and watering by spraying (if necessary).

5.1.4. Partners and Beneficiaries

The project partners are:

- Leadership of Mestia Municipality, which is interested in preserving the healthy/risk-free territories and has expressed its readiness to mobilize the local population for planting works;
- Samegrelo-Upper Svaneti Forest Service, which is interested in the rehabilitation of the old nurseries. The agency will be involved in the establishment of the nurseries and the slope planting works;
- The Ministry of Environment and Natural Resources Protection as the agency responsible for implementing the principles of the UNFCCC in the country. The Ministry promotes attracting investment for the projects that are related to climate change risks and the increase in their intensity;
- Forestry Department of the Ministry of Environment and Natural Resources Protection, which is interested in the restoration of forest massifs and their expansion as a sink for the carbon dioxide, in the introduction of new forest management methods and technologies, including adoption of the forest management practices resistant to climate change;
- Government of Georgia, which under the Convention is responsible to increase the carbon dioxide sinks sources wherever possible.

Project Beneficiaries:

- The population living on the territory of Upper Svaneti, which will benefit from the erosion-free pastures, meadows and also, the restored forest ecosystem from which, in case of proper management at the later stage, they can also rip the economic benefits of the proper management.
- Leadership of Mestia Municipality, which is interested in the introduction of the sustainable forest management in Upper Svaneti and the maintenance of the healthy territories/areas;

5.1.5. Factors Contributing to the Implementation of the Projects

- The population of mentioned above territories is interested in the aforestation of the damaged and eroded slopes (it is desirable, this should be an energy forest, if it maintains its soil protection function), which later will bring the economic benefits;
- First time in Georgia, the resistant to climate change artificial forest massifs and the degraded hayfields and pastures in the mountain ecosystems will be rehabilitated. The experience in Upper Svaneti can be used in other districts with similar conditions.

5.1.6. Constraints to the Implementation of the Project

- The population mainly uses the project territory as pasture, despite the fact that some of the plateaux are so degraded and washed off that are almost completely devoid of the grass cover. The reforestation will reduce the pasture areas, which initially may lead to the dissatisfaction of the local population. It will be necessary to explain in detail the long-term prospects/benefits to the local residents in order to avoid the negative attitude;
- A lack of the experience in Georgia of cultivating the new types of forests that are resistant to climate change. The assistance and involvement of the foreign experts in the process will be necessary. This, therefore, will increase the project expences. The cost of the foreign experts was not included in the initial budget;
- The lack of qualified personnel in the nursery, who will have the necessary qualifications and experience to propagate the planting material with the high (70-80%) percentage of survivability index by using modern technologies;
- The additional examination of the soil on the project areas may be needed, which will further increase the project budget.

5.1.7. Project Milestones and Budget

Three years are necessary for the implementation of the project (The detailed cost estimate for the planned actions is given in Appendix 4).

Activity	Implementing Agency	Implementation Duration (months) and Budget (US $)	Expected Result
1. Reforestation of Degraded Slopes (23.3 ha)			
1.1. Purchasing fencing materials (wood poles, barbed wire, nails) and fencing	Samegrelo-Upper Svaneti Forest Service, Mestia Municipality, the population living near the reforested slopes	5 7 727	The territory is protected from cattle
1.2. Cleaning and preparing the area	Samegrelo-Upper Svaneti Forest Service, Mestia Municipality, the population living near the reforested slopes	5 1 258	The areas selected for the project are cleaned and dried from the dried and damaged woody plants and shrubs.
1.3. Preparing platforms and pits on the area (size 0.5mX0.5m)	Samegrelo-Upper Svaneti Forest Service, Mestia Municipality, the population living near the reforested slopes	12 15 748	The selected areas are prepared for planting
1.4. Extracting seedlings in the nursery, planting on the selected areas and watering	Samegrelo-Upper Svaneti Forest Service, Mestia Municipality, the population living near the reforested slopes	6 13 716	Two-year seedlings extracted from the nursery are planted on the selected areas, seedlings are irrigated.
Total:		**38 449**	

2. Arrangement of the Nursery for the Woody Plants and Conifers (0.3 ha)			
2.1. Purchasing fencing materials (wood poles, barbed wire, nails) and fencing	Samegrelo-Upper Svaneti Forest Service	5 854	The territory is protected from cattle
2.2. Cleaning, fencing, plowing, harrowing and doing sowing furrows;	Samegrelo-Upper Svaneti Forest Service	6 278	The selected area is prepared for sowing
2.3. Purchasing category 1 seed material and its subsequent spraying (with anti-fungal drug);	Samegrelo-Upper Svaneti Forest Service	5 291	Category 1 seed material is purchased and is subsequently sprayed with anti-fungal drug (Fundasol)
2.4. Spraying the furrows prepared for sowing (with anti-fungal drug) and afterwards, seeding;	Samegrelo-Upper Svaneti Forest Service	6 1 225	The anti-fungal drug (Fundasol) is applied to the area and prepared in advance seed material is sawn
2.5. Applying herbicides to new coniferous sprouts, shading germs/sprouts, watering and thinning of the annual seedling.	Samegrelo-Upper Svaneti Forest Service	6 1 800	The sprout is protected from sun rays and weeds and is irrigated as needed
Total:		**4 448**	
3. Arrangement of the Nursery for Deciduous Woody Plants (0.3 ha)			
3.1. Purchasing fencing materials (wood poles, barbed wire, nails) and fencing	Samegrelo-Upper Svaneti Forest Service, Mestia Municipality	5 854	The territory is protected from cattle
3.2. Cleaning, plowing and harrowing of the area;	Samegrelo-Upper Svaneti Forest Service, Mestia Municipality	6 323	The selected area is prepared for sowing
3.3. Purchasing category 1 seed material, doing sowing furrows and sowing;	Samegrelo-Upper Svaneti Forest Service, Mestia Municipality	6 1588	Class 1 certified seed material is purchased
3.4. Applying herbicides into the areas and watering by spraying (if necessary).	Samegrelo-Upper Svaneti Forest Service, Mestia Municipality	6 500	Sprout protection works are conducted
Total:		**3 264**	
Grand Total:		**46 161**	

5.2. Minimizing the risks of damaging the Lakhamula section of Lakhamula Village and Zugdidi-Mestia Motor Highway by landslides and mudflow processes and mitigating the negative impact of natural disasters

5.2.1. Problem Description

In the last century, a landslide has developed north to Lakhamula Village, in the gorge of the small river known as Tvibra, which is the right tributary of Enguri River. The landslide process reached its peak in 2013. Today we are faced with hundreds of thousands of cubic meters of landslide body, strongly damped, with predominantly clay soil and slopes with dynamic behavior.

In the landslide ending zone, which is located at the altitude of 1 500 m ASL, the transformation of landslide soils into mudflow streams takes place under the influence of atmospheric, groundwater and infiltrated water. Mudflow streams emerging periodically pass a narrow gorge and damage Zugdidi-Mestia Motor Road as well as the residential houses and plots located at the territory of Lakhamula Village.

Presently, the territory of Lakhamula Village is considered as the zone of the hazardous geological processes, the high mudflow risk, where life is related to the actual risk. The implementation of the project will minimize the mudflow threats. The historical village will be preserved and the operation of the road will continue. This last factor is the most necessary precondition for maintaining the tourism in Upper Svaneti, not to speak of its development.

According to the assessments made within Georgia's Third National Communication on Climate Change, based on the data from Mestia Meteorological Station, the sum of annual precipitation on the territory of Mestia Municipality increased by 10% in the period of 1986-2010 in comparison with the period of 1961-1985. According to the forecast, this growth continues until 2050 and the increment reaches 12% in comparison with the period of 1961-1985. The daily average spring precipitation also increases until 2050, which means that the spring rains will become more intense. The increase in the sums of seasonal precipition for the current period is observed at every season except for summer (8% decline is observed in the second period i.e 2050-2100), but the biggest increase is observed in the winter period (+30%).

The maximum number of consecutive 5-day precipitation (Rx5day) also increased in all seasons, but the increase is the largest in fall (64%). However,summer and annual precipitation sums decreased. The annual amounts of consecutive rainy days increased by an average of 3 days per year. Changes in the amount of precipitation and the distribution regime is undoubtedly one of the most important factors contributing to the recent increase in the intensity of geological extremes in Mestia Municipality. The daily precipitation maxima also increased in all seasons (except summer) and especially in winter (by 31%). The increase is 15% in spring. Therefore it is expected that the possibility of the extreme manifestations of the mudflow streams on the territory adjacent to Lakhamula Village will be further activated, which adds to the urgency of the need to solve the problem.

5.2.2. Project Goal

The goal of the project is to (1) preserve the safe living environment on the territory of Lakhamula Village by minimizing the threat of forming landslides and mudflow streams, (2) establish a precedent for the successful containment of the geological threats and (3) introduce the methodology for resisting natural geological processes in similar natural environments.

5.2.3. Project Implementation

Methodology

Since Lakhamula landslide area became unusually activated in 2013, it is necessary to conduct a detailed study before giving out final recommendations. The survey should be undertaken based up on old and new research materials and only then will it be possible to recommend the more reasonable and reliable measures than those included in this project proposal.

Planned Activities

- **Reviewing existing Scientific Material.** In order to determine preventive measures for mitigating the negative impact of Lakhamula Landslide, it is necessary to carry out the so-called desk research of the Lakhamula Landslide at the initial stage. The main component of such research will be to search and analyse geological information preserved in relevant funds and published elsewhere.
- **Remote Landslide Research.** In parallel to conducting the research of scientific sources (desk research), information about the spatial distribution of landslide should be obtained by using the modern remote research methods;
- **Implementation of complex field research.** Based on the results of the desk research, the directions of the complex field research should be determined, the implementation of which will allow to develop effective anti-landslide and anti-mudflow protective measures for the Lakhamula Village and Zugdidi-Mestia Highway. The risk of the geological threat will be significantly reduced as a result of their implementation. It is also possible to completely eliminate these risks.

Landslide field research should be based on the modern, well-proven methodology. Implementation of topo-geodetic, geophysical, drilling and testing works by passing relevant stages are considered as the main components of the research during the field survey period. A laboratory study of landslide-affected soils should be conducted at the next stage of the research. The analysis of the collected information at the final-cameral stage will provide the objective picture of the development prospects of the processes, as well as the danger of landslide and mudflow.

- In the research process, preference should be given to the modern research and prevention methods and the recommended actions should be carried out as soon as possible taking into account real geological threats and high risk;
- **Working out Recommendations for Short-Term and Long-Term Practical Measures.** The measures to be implemented in the short-term and long-term perspective should be designed based on the research. These measures will be selected from a wide range of well-proven engineering works. Their implementation will minimize the risks described above and will ensure with the maximum efficiency the protection of the residential areas and the roads in Upper Svaneti. Presumably, the following measures will be included in the list: Increasing capacity of the mudflow bed (the straightening and lining of bed, deepening, widening), construction of the barrier along the settlement - arranging stockpiles, etc.
- **Implementation of the Recommended Measures**. After the assessment of the recommended measures and their value, the project will move to the practical implementation phase;
- **Monitoring.** In order to ensure sustainability of the implemented measures and prevention of the facilities from the future risks, it is necessary to conduct permanent monitoring of the system locally and to develop the action plan of the long-term measures.

5.2.4. Partners and Beneficiaries

The project partners are:

- Ministry of Regional Development and Infrastructure of Georgia, which is directly responsible for the protection of infrastructural facilities (roads) from a variety of risks;
- Ministry of Environment and Natural Resources Protection, as the agency responsible for the implementation of the principles of the UNFCCC in the country. The Ministry promotes attracting investment for the projects related to climate change risks;
- **Environmental Protection Agency of the Ministry of Environment and Natural Resources Protection,** which has information about the latest technologies and methodologies for landslide and mudflow control;
- **The leadership of Mestia Municipality,** which is interested in ensuring the safety of its citizens, improving their living environment and reducing the risks associated with infrastructure development in order not to harm the development of tourism;
- **The Government of Georgia and the Tourism Department.** One of the important tasks for the Department is to develop the tourism infrastructure and reduce risks in this process.

Project Beneficiaries:

- **The population of Lakhamula Village,** who lives under the constant threat and psychological pressure. For them it is important to minimize the risk to the maximum extent and to stabilize the situation (if possible). This is why it is important to explain to them what measures they are to conduct in order not to increase the risk or how they should act in case of the sudden activation of the landslide.
- **The part of the population of Mestia Municipality** (and a pretty big part)**,** who is involved in family tourism business;
- **The leadership of Mestia Municipality,** whose main function is to promote the development of the infrastructure in Upper Svaneti and the sustainable and secure development of the economy.

5.2.5. Factors Contributing to the Implementation of the Projects

- Mestia municipality's interest and readiness to participate in the solution of the problems;
- The urgent need to ensure the safety of the population in Lakhamula Village and their willingness to engage in risk reduction activities to the maximum extent;
- Full support from the Ministry of Regional Development and Infrastructure of Georgia. The ministry has already funded some of the works aimed at the primary prevention.

5.2.6. Constraints to the Implementation of the Project

- Difficult terrain, which greatly complicates the implementation of the effective landslide prevention measures is an important barrier to the project;
- Absence of the local Geological Service, which in case of conducting constant monitoring and in the favourable conditions, can increase safety;
- Very high project cost, which complicates the task of attracting funds to the project and creates the additional barrier to the project.

5.2.7. Project Milestones and Budget

The expected project duration is 2 years.

Activity	Implementing Agency	Implementation Duration (months) and Budget (US $)	Expected Result
Desk study (review and analysis) – about Lakhamula landslide	NEA	1 1 500	Initial report about Lakhamula landslide is prepared based on existing studies
Conducting the field study of Lakhamula landslide (from topo-geodesical, geophysical, geological-engineering, hydro-geological points of view)	NEA through invited contractors	4 50 000	Complex field studies of landslide are executed and materials delivered to NEA for further analysis
Analysis of obtained field studies (other materials)	NEA	2 5 000	Analytical report based on the results of field studies
Preparation of project document for implementation of effective anti-landslide and anti-mudflow protective measures	NEA through invited contractors	1 5 000	Project document
Implementation of the project	NEA through invited contractors	5 200 000	Danger from landslide and mudflow is minimized, living conditions of Lakhamula househols is improved, the risks for safe operation of highway are reduced
Establishment of permanent monitoring process and preparation of the long-term action plan of risks reduction	NEA, Mestia Municipality	12 200 000	System for permanent montiroing and planning of preventive measures is established
Total		**461 500**	

5.3. Assessment of mudflow hazard in Mestia Municipality Village Nakra and recommendations for carrying out protection activities

5.3.1. Problem description

Small rivers – Utviri, Lekverari and Laknashera flow into River Nakra, from the right side at the Village Nakra- Naki section. Lekverari and Laknashera originate at R. Nakra and R. Nenskra dividing ridge at absolute elevation of more than 3 000 m. They are characterized by considerable inclination of river bed and the presence of small glaciers at the river-head. According to 2014 data 28 glaciers with overall area of 10.2 km^2 were registered in R. Nakra basin. Since 1960 the number of glaciers has decreased by three, while area decreased by 45%. Currently largest glaciers in this basin are Leadashti (3.47 km^2) and Nakra (1.42 km^2). As a result of retreat of these and other glaciers, large amount of friable material has been accumulated at their bottoms, which, under the conditions of heavy rains contributes to the development of mudflows. The mentioned circumstances, accompanied by geological makeup of the area condition mudflow nature of River Nakra tributaries, which poses hazard to settlements. Mudflow currents developed in recent past, namely in 2006, 2010 and 2012 have demolished and damaged several residential houses and auxiliary buildings, bridges and a motor road. The volume of solid material brought by mud torrents during this period, according to visual estimation, is close to million cubic meters. The losses from extreme events impact has been established at GEL hundreds of thousands. Fortunately, severe weather did not result in any casualty.

The latest developments in Nakra gorge should be viewed in the context of climate change, for, starting from 1990's, throughout the monitoring performed by the NEA an event of such scale had not been identified in Nakra gorge until 2006. Torrential rains that form mudflows have become more frequent in Mestia that, perhaps, is an attendant to ongoing global warming process.

According to the estimations made based on the Mestia meteorological station data under the Third National Communication on Climate Change, total annual precipitation throughout Mestia Municipality has increased by 10% during 1986-2010 as compared to 1961-1985. The increase of seasonal sums of precipitation in current period can be observed on all seasons except for summer (there is 8% fall in the second period in summer), but the largest increase is during the winter period (+30%). Peak precipitation over the consecutive 5 days (Rx5day) on the average has also increased on all reasons and most of all – in autumn (by +64%), while it has decreased in summer and in respect of annual totals. Annual number of consecutive days with precipitation has increased by 3 days. The identified changes in the amount of precipitation and the regime of distribution is undoubtedly one of the most important factors contributing to the rise of intensity of geological extremes developed lately in the Mestia municipality. Peak daily precipitation has also increased in all seasons (except for spring) and especially during the winter period by 31%, while by 15% in spring. Therefore, it is expected that there is a likelihood of further intensification of extreme manifestation of mudflow currents on Vill. Lakhamula adjacent territory thus raising the urgency of resolving the problem.

The above-mentioned precipitation data of 2006, 2010 and 2012 have been independently analyzed and compared with multi-year averages for this project proposal. The results are given in Tables 5.3.1 and 5.3.2.

Table 5.3.1. Results of annual and seasonal precipitation analysis of Mestia meteorological station in Nakra mudflow activation years

Period	Winter (mm)	Spring (mm)	Summer (mm)	Autumn (mm)	Annual (mm)	Daily max. (mm)
1961-1985	185.4	235.5	295.7	247.3	961.8	145
1986-2010	241.8	277.6	270.8	271.1	1058.4	70
2006	306	387	229	345	1194	27
2010	221	337	257	330	1145	41
2012	111	108	312	213	751	37

Table 5.3.2. Results of extreme precipitation analysis of Mestia meteorological station in Nakra mudflow activation years

Period	R10[38] (day)	R20[39] (day)	CWD[40] (day)	Rx5day[41] (mm)
1961-1985	31	9	8	168
1986-2010	37	11	10	160
2006	48	6	20	73
2010	42	17	9	95
2012	22	11	5	84

The Tables demonstrate clear correlation between the mudflow events and precipitation in relevant years, although this correlation is not always related to the same type of occurrence. The sum of annual precipitation in 2006 and 2010, respectively, is by 12% (136 mm) and 8% (87 mm) higher than multi-year average during 1986-2010, when average precipitation had already increased by 10% as compared to prior period. Furthermore, in 2006 annual number of days with heavy precipitation has increased significantly and exceeded averages, when the amount of precipitation ≥ 10mm and the number of consecutive days with precipitation has been doubled. Peak amount of precipitation that fell during consecutive 5 days is significantly lower over these years, compared to the multi-year average. As for the extreme weather in the summer of 2012, Table 5.3.2 shows that this was perhaps due to increased precipitation on this season. This was accompanied by high temperature and the rise in the number of extremely hot days, which, perhaps, has caused accelerated melting of glaciers. In particular, air temperature in June was 2.2

[38] R10-amount of extreme precipitation days (here per year), when the amount of precipitation exceeds ≥10 mm.
[39] R20-amount of extreme precipitation days (here per year) when the amount of precipitation exceeds ≥20 მმ-ზე.
[40] CWD-consequent precipitation days.
[41] Rx5day-maximum amount of precipitation fallen on 5 consequent days (mm).

^{0}C higher than average of 1986-2010, while the number of extremely hot days in the same month was by 10 days higher as compared to average of the mentioned period.

As a result of the implementation of this project proposal the cause-and-effect patterns of mudflow currents formation should be identified, the maps of mudflow hazard and area zoning should be developed, the recommendations for the activities to be implemented and optimal development of the territory should be worked out.

5.3.2. Project goal

The goal of the project is to minimize mudflow risk in River Nakra gorge, and specifically, in Village Nakra (Naki), forming safe living conditions for local residents, refinement of the ways for optimal development of the area and of the methodology for the study of mudflow processes, which is extremely urgent for the Mestia municipality.

5.3.3. Project implementation

Methodology

Since the specific location reviewed in the project and its adjacent areas have not been studied before in terms of mudflow hazard, the methodology envisages the review of existing studies for these areas, as well as the geological, geodynamic, hydrological and glaciological field studies using modern methods and technologies.

Planned activities

- At the initial stage "desk study" of the problem - mudflow hazard of Nakra Gorge should be carried out and a report should be prepared on its basis;
- Based on the report developed at the first stage field studies should be planned, such as the engineering-geological-geodynamic and hydrological study of the catchments of small rivers, in the course of which the volume of potentially mudflow forming solid material should be identified, geodynamic processes facilitating the formation of mudflow processes (landslide, erosion, gravitation), morphological peculiarities of the slopes should be determined, the risk of formation of glacial mudflows, and other aspects. should be assessed;
- At the desk study stage, obtained information will be processed and analyzed, and based on the above the report of the performed study, zoning maps of mudflow risk areas and recommended actions should be prepared.

5.3.4. Project partners and beneficiaries

The following are the partners of the project:

- **The Ministry of Regional Development and Infrastructure of Georgia,** the functions of which include assistance of local authorities in maximum reduction of damages to infrastructure caused by the hazardous events within the localities and of the hazards faced by the residents;
- **The Ministry of Environment and Natural Resources Protection**, as an entity responsible for the implementation of the principles of the UNFCCC in the country. The MoE is at most supporting attracting investments for the projects related to the risks caused by climate change;
- **MoE National Environmental Agency (NEA)** that possesses information about modern technologies and methodologies for landslide and mudflow protection;
- **Mestia Municipality leadership** that is interested in ensuring security of its residents, improve their living environment and maximally reduce risks related to infrastructure development, so as not to harm tourism development.

The following are project beneficiaries:

- **Village Nakra residents** who so far have only been incurring material damages and are thus interested in having information about expected risks and about the activities they have to take on a daily basis so as to contain risk, or how to act in case of unexpected intensification of mudflow processes;
- **Village Nakra local authorities and Mestia Municipality leadership,** one of the key functions of which is to support sustainable and safe development of Upper Svaneti infrastructure and economy, ensuring the security of local residents.

5.3.5. Favorable factors for project implementation

- The interest and readiness of the Mestia Municipality and Village Nakra leadership to participate in problem resolution;
- Urgency to ensure the security of Village Nakra residents and their willingness to maximally get involved in the works aimed at risks reduction;
- Full support from the Ministry of Regional Development and Infrastructure of Georgia;

5.3.6. Barriers to project implementation

- Complex relief conditions represent significant barrier to project implementation, which will significantly complicate the implementation of effective mudflow protection activities;

- The lack of knowledge on modern technologies and methods for conducting highly qualified field studies. Perhaps, it will be necessary to purchase costly monitoring systems and invite international experts, that increases the cost of the project;
- The barriers to the implementation of concrete activities should be identified based on the analysis of the results of field studies;
- The absence of Geological survey unit in the Region that can increase the security of residents in case of constant monitoring and support.

5.3.7. Project implementation stages and cost

It is scheduled to implement the reviewed stage of the project in 5 months

Activities	Implementing unit	Implementation time (in months) Budget (USD)*	Estimated outcome
Desk study – obtaining existing information about this specific territory	NEA	1 1 500	The report is prepared based on existing scientific studies
Conduction of field-engineering-geological, geodynamic, hydrological and glacial study	NEA	2 25 000[42]	Potential volume of mudflow solid materials is assessed, geodynamic processes (landslide, erosion, gravitation) contributing to the formation of mudflow processes are identified, the risk of formation of glacial mudflows is estimated, etc.
Desk processing and analysis of obtained materials	NEA	1 5 000	Field study data obtained
Preparation of final report and recommendations	NEA	1 5 000	Summary report on performed field and desk works with the recommended activities
Total		**36 500**	

[42]This amount has been estimated for the case of conducting study using the technologies available in Georgia and it does not include the expenses for inviting a foreign expert. In case funds are raised from adaptation funds for this project the amount will increase significantly.

5.4. Project Proposal for Preserving and Restoration of Cultural Heritage Monuments in Upper Svaneti (village Hadishi)

5.4.1. Problem Description

Upper Svaneti cultural heritage is quite diverse compared to other regions of Georgia and is particularly rich in monuments. A number of churches, as well as secular architectural monuments, have survived here. Almost all Svanetian villages have Svanetian tower and house (Machubi). The churches are particularly rich in preserved monumental art of the Middle Ages, chased-metal or painted icons and other religious items.

Upper Svaneti is one of the most vulnerable regions of Georgia in regard to climate change. Changes have been particularly conspicuous for the last 20-25 years. Inguri dam also influenced the surrounding area. Upper Svaneti is densely populated mountainous area with frequent landslides, avalanches and heavy snowfall endangering population and infrastructure, historical monuments and other buildings.

In Upper Svaneti area, Mestia municipality, monument damage from frequent extreme weather conditions e.g. floods, torrents, landslides, mudflows and avalanches are relatively rare. At present, impact of less severe and longer-lasting climate conditions (e.g. lasting rains, droughts, winds etc.) can be observed, gradually damaging the monuments. Such extreme weather conditions affect historical monuments in various ways and cause:

- Insect invasion and increase in fungal damage in high-temperature and humid conditions;
- Structural problems caused by land/soil reduction in hot and dry summer;
- Weathering/erosion of rocks and building material due to frequent temperature change (freeze-thaw action);
- Thermal effect on building material easily influenced by temperature i.e. wood and paint (painting);
- Requirement for frequent repair and restoration significantly increasing care and insurance costs.

This project proposal deals with village Hadishi located in Ipari Community 9 km east of village Bogreshi, in the ravine of the River Hadishistskali, 2100 m above sea level. Three churches have been preserved here – of the Savior, Archangel (Taringzeli) and St. George (Jgragi). Condition of the churches is satisfactory, roofing have been changed recently. There is a minor crack at the eastern façade foundation of the Church of the Savior. Monumental paintings of the churches are in much poorer condition. XII-century mural of the Church of the Savior is completely blackened with smoke and candles. Paint color is also lost, supposedly related to 14-day increase in the number of extremely hot days when thermal damage of material (paint) takes place.

Condition of Jgragi and Tarindzeli church murals is relatively better as some restoration has been conducted here.

Machubs and towers are in particularly poor condition. There 14 towers in Hadishi alone, 2 of which have been restored, or, more precisely, only roofing has been restored. The remaining 12 towers are either ruined and halved in height, or broken in two with one ruined side. Machubs are in even poorer condition. Of 32 remaining Machubs, 3-4 are used for animal housing, others either have ruined roofs or are half-ruined. According to villagers, 10 Machubs were ruined last year alone due to heavy snowfall. Annual total precipitation in Mestia has increased by 10%, but increase is most for winter precipitation - 30%, for spring and autumn - 18 and 10% respectively and precipitation reduced by 8% in summer with temperature increase of 0.7 ^{0}C. Summers have become hotter and drier while other seasons more humid, with more precipitation. Main problems of the village are heavy snowfall and lack of population.

At the edge of the village there is Kaldani family tower which is quite different from other towers. There is a stream next to the tower, which often floods and damages the foundation of the building, endangering the cracked tower. This crack is dangerous for the integrity of the structure. Furthermore, the building has no roofing and majority of embrasures are collapsed too.

Malkhaz Kaldani tower is also in poor condition, roofing is completely destroyed and might collapse, as for Machubi, it is in relatively better condition and requires roofing alone.

At present only 11 families live in Hadishi all year round (mostly elderly people). Only 5 families remained in the village by 2008. According to the population majority of the locals wish to come back and settle in the village. They say about 10 families are ready to return. The problem is that their houses have collapsed and they cannot afford to repair the houses themselves.

It should be noted that Hadish has high development potential. There is a pedestrian trail going from Mestia to peak Tetnuldi. Tourists often use this road and stop at Hadishi. Village Hadishi is comparable with Ushguli in beauty, located at almost the same height from sea level as Ushguli while it is much more compact and easy to see. All three churches of Hadishi were pained by frescos of XII-XIII centuries, also there is façade mural characteristic of Svanetian churches (Jgragi church). It is possible to see many chased-metal and painted icons in the Church of the Savior. In Bachvi Kaldani tower of this village famous Hadishi Four Gospels were kept before moving to Mestia museum.

Photo 5.4.1. General View of Village Hadishi from Space

5.4.2. Objective of proposal

The goal of this project is to restore and preserve cultural heritage monuments in one of the oldest and most beautiful villages of Hadishi, helping to attract tourists by including the village into tourist routes and revival of the village almost entirely emptied from population. After restoring Machubs and towers, indigenous population will probably continue to return, potential and quality of service will increase which will promote increase in the number of tourists. Participation of the local population in the process will contribute to more effective implementation of historical monument protection measures and ensure sustainability of protection process.

From religious and secular buildings preserved in the village, secular buildings are in poorest condition, Majority of towers require immediate structural reinforcement and restoration while condition of Machubs is alarming. (Photo 5.4.2 and 5.4.3).

Photo 5.4.2. Collapsed Machubi and tower in Hadishi

 

a) b)

Photo 5.4.3. Collapsed Machubi and tower in Hadishi

The project involves full inventory taking of the existing cultural heritage monuments in Hadishi required in order to identify priorities and order of works to be conducted in regard to the monuments.

The climate conditions the monuments experienced for final 20-25 years should be considered as much as possible. At the same time, all restoration principles should be met and historical appearance retained (restoration).

5.4.3. Project Implementation

Methods

Planned methodology for project implementation involves complete inventory-taking of cultural heritage monuments from village Hadishi and making a registration card for each monument (updating existing cards). Next stage is identifying priorities among the monuments and developing restoration projects for the monuments involving multidisciplinary study of each monument. Two towers and one Machubi have been selected at this stage - Kaldani family tower and Malkhaz Kaldani complex, also restoration of the murals of Church of the Savior.

Actions to be taken

- **Inventory of cultural heritage monuments in village Hadishi.** As village Hadishi practically has a complex of monuments, it is necessary to conduct complete inventory taking and detailed study of climate change effect on the monuments within the project;
- **Develop restoration project for Kaldani Family tower and Machub.** During restoration project development, among other issues, it is necessary to consider climate change detected in Mestia municipality due to Global Warming;
- **Conduct restoration works for Kaldani family tower (Photo 5.4.4) and Machub.** The following principles should be applied during implementation: use of authentic material; at exceptional cases it is possible to use modern material, provided it does not show from

the side of façade or interior (e.g. reinforced concrete belt inside the wall if required by the constructor); Roofing structure should be made, using old method, from wooden beams and roofs should be covered with wood shingles (for towers and Machubs too). Wood shingles are not resistant to weather conditions, so we consider it possible to make insulation layer of tin or other material underneath.

In Upper Svaneti they say that if walls of the house and tower are not plastered, the family is poor. It can be observed that towers and Machubs used to be fully plastered with lime. Bare stone look with damaged plastering is familiar to modern eye. Thus, when old areas of Mestia were restored without any underlying study, stone surface was left on the buildings. It seems quite unlikely that plastering of walls only served to mark social status. The plastering is sure to have determined stability of the structure. Not only does it help to preserve stable temperature during winter and summer but also contributes to wall structure stability in the first place as it prevents direct contact of precipitation to stone and mortar.

The team involved in preparing this project proposal assume that plastering the structures is a necessary condition considering climate change: daily precipitation during spring and winter has increased by 22 44%, number of days with frost increased by 4 days per year (in spring) while nights with frost increased by 9 days (mostly in winter). Consequently, it will probably be better to use hydraulic lime for plastering.

Photo 5.4.4. View of the Kaldani Family Tower

Technical study of the mural of Hadishi Church of the Savior and project development. It is absolutely necessary to to restore painting of the Church of the Savior (photo 5.4.5.). Technical study of the painting should be conducted for this purpose and project should be prepared. As a result, method of conducting works will be determined. The following studies are required prior to restoration: archaeological investigation; study of geological conditions; study and analysis of structural integrity of the building and making structural drawings; making measurements by restorers and making restoration project based on the study. Historical and history of art research will be conducted within the project based on archived material, which will specify aspects of climate change with most effect on the monument;

Restoring mural of Hadishi Church of the Savior. Mural of the church should be restored in accordance with recommendations within the project prepared in accordance with study conducted in advance. The recommendations should consider new aspects of climate change such as extreme increase in precipitation and relative humidity and increased number of very hot days (SU30).

a) b)

Photo 5.4.5. Elements of inside mural (a) and interior (b) of Hadishi Church of the Savior

5.4.4. Project Partners and Beneficiaries

Project Beneficiaries:

- **Government of Georgia** because in the event of restoration and correct care, matched with improvement in infrastructure and service, Svaneti has a high potential of attracting tourists;
- **Local population**, living environment will be improved and population will return to their homes (the process has started and it needs support). Increased number of tourists will improve standard of living;
- **Tourism department,** will gain additional, very interesting historical monument for diversification of existing tours;
- **Local self-government,** which will receive proper village infrastructure, employed population and improved standard of living;

- **Local tourist centers and local guides,** whose employment and income will increase.

Project Partners:

- **Ministry of culture and Monument Protection of Georgia**, one of the priorities of which is restoration and preservation of historical monuments;
- **National Agency for Cultural Heritage Preservation of Georgia**, the priorities of which are: preparation of the project documentation for rehabilitation of architectural complexes and separate samples of cultural heritage of Georgia; restoration-rehabilitation of architectural complexes and separate samples of cultural heritage of Georgia; Creation of an integrated infrastructure of museums and museum-reserves; updating of the Integrated Data Base of Cultural Heritage; cultural heritage promotion. Some actions defined within this project proposal serve the above priorities;
- **Goerge Chubinashvili National Research Center for Georgian Art History and Heritage Preservation**, one of the main activities of which is study of the protection and preservation problems of works of art. Likewise important is generalization of both local and international experience of the heritage of preservation, elaboration of theoretical conclusions and practical recommendations, critical discussion of the newest achievements and tendencies, dissemination of positive innovations among professional community and their introduction into practice. The center also undertakes art historical study of the sites to be restored and provides methodological supervision, assessment and monitoring of works. The center takes part in recording immovable and movable heritage monuments. For successful implementation of this project sharing the experience of this center is very important and success of this project will also provide opportunity for the center to conduct new and interesting studies;
- **Georgian National Tourism Administration** is both partner and beneficiary of this project. It will assist the project in becoming more attractive to tourist ensuring that antiquity of the monuments is retained**;**
- **Local Self-Government** was involved in preparation of this project proposal and supports its implementation.

5.4.5. Factors of Successful Project Implementation

- The key factor of successful project implementation is interest of the local and central government. National Agency for Cultural Heritage Preservation of Georgia expressed willingness to participate in the project implementation by co-financing. In addition, G. Chubinashvili National Research Center for Georgian Art History and Heritage Preservation is ready to provide its staff for inventory of the monuments;
- Tourism is one of the key priorities of the country, which is particularly true regarding tourism development in Svaneti. Thus it would be important for the region to open Hadishi to tourists

- Important condition for proper implementation of the project is existence of highly competent restoration institutions in the country and in Mestia in particular, with experience of work on Svanetian towers and Machubs;
- One of the project success factors is that stones from collapsed buildings, in the form of building material, are still preserved on the spot and can be reused, partially reducing project costs.

5.4.6. Barriers to Project Implementation

- One of the main obstacles to project implementation is mountainous area and poor conditions of access roads to the village;
- Shortage of various construction materials on the spot. It will be required to transport large part of the material from other regions of Georgia, significantly increasing project costs;
- Opinion of various interested parties regarding restoration methods and material which has frequently become subject of disagreement and barrier for implementation of similar projects. One of the most effective methods for overcoming such barrier is to involve all interested parties in the process of preparing recommendations from the beginning;
- Opinions, consciousness and personal interests of the local population do not always coincide with the opinions of scholars and restorers and common interest, frequently hampering sustainability of the achieved results.

5.4.7. Project Implementation Schedule and Budget*

Project implementation is planned for 2 years.

Activity	Performer	Period of Implementation (in months) and Budget (USD)	Expected Result
Inventory of village Hadishi cultural heritage monuments	Goerge Chubinashvili National Research Center for Georgian Art History and Heritage Preservation	1 2 400	Develop full database of village Hadishi cultural heritage monuments
Create restoration/rehabilitation project for Kaldani Family tower and Machub	National Agency for Cultural Heritage Preservation of Georgia; Hired Contractor	3 17 000	Prepare appropriate project and cost estimate documents for each monument
Implement restoration/rehabilitation works on Kaldani Family tower and Machub	Hired Contractor	12 70 000	Complete restoration-rehabilitation of the monuments leading to return of the population and

*Restoration cost estimate will be specified after preparing project documents.

			increase in tourist flow
Technical study of the mural of Hadishi Church of the Savior and development of the project	National Agency for Cultural Heritage Preservation of Georgia	2 4 600	Description/analysis of mural problems and development of restoration methods
Restore mural of Hadishi Church of the Savior	Contractor Company	4 30 000	Restoration of murals
Total:		**124 0**	

5.5. Project Proposal for Preservation and Restoration of Upper Svanetian Cultural Heritage Monuments (Village Zhamushi)

5.5.1. Problem Descriptions

Upper Svaneti cultural heritage is quite diverse compared to other regions of Georgia and is particularly rich in monuments. A number of churches, as well as secular architectural monuments, have survived here. Almost all Svaneti villages have Svanetian tower and house (Machubi). The churches are particularly rich in preserved monumental art of the Middle Ages, chased-metal or painted icons and other religious items.

Upper Svaneti is one of the most vulnerable regions of Georgia in regard to climate change. Changes have been particularly conspicuous for the last 20-25 years. Inguri dam also influenced the surrounding area. Upper Svaneti is densely populated mountainous area with frequent landslides, avalanches and heavy snowfall endangering population and infrastructure, historical monuments and other buildings.

In Upper Svaneti area, Mestia municipality, monument damage from frequent extreme weather conditions e.g. floods, torrents, landslides, mudflows and avalanches are relatively rare. At present, impact of less severe and longer-lasting climate conditions (e.g. lasting rains, droughts, winds etc.) can be observed gradually damaging the monuments. Such extreme weather conditions affect historical monuments in various ways and cause:

- Insect invasion and increase in fungal damage in high-temperature and humid conditions;
- Structural problems caused by land/soil reduction in hot and dry summer;
- Weathering/erosion of rocks and building material due to frequent temperature change (freeze-thaw action);
- Thermal effect on building material easily influenced by temperature i.e. wood and paint (painting);
- Requirement for frequent repair and restoration significantly increasing care and insurance costs.

This project proposal deals with living/family complex of the Naverianis and Kaldanis located in village Zhamushi of Mestia municipality. It is located in Mulakhi community, in 1 km from Mestia-Ushguli road. The mentioned complex is divided in two parts, one is erected on the right and the other on the left side of the road going into the village. There are two towers in the right complex and the main church is also here (Photo 5.5.1) which is painted with XII-century frescos. Both complexes initially belonged to Naveriani (Avlatsha) family. In about XVIII century the family sold the complex to Kaldani family. The area selected for project implementation which experienced avalanche in the 1980s is in poor condition now. Roofing of all Machubs and part of the walls are collapsed. Only one tower has been restored. The entire length of other one, close to the church is half-collapsed. Such damage of the structures happened for the last 25-30 years, before that population lived in the village. Annual total precipitation has increased by 10%, but increase is most for winter precipitation - 30%, in spring and autumn - 18 and 10% respectively and precipitation reduced by 8% in summer with temperature increase of 0.7 ^{0}C. Summers became hotter and drier while other seasons more humid, with more precipitation. The tragic event of 1987 has probably resulted from this: avalanche fell in the morning killing 43 people. The avalanche only damaged newly constructed buildings and missed the complex by several meters.

Photo 5.5.1. View of main church in village Zhamushi

It is also important to restore Zhamushi Church mural, because painting is in poor condition. Color loosening and plaster damage is going on. This is particularly alarming as the number of extremely hot days has increased by 14 days, endangering painting the most. Number of extremely hot days (SU25) is expected to increase by 19 more days by 2050, further worsening the condition of the monuments.

Thus, restoration of Zhamushi complexes is important for the purpose of preserving historically important cultural heritage monument, as well as promoting tourism in Mestia municipality.

5.5.2. Objective of proposal

The goal of this project is to restore and preserve one of the oldest and most interesting cultural heritage monuments in village Zhamushi, Upper Svaneti. From religious and secular buildings preserved in the village, secular buildings are in poorest conditions, Majority of towers require immediate structural reinforcement and restoration, while unless condition of Machubs is immediately improved, the walls will soon turn to ruins (Photo 5.5.2 and 5.5.3).

It is also necessary to completely restore Zhamushi church mural to prevent plaster and color from falling.

Photo 5.5. 2. Wall of Machubi selected for restoration in Village Zhamushi

Photo 5.5.3. General view of the tower selected for restoration in village Zhamushi

The complicated climate conditions (high humidity and extremely hot days) should be considered during restoration process. At the same time, all restoration principles should be met and historical appearance retained.

5.5.3. Project Implementation

Methods

First of all restoration project should be prepared for the complex of village Zhamushi, which implies conducting multiple studies for each monument, in particular, historical and history of art study of the monuments, archival work, archeological study if required, study of geological conditions, study and analysis of structural integrity of the building and making structural drawings; making measurements by architect-restorers; finally, considering all data, restoration project will be prepared;

The tower next to the church is heavily damaged with half-collapsed entire length of the structure. The debris from inside the building should be removed from the tower; the remaining walls should be reinforced and collapsed walls restored (photo 5.5.4).

Photo 5.5.4. Tower selected for restoration (left) and tower in good conditions (right)

Machubs are in very poor condition. Although most walls are still retaining original height, no building has roofing, which may lead to fast collapse of the walls (photo 5.5.5).

Authentic material should be used while conducting the works; at exceptional cases it is possible to use modern material, provided it does not show from the side of façade or interior (e.g. reinforced concrete belt inside the wall if required by the constructor); Roofing structure should be made from wooden beams using old method, and roofs should be covered with wood shingles (both for towers and Machubs). Wood shingles are not resistant to weather conditions, so we consider it possible to make insulation layer of tin or other material underneath[43].

[43]The opinion expressed herein in regard to methods of restoring the mentioned monuments belong to an expert and have not been founded on deep and multifaceted research, which is planned in the event of funding of this project and which will involve consultations with all interested parties.

Photo 5.5.5. General view one of the machubis selected for restoration

In Upper Svaneti they say that if walls of the house and tower are not plastered, the family is poor. It can be observed that towers and Machubs used to be fully plastered with lime. Bare stone look with damaged plastering is familiar to modern eye. Thus, when old areas of Mestia were restored without any underlying study, stone surface was retained on the buildings. It seems quite unlikely that plastering of walls only served to mark social status. The plastering is sure to have determined stability of the structure. Not only does it help to preserve stable temperature during winter and summer but also contributes to wall structure stability in the first place as it prevents direct contact of precipitation to stone and mortar.

Thus it can be assumed that plastering the structures is a necessary condition while considering climate change: daily precipitation during spring and winter has increased by 22 and 44% respectively, number of days with frost increased by 4 days per year (in spring) in Mestia, while nights with frost increased by 9 days (mostly in winter). Consequently, it will probably be better to use hydraulic lime for plastering.

The painting of the church should necessarily be restored too (photo 5.5.6). First of all technical study of the painting should be conducted and project prepared, after which method of works should be determined.

a)

b)

Photo 5.5.6. Elements of inside mural (a) and interior (b) of Zhamushi Church.

Actions to be taken

- Develop restoration/rehabilitation project for both complexes with proper project and cost estimate documentation;
- Conduct restoration/rehabilitation project for both complexes, complete restoration of the monuments, probably followed by return of the population and increase of tourist flow.
- Complete technical study of Zhamushi Church mural and prepare project. Describe-analyze mural problems and develop methods for its restoration;
- Restore Zhamushi Church

5.5.4. Project Partners and Beneficiaries

Project Beneficiaries:

- **Government of Georgia** because in the event of restoration and correct care, matched with improvement in infrastructure and service, Svaneti has a high potential of attracting tourists;
- **Local population**, living environment will improve and population will return to their homes (the process has started and it needs support). Increased number of tourists will improve standard of living;
- **Tourism department,** will gain additional, very interesting historical monument for diversification of existing tours;
- **Local self-government,** which will receive proper village infrastructure, employed population and improved standard of living;
- **Local tourist centers and local guides,** whose employment and income will increase.

Project Partners:

- **Ministry of culture and Monument Protection of Georgia**, one of the priorities of which is restoration and preservation of historical monuments;
- **National Agency for Cultural Heritage Preservation of Georgia**, the priorities of which are: preparation of the project documentation for rehabilitation of architectural complexes and separate samples of cultural heritage of Georgia; restoration-rehabilitation of architectural complexes and separate samples of cultural heritage of Georgia; Creation of an integrated infrastructure of museums and museum-reserves; updating of the Integrated Data Base of Cultural Heritage; cultural heritage promotion. Some actions defined within this project proposal serve the above priorities;
- **Goerge Chubinashvili National Research Center for Georgian Art History and Heritage Preservation**, one of the main activities of which is study of the protection and preservation problems of works of art. Likewise important is generalization of both local and international experience of the heritage of preservation, elaboration of theoretical conclusions and practical recommendations, critical discussion of the newest achievements and tendencies, dissemination of positive innovations among professional community and their introduction into practice. The center also undertakes art historical study of the sites to be restored and provides methodological supervision, assessment and monitoring of works. The center takes part in recording immovable and movable heritage monuments. For successful implementation of this project sharing the experience of this center is very important and success of this project will also provide opportunity for the center to conduct new and interesting studies;
- **Georgian National Tourism Administration** is both partner and beneficiary of this project. It will assist the project in becoming more attractive to tourist ensuring that antiquity of the monument is retained**;**
- **Local Self-Government** was involved in preparation of this project proposal and supports its implementation.

5.5.5. Factors of Successful Project Implementation

- The key factor of successful project implementation is interest of the local and central government. National Agency for Cultural Heritage Preservation of Georgia expressed willingness to participate in the project implementation by co-financing. In addition, G. Chubinashvili National Research Center for Georgian Art History and Heritage Preservation is ready to provide its staff for inventory of the monuments;
- Tourism is one of the key priorities of the country, which is particularly true regarding tourism development in Svaneti. Thus it would be important for the region to open Zhamushi complex to tourists
- Important condition for proper implementation of the project is existence of highly competent restoration institutions in the country and in Mestia in particular, with experience of work on Svanetian towers and Machubs;

- One of the project success factors is that stones from collapsed buildings, in the form of building material, are still preserved on the spot and can be reused, partially reducing project costs.

5.5.6. Barriers to Project Implementation

- One of the main obstacles to project implementation is mountainous area and poor conditions of access roads to the village;
- Shortage of various construction materials on the spot. It will be required to transport large part of the material from other regions of Georgia, significantly increasing project costs;
- Opinion of various interested parties regarding restoration methods and material which has frequently become subject of disagreement and barrier for implementation of similar projects. One of the most effective methods for overcoming such barrier is to involve all interested parties in the process of preparing recommendations from the beginning;
- Opinions, consciousness and personal interests of the local population do not always coincide with the opinions of scholars and restorers and common interest, frequently hampering sustainability of the achieved results.

5.5.7. Project Implementation Schedule and Budget*

Project implementation is planned for 2 years.

Activity	Performer	Period of Implementation (in months) and Budget (USD)	Expected Result
1.Create restoration/rehabilitation project for both complexes	National Agency for Cultural Heritage Preservation of Georgia; NGO Sector	3 22 800	Prepare appropriate project and cost estimate documents for each monument
2.Implement restoration/rehabilitation works of both complexes	Hired Contractor	12 100 000	Complete restoration-rehabilitation of the monuments leading to return of the population and increase in tourist flow
3. Technical study of Zhamushi Church mural and project preparation	National Agency for Cultural Heritage Preservation of Georgia	2 5 000	Description/analysis of mural problems and development of restoration methods
4. Restore Zhamushi Church mural	Hired Contractor	4 40 000	Restoration of murals
Total:		**167 800**	

*Restoration cost estimate will be specified after preparing project documents.

5.6. Climate Change Risks Reduction in Health Care Sector in Mestia Municipality, Zemo Svaneti

5.6.1. Description of the problem

While preparing Georgia's Third National Communication on climate change, the impact of climate change on Health sector in Zemo Svaneti's has been studied. The study has been done based on the distribution of climate-related diseases connected with climate change trends in Zemo Svaneti region.

Climate change processes may affect human health in different ways: increase in frequency of hot days may increase the risk of heat waves. Heat waves are characterized with high temperature and humidity and have negative impact on human health (heat stroke, hypertension, etc.). Besides direct impact, increase in frequency and severity of hot days can lead to the problem with alpinism that is considered as one of the activity strongly connected to the development of tourism – without favourite weather conditions for alpinism, the risk of injuries may dramatically increase.

It is expected that the tourist industry (mainly alpinism, rafting, skiing, etc.) would greatly contribute to the growth of Zemo Svaneti's socio-economic potential and, in general, to the sustainable development of the region. Hence, aimed at the maximum use of Zemo Svaneti's tourism potential it is highly important to implement those adaptation measures, which should lessen the risk of climate-related diseases and provide the tourists with comfortable and healthy environment.

Significant changes are observed in climatic parameters having significant impact on human health, such as: extremely hot or cold days, length of consecutive hot and cold days, the days with intensive precipitation (more than 20 mm that increases the risk of natural disasters). In particular, according to the meteorological data observed at the Mestia meteo-station, the following changes are revealed in climatic parameters mentioned above within the two time periods (1961-1985 and 1986-2010): absolute maximum meaning of the temperature of the year has been increased by 0.3 C; the number of hot days (temperature more than 25^0 C) has been increased by 178; the meaning of precipitation of the year increased by 10%, etc.

Statistics produced by the Health statistic Department, National Center for Disease Control and Public Health and available at link: www. http://www.ncdc.ge/?lang=eng showed that frequency of some climate-related diseases increasing in Zemo Svaneti region among high risk diseases should be considered:

Traumas, that may be associated with natural disasters, which were observed to be increased in frequency and severity, and also associated with increased frequency and severity of hot days can lead to the problem with alpinism as without favorite weather conditions for alpinism, the risk of injuries may dramatically increase.

Other non-communicable diseases, that creates the highest economical burden on health sector in general, and particularly – on regional level. Those diseases first of all are: mental illnesses (may be post-traumatic disorder after natural disasters), cardio-vascular diseases, especially – hypertension, and respiratory diseases (high mortality rate of flu) (Fig 5.6.1-5.6.3).

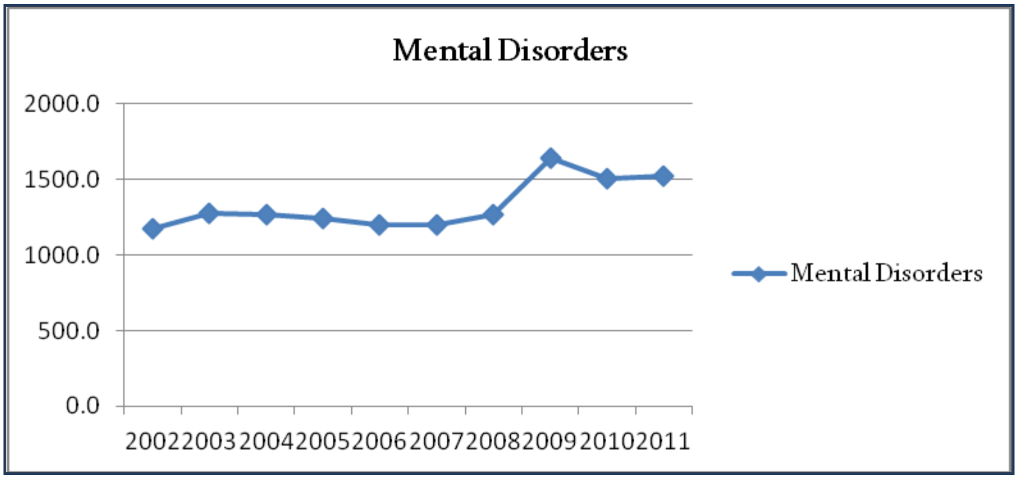

Fig. 5.6.1 Prevalence of Mental disorders in Zemo Svaneti, 2002-2011

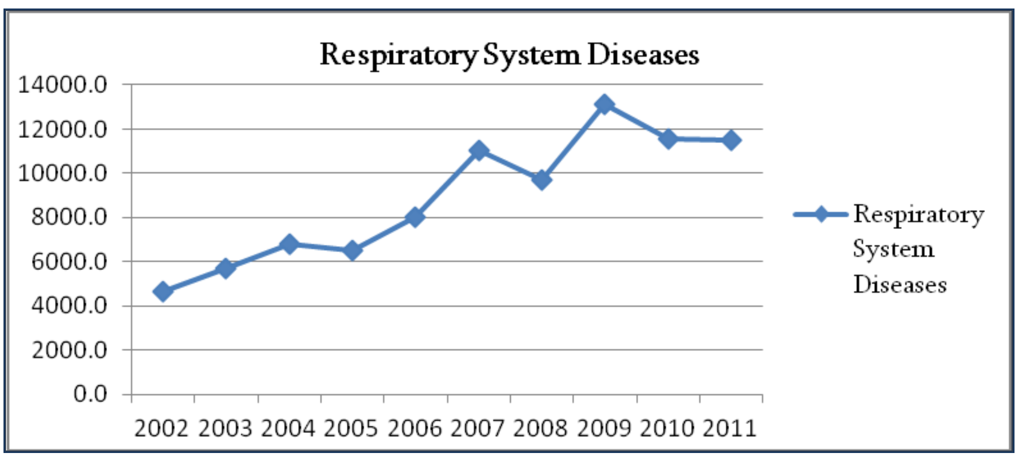

Fig. 5.6.2 Prevalence of Respiratory system diseases in Zemo Svaneti, 2002-2011

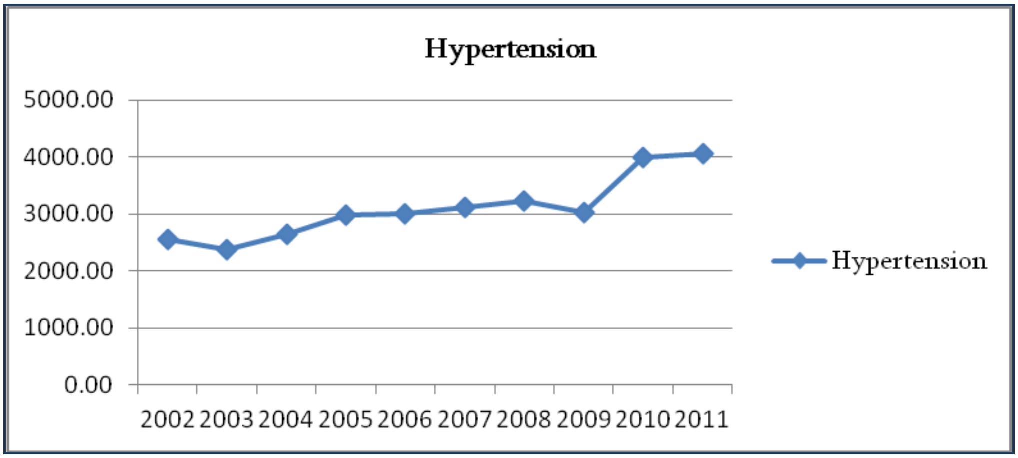

Fig. 5.6.3. Prevalence of Hypertension in Zemo Svaneti, 2002-2011

To reduce the risk of mentioned above pathologies and their harmful impact, the improvement of health sector services is necessary, manifested in the mobilization of sector during whole year as Zemo Svaneti provides different tourism activities in different seasons (rafting, alpinism, skiing, riding, hiking, etc.) and in provision of local community and tourists with adequate health service, e.g. in case of traumas – adequate urgent medical and post-traumatic rehabilitation services should be provided. This is one of the important pre-conditions for sustainable tourism development in the region.

Situation analysis – what is offering the health sector at present:

- In Zemo Svaneti, Mestia the medical providing network is represented by the primary health care and hospital sector, as well as emergency medical centers, the services of which are not specifically oriented on serving tourists according to international standards, and even more – the medical service lacks even national standarts and is very poor: the region is divided into 13 health districts, where the population is served by one doctor and one nurse. Every district level medical center is not properly equipped – the health professionals do not have basic medical equipments. Medical staff have only medical bag which they must purchase by themselves. Also, the medical centers of almost every district have very hardly reachable location for doctors as well as for population.
  In case of need a patient is sent from district medical center to the regional one, and if there is no the appropriate health specialist, he/she is sent to the regional center in Zugdidi, which is 105 km far from Mestia. The transportation of the patient is done by "Reanomobile" (special emergency van).
- The personnel engaged in the acting medical service is not adequately informed and trained on the measures which are to be taken against the risks, related with the impact caused by the temperature and other climate conditions. Another problem is the lack of health professionals themselves, and especially those, who should be engaged into the management of climate-related diseases, including: traumatologist, cardiologist, psychologist, angologist, infectionist, etc.

- There is lack of the information on climate-related diseases among the personnel serving in the tourist sector, which are not familiar with practical skills of informing and providing medical assistance to holiday-makers.

5.6.2. Objectives of the project

Objective of the proposal is to reduce of vulnerability of local population and tourism sector to climate change through increasing the capacity of local health care system. Activities to be implemented to reach the objective are:

1. Assessment of baseline situation (SWOT analysis);
2. Prepare recommendations on preventive measures;
3. Development of optimal scheme for mobilization of local and central health care systems in emergency situations;
4. Ensure the availability of medical services (locally;
5. Establish post traumas rehabilitation process locally.

Outcome of the proposal will be reduction of risks of traumas, and post-traumatic mental disorders through establishing adequate prevention, effective emergency management and rehabilitation processes.

The project basically will be directed towards the prevention and early diagnostics of climate-related diseases and disasters related traumas by means of introduction of relevant services according to modern standards, adapting to and implementing in Zemo-Svaneti region the best practices in worldwide touristic areas thus enabling to decrease risks related with these illnesses and emergencies and creating more comfortable conditions for local community and tourists.

5.6.3. Project Implementation

Methodology

The project methodology implies the detailed research on the vulnerability of health care sector to climate change that is crucial to prepare the recommendation for prevention climate-related illnesses and for adaptation of healthcare secto to climate change; the preparation of Health Disaster Management Plan (HDRMP) that will lessen the traumas and post-traumatic disorders as well as other post-disaster health consequences; creation of the Early Warning System and raise awareness among health and tourist sector and local community for better prevention of negative effects of climate change in Zemo Svaneti reigon.

Activities to be carried out

The project consists of four basic components:

1) Assessment of baseline situation and preparing of the recommendation
2) Preparing Health Disaster Management Plan (HDRMP)
3) Establishing Early Warning System (EWS)
4) Raising awareness among health professionals and tourism sector.

Component 1. Aassessment and preparing of the recommendation: In spite of the fact, that vulnerability assessment of the heaclcare sector was done in the frames of TNC, further assessment is needed. To achieve the sustainable economic development of the region the deep, detailed analysis of the situation is necessary. It is impossible to implement adaptation and mitigation measures without strong linkage between climate change and health outcomes and without making SWOT analysis of the baseline situation in the region. Thus, the further research is needed which should be done by means of local and/or international experts.

<u>**Assessment should be done on:**</u>

1) **Climate change and extreme weather events impact on the health through climate variability effects, that include:**
   a) Improving understanding of extreme weather events associated with naturally occurring climate phenomena and their impacts on human health
   b) Assessing the ability of health care systems to respond to extreme weather events and provide uninterrupted access to and delivery of health care services under a variety of scenarios
   c) Developing strategies for linking health databases with real-time monitoring and prospective assessment of weather, climate, geospatial, and exposure data in order to better characterize the health impacts of extreme weather events
   d) Enhancing predictability, modeling, and ongoing assessment of the effects of climate variability and change (seasonal-to-interannual and decadal) on extreme events and correlation with short- and long-term health outcomes.

2) **Climate change impact on mental health, that includes:**
   a) Understanding of how psycological tsress acts synergically with different forms of environmental exposures to cause adverse mental health effects
   b) Understanding the critical social and economic determinants for mental health and overall community well-being that might be altered by climate change
   c) Developing and implementing monitoring networks to help track the migration of environmentally displaced population to assist with the provision of mental health care and services

d) Identifying the most beneficial means of encouraging utilization of mental health services and delivering such services following extreme weather or other climate change events
e) Developing mental health promotion and communication programs related to proposed climate change mitigation and adaptation strategies.

3) **Identification of heat-related illnesses, that include:**

a) Developing and implementing a standard definition of heat-related health outcomes, as well as standard methodologies for surveillance (using Heat Indices (HI), of outcomes and evaluation of adaptations
b) Understanding risk factors for illness and death associated with both acute exposure to extreme heat events and long-term, chronic exposure to increased average temperatures
c) Determining attributes of communities, including regional and seasonal differences, that are more resilient or vulnerable to adverse health impacts from heat waves
d) Enhancing the ability of current climate models to capture the observed frequency and intensity of heat waves across various timescales to support weather-climate predictions and use of heat early warning systems in decision making
e) Evaluating heat response plans, focusing on environmental risk factors, identification of high-risk populations, effective communications strategies, and rigorous methods for evaluating effectiveness on the local level

4) **Assessment of baseline situation of health care services available in the region.**
The general assessment was done in the frames of TNC, but due to the distance and location of Zemo Svaneti it was impossible to reach all necessary spots (health care facilities, medical staff) during the short period of time. Thus, further communication with the representatives of health care sector of the region is crucial.

Recommendations should be prepared (based on the best practices of health care sector services in mountainous tourism developing regions):

1. Expanding research on prevention and preparedness for extreme weather events including development of disaster planning tools such as data and communication systems for public health and emergency care, including enhanced access to medical records and capabilities across hospitals on a regional level
2. Evaluating and developing new funding and reinsurance strategies and policies for disaster relief and rebuilding infrastructure
3. Developing and validating downscaling techniques from global climate models to provide regional information for health early warning systems
4. Ensure the availability of medical services locally: giving the recommendation on the creation of multidisciplinary consulting medical offices equipped with the necessary technologies and medical staff (traumatologist, cardiologist, psychologist, etc.) to manage climate-related diseases;

Component 2. Preparing Health Disaster Risk Management Plan (HDRMP): Deaths, injuries, diseases, disabilities, psychosocial problems and other health impacts can be avoided or reduced by disaster risk management measures involving health and other sectors.

Disaster risk management for health is multisectoral and refers to the systematic analysis and management of health risks, posed by emergencies and disasters, through a combination of

(i) Hazard and vulnerability reduction to prevent and mitigate risks,
(ii) Preparedness,
(iii) Response and
(iv) Recovery measures.

One of the main component of HDRMP should be the creation of post trauma rehabilitation service, including the treatment of post-trauma mental disorders.

Component 3. Establishing Early Warning System (EWS). It helps local medical staff and local community to be well-prepared for the climate threats to reduce the risk of climate-related diseases;

Assessment of illness risk increase. To assess the illness risk increase the continuous monitoring system on climate parameters is necessary along with the provision of timely identification and registration of initial cases (National Center on Disease Control and Public Health – NCDCPH).

Component 4. Raising awareness among health professionals and tourism sector

Creation of information network and provision of relevant stakeholders with necessary information. In the first place medical personnel and tourism sector should be informed on possible hazards and ways for their prevention, as well as on methods of correct response to them. The awareness rising of holiday-makers is also important by disseminating special printed materials (flyers, booklets. etc.) using visits to dispensaries, through medical personnel of hotels, pharmacies, the tourist information services.

5.6.4. Partners and beneficiaries

- Holiday-makers, especially for alpinists, skiers, etc. who will be able to receive general information on the prevention and treatment of climate-related illnesses and get timely and proper medical assistance from the medical personnel as well. As a result they will be at most protected at the tourist season from the climate-related sicknesses.
- Medical personnel who improve their professional skill on the management of climate-related diseases and the knowledge will allow them to be directly engaged in the prevention, early identification and timely treatment of illnesses.

- Private sector – (a) Personnel of the hotels, among them owners of small family hotels, which will receive the detailed information on the essence, prevention and curing of climate-related diseases. The information which will be disseminated in the hotels, will provide the rising of awareness among holiday-makes and efficient protection from climate-related illnesses. This will be responded with the growing satisfaction of holiday-makers, causing further development of tourism and the private sector. (b) Private insurance companies which would be able to save the treatment expenses through the prevention of climate-related diseases.
- Population which will receive the information on the prevention and treatment of climate-related sicknesses and will be prepared and protected during the natural disasters;
- The state which will increase the tourist potential of the region, by means of creating through this project the comfortable recreation conditions for holiday-makers. At the same time the state will be able to save the state insurance expenses by preventing the diseases.

5.6.5. Factors supporting the project implementation

- The interest of structural rings engaged in the project (local government, Department of Tourism, personnel of the hotels), demonstrated at the personnel meeting. Tourism development is the one of the priorities of the Government of Georgia. It is expected that the tourist industry would greatly contribute to the growth of Zemo Svaneti's socio-economic potential and, in general, to the sustainable development of the region. Thus, implementing the project which aims to strengthen the tourism industry, should be highly supported by policymakers.

5.6.6. Barriers to project implementation

- Lack of awareness and information. In Georgia virtually that is the first attempt to lessen the risks caused by climate change in health and tourism sectors;
- Insufficiency of studies carried out in this direction.
- Location of the region: high altitude and distance of Zemo Svaneti may be considered as an obstacle for frequent business traveling during the implementation of the project, especially during the wintertime.
- Inadequacy of climate parameters permanent monitoring system.
- Potential risk-factors for the successful implementation of the project may be insufficient interest of stakeholders (State Public Health system, private and state structures engaged in tourism) to the project, though this was not mentioned during the project preparation process. Additional barrier is also the provision of project sustainability.

5.6.7. Project implementation stages and costs

The project is represented by 4 major components:

1. Vulnerability assessment and preparing of the recommendation;
2. Preparing Health Disaster Management Plan (HDRMP);
3. Establishing Early Warning System (EWS);
4. Raising awareness among health and tourism sector professionals

The implementation of the project and each of its components will require 3 years with the execution of above mentioned stages.

Project Budget

Activity	Implementing agency/group	Terms of implementation (months) and budget (USD)
Assessment of baseline situation and preparing of the recommendation	Ministry of Labor, Health and Social Affairs of Georgia (MoLHSA); Ministry of Environment and Natural Resources; International and National experts	9 60 000
Preparing Health Disaster Management Plan (HDRMP)	MoLHSA, Ministry of Environment and Natural Resources; International and National experts	6 45 000
Support of creation of post trauma rehabilitation service	MoLHSA	12 90 000
Establishing Early Warning System (EWS)	MoLHSA, Tourism Department	9 50 000
Raising awareness among health professionals and tourism sector.	NCDC&PH, Ministry of Environment and Natural Resources; Tourism Department	6 50 000
Total		**295 000**

5.7. Possibility to install Thermophilic and Mezophilic Biogas Plants to Hadishi and Ushguli villages in Mestia Municipality

5.7.1. Description of the Problem

Hadishi and Ushguli villages are located in the alpine zone of Mestia Municipality at the altitude of 2 100 and 2 200 meters above sea level. As this is the alpine zone, the firewood material is not available in these villages. The local population has to transport firewood from the lower villages at the distance of about 15-20 km. The failure of the electricity system in Mestia District (the voltage is too low and there are often long electricity outages) virtually makes it impossible to heat houses with electric heaters. The liquid gas distribution network operated by SOCAR is available in Mestia, but this energy source is quite expensive for the local population (the cost of 1 kilogram natural gas is an equivalent of 1 US dollars in GEL) and regularly needs to be transported from Mestia Borough to the villages, which is very difficult during the heavy snow periods.

Mestia Municipality is one of the highest mountainous municipalities in Georgia. Its hypsometric height varies in the range of 500-5203 meters and makes an average of 2 300 m. Due to the geological and climate conditions, avalanches, landslides, floods and mudflows are frequent here, which seriously harms the local population. Hadishi Village is included in the list of the villages affected by the 1987 avalanches, after which the population was evacuated to safer places. A return of the environmental migrants evacuated from these places is observed here lately. The return process of the local population to the villages has to be accompanied with the supply of energy and its accessibility.

In climate conditions such as in Mestia District, where winter lasts for six months with very low temperatures and where firewood consumption is very high in other periods too, the average annual firewood consumption is 20-22 m^3 and the annual liquid gas consumption is 300-350 liters per household. At the same time, dung excreted by cattle is available locally and can be used for producing methane gas in domestic conditions. This can reduce energy costs for families and at the same time, contribute to the creation of more pleasant and comfortable environment for tourists in the villages. Odor from decayed manure will be reduced and the amount of fuel produced by the local renewable resources will increase. In addition, the family will get burned manure, which is the highest quality fertilizer used in agriculture.

Tourism is already developed in Ushguli, while Hadishi has a huge tourism potential, as it is rich in cultural heritage monuments. The lack of energy resources is one of the main obstacles in the process of developing tourism in the area, as it is difficult for the local population to provide tourists with food and hot water. Replacing firewood with the electricity totally is not quite reliable in Mestia due to the insecurity of the local electricity supply system. In such circumstances, the non-use of biofuel and dumping it in Enguri River is a non-energy efficient action, which should be replaced with a more efficient approach. One of such opportunities is to offer the installation of biogas digesters to the local population, for which livestock manure in rural areas are more than enough. (Note: Each family here has an average of 8-10 cattle heads).

5.7.2. Objective of the Project

The goal of the project is to use the local renewable resource (livestock dung) to the maximum extent for the production of domestic biogas. As mentioned above, Hadishi is the village affected by the natural disasters. It is almost completely empty. Only 11 families live in the village permanently. For the reasons described above, there is an acute lack of fuel resources in the village. The main activity of the population living in Hadishi, as well as in Ushguli Village is animal husbandry, in the process of which manure, a biogas source is generated. Consequently, it is recommended to arrange biogas installations for the residents of these villages. In particular, because of the lack of space for the large installation in Hadishi Village, it was decided to offer here a small-size thermophilic biogas digester and larger mezophilic plant in Uhsguli that consumes less energy for heating.

One of the households (Avaliani) was selected for the pilot project in Hadishi Village. Five persons live in the family, all of them are able-bodied, which is one of the necessary conditions for the operation of the bio-installation. The family (currently) has 9 cattle heads. Another household (Nizharadze) was selected for the pilot project in Ushguli Village. The family has six members, all of them are able-bodied. The family (currently) has 13 cattle heads. Both families have a good location of the stables and potato fields necessary to reduce the dependence of the digester on external energy and therefore, to diminish the risks deriving from this fact. In particular, the cattle stable and the fields are both located on the slope, which reduces the complexity of assembling the installation and the operation of the equipment. Due to such location, it is possible to deliver biomass by gravity from the stable to the digester and the processed biomass will be discharged by gravity to the special tank installed near the field, from which the potato crops will be fertilized.

One of the main goals of the project is to reduce emissions of methane, the global warming effect of which is 21 times greater than the effect of the carbon dioxide. The share of methane (CH_4) emissions in agriculture is 29% in Georgia, while the share from the manure management is 17%. In addition to inactivating methane, in case of producing and consuming biogas from sludge, the relevant amount of firewood is released from the consumption and the deforestation process is slowed down, as a result of which, carbon dioxide (CO_2) accumulated in the forest/trees is no longer emitted into the atmosphere.

The implementation of this project will promote the reduction in the methane, as well as nitrous oxide emission. It is noteworthy that the global warming potential of nitrous oxide is 310 times higher compared with CO_2. Applying livestock manure (as the fertilizer) in soil or its improper storage is one of the N_2O emission sources in agriculture.
The emission of this highly active greenhouse gas is reduced as a result of using the bio-fertilizer produced from the digester, namely:

1. N_2O emission caused by the superficial storage of the manure does not take place;

2. N_2O emission is stopped as the result of placing manure applied in the soil under anaerobic conditions;
3. Fast and easy absorption of nitrogen from the solution processed in the biogas unit, N_2O emissions from plants are reduced.

5.7.3. Project Implementation

Methodology

In thedigester, methane excretory bacteria function in an oxygen-free environment and educe/produce biogas by processing organic materials. The bacteria operate at different speed depending on the temperature in the biogas plant. The time of forming biogas depends on this speed. There are three types of digesters according to the temperature existing in the unit:

A) Psychophilic installation operating at 12-20 ^{0}C, the period for educing methane is 60 days;
B) Mezophilic installation operating at 20-42 ^{0}C, the period for educing methane is 30 days;
C) Thermophilic installation operating at 45-55 ^{0}C, the period for educing methane is 10 days.

With the increase of the temperature in the digester, it needs fewer manure or the resources and has more productivity in the time period.

Both villages (Hadishi and Ushguli) face the problem of the access roads to the village, as well as the problem of accessing individual households with cars. This somewhat limits the construction volume that should be considered in the design process. The space required for the biogas installation is especially limited in Hadishi. Because of this, the equipment capacity is limited that requires the use of the thermophilic equipment.

Depending on the amount of the family-owned cattle and the space limitations, it is recommended to install the 3 m^3 thermophilic biogas digester in Avaliani household and the 6 m^3 mezophilic biogas producing digester in Nizharadze family. The sites selected for the biogas installation are given on Photos 5.7.1 and 5.7.2.

Photo 5.7.1. The Avaliani household’s yard identified for installation of thermophilic biogas plant

Photo 5.7.2. The Nizharadze household’s yard identified for installation of mezophilic biogas plant

Activities

The following **activities** will be implemented within the framework of the project:

- **Familiarizing the inhabitant-beneficiary with the biogas plant.** In general, it is necessary to raise awareness about the digester in the selected family and to teach the family its usage, operation and safety rules. In order to successfully implement the project, the beneficiary family should in advance have sufficient information about the operation of the digester in his/her family. Information will enable the family to ensure its efficient operation. During the installation period the family should be involved in the installation works together with the project implementing agency. In particular, it is possible to involve them in carrying out the preparatory works, for instance, land leveling, supplying the stall with water and electricity, etc. Such participation increases the beneficiary's interest, otherwise the installed equipment could be carelessly abandoned and incorrectly operated that will have an adverse effect on the overall results of the project;
- **Constructing 3 m^3 thermophilic (Hadishi) and 6 m^3 mezophilic (Ushguli) biogas installations.** Unlike the phsycophilic installations, which are often constructed by the inhabitant-beneficiaries, the thermophilic and mezophilic digesters have complex structure and cannot be constructed by residents. Bio-reactors must be manufactured by experienced specialists. Both types of equipment should be designed for the cold winter climate and frosts, which are typical for Mestia. The following conditions should be satisfied for the normal and continuous operation of the equipment:
    1. The digester should be packed with a thick layer of high-efficiency heat-insulating material, which in case of the temporary suspension of the operation of heating system ensures the maintainance of the temperature and the functioning of the device in a continuous mode;
    2. As the power supply system is not functioning properly in the village (low voltage, frequent outages, etc.) and is unknown exactly when it will be rehabilitated, the system must be calculated for the lower power consumption (as much as possible);
    3. Electricity is mainly used for water heating in both digesters. Electricity warms up the biomass placed in the device via the radiators, as well as water, which should be diluted with the biomass loaded in the installation. In addition, it operates pump and the device to mix dung. In both cases, due to the inclination, a diluted solution is supplied by gravity flow to the installation. In this case, the use of the pump is not required. Until the device moves to the high-intensity eduction of gas and it will be possible to use produced biogas for heating water, solar energy can be used for producing heat. The solar panel (area 6 m^2) can be installed on the top of the stable in both cases. As Hadishi is the mountainous village, solar radiation is quite intense here and ensure the maintenance of the

temperature of 150 liters of water at 35-37^{0}C during 24 hours. This, in turn, provides with sufficiently stable heated water from the solar panel[44];

4. Regarding the device for mixing biomass in the digester that mainly operates with the electric actuators (it is necessary to mix the solution periodically, at least twice a day) - we can use a low-power engine/motor-reductor equipped with the appropriate time relay, which ensures switching on and off of the automatic actuator without the human involvement.
5. There is a second option of the biomass mixer – manual actuator, which is very effective. It will not be difficult for the inhabitant to manually operate it. In case of maunting the high-quality device, as well as after its proper installation, a worker pulling down the handle of the installation will need 12 kg/force capacity. Mixing up the mass twice a day will require 60 kg/force in the morning (pulling down the handle 5 times) and the same capacity in the evening.
6. It is very important to properly select and install the gasholder. There are several possibilities for accumulating and temporary storing gas. From the installations reviewed in this chapter, it is recommended to mount metal gasholder equipped with the frost-resistant solution or the rhumb-shaped inflatable gasholder in the household of M. Avaliani.

- **Transporting the plant to the site and its installation.** Taking into account the location and size of the cowshed, it is possible to place the biogas digester in the building in both cases (Overall dimensions of the equipment to be installed in Hadishi and Ushguli: (1.9 m x 2.2 m x 2.8 m and 2.2 m, respectively), which gives the possibility to maintain the high temperature in the winter (50-55 ^{0}C for the thermophilic and 37-42 ^{0}C for the mezophilic device). In case of maintaining such temperatures, both equipment will work in the relevant modes and the gas generation speed will be 3-4 m^3 methane a day on 1 m^3 volume of the installation in case of the thermophilic equipment and 1.5-2 m^3 – in case of the mezophilic equipment.
- Conducting the periodic monitoring during two years until the inhabitants are well acquainted with the equipment operation and maintenance guidelines.

The implementation of the project will increase the energy independence of the family/beneficiary. This will give the opportunity to the family to satisfy its energy needs/requirements and should also ensure hosting tourists. Bio-fertilizer produced by the digester is the best solution for applying it in the yard for growing ecologically clean vegetables (mainly potato).

[44] This system cannot operate in the winter period and here it is assumed that this method can reduce energy consumption in the rest of the seasons.

5.7.4. Beneficiaries and Partners

Project Beneficiaries:

- The family of Mukhran Avaliani residing in Hadishi Village and the family of Temraz Nijaradze livig in Ushguli Village of Mestia Municipality. Both beneficiaries were selected using the following criteria:
  1. The number of the cattle heads in the family (Avaliani family has 9 cattle heads and Nijaradze family – 13 cattle heads);
  2. The number of the able-bodied family members (Avaliani family – 5 members, Nijaradze family – 6 able-bodied members);
  3. Territorially favorable conditions for installing the biogas plant;
  4. An interest expressed by the family for installing the device in their family and their readiness to provide in-kind labor contribution in the process of mounting the installation.
- Both families that were selected for the project meet the above-listed criteria. In addition, both families have the land plots located on the slope next to the stall. Bio-fertilizer produced as a result of manure burning will move by gravity flow to the land plot and will bring an additional benefit to these families;
- The Tourism Information Center operating at the Mestia Municipality Gamgeoba, as new touristic routes will be developed (in case of Hadishi);
- Mestia Municipality leadership, as in case of the successfull implementation of the project, it will be easy to replicate this plant in other families. The tourism infrastructure will be developed, the amount of manure on local roads will be reduced and heavy dung odor in the villages will be decreased. The local renewable resources will be utilized and will partly replace expensive firewood.

Project Partners:

- Mestia Municipality Gamgeoba, which is interested in the development of additional thermal energy resources in Mestia Municipality for the families/local inhabitants, as well as for farms (in this case we mean cattle farms);
- Union "Svaneti Tourism Center", which is ready to assist the project in the process of its implementation and work with the local beneficiaries for raising their awareness;
- Ministry of Energy of Georgia, which is interested in developing small and renewable energy sources in high mountanous regions of Georgia;
- Ministry of Environment and Natural Resources Protection of Georgia, which is the agency responsible for the implementation of the UNFCCC in Georgia. The Ministry is responsible for the implementation of the projects that reduce the greenhouse gas emission into the ambient air.

5.7.5. Factors Supporting Project Implementation

- One of the factors contributing to the implementation of the project is the fact that the country is a party to the UN Framework Convention on Climate Change, which currently does not have quantitative obligations to reduce greenhouse gas, but the government is developing the low emission development strategy for Georgia. One of the directions of the strategy will be the effective utilization of local renewable energy resources and introducing modern technologies in the country;
- Heads of the local tourism development services, Tourism Department of Georgia and Union "Svaneti Tourism Center" will be partners to the project. They are interested in developing new routes. Upper Svaneti is especially rich in historical monuments, a large part of which is not included in the tourist routes as they are not adequately rehabilitated, the access roads are not built, the local infrastructure and the small family business are not developed. One of the important directions in terms of developing the tourism service is to supply the local population with fuel. This project proposal serves exactly this goal, this is why many different agencies partner to it.
- Ministry of Environment and Natural Protection of Georgia as the agency responsible for the UNFCCC in Georgia is obliged to support the implementation of such projects that reduce the greenhouse gas emissions.
- Ministry of Energy of Georgia interested in the development of small and renewable power engineering in the high mountanous regions of Georgia.

5.7.6. Barriers to the Project Implementation

The biomass utilization and the installation of biogas plants in Georgia has started in 1990's and is considered as one of the less successful technologies in the renewable energy sector. First it was used in the warm climate zones, but later these zones were supplied with natural gas and this is why, this technology proved to be uncompetitive. In 2012-2013, first attempts were made to install the thermophilic bio-plants in high mountainous regions with harsh (cold) weather conditions. The thermophilic bio-plant is much more difficult to control and the owner has to have enough knowledge and experience of different energy-related issues. Thus, at this stage there are serious difficulties in this respect too.

Two local biogas plant manufacturers operate in Georgia: Bio-Energy and Global Energy. Unfortunately, they are unable to independently ensure the proper functioning of the technology. For the first stage, it is necessary to establish a joint venture, which will develop the local capacity (will train the technical staff). It is necessary to deploy regional, mobile service teams locally for producing these types of renewable energy and ensuring the continuous operation of the biogas plants:

- Local manufacturers' technical qualification level is low. Often they use low-quality materials and spare parts, which leads to frequent accidents that is difficult to repair in the mountainous zones. At this stage, the majority of clients and users of the biogas digester are dissatisfied with the services of these manufacturers and demonstrate a negative attitude towards this technology. As stated above, it is necessary to establish the joint ventures and build the local capacity and ensure the service provision;

- Also, it is also important to train and raise awareness of the population. In case of installing the thermophilic digester, the residents will have to deal with not only the electrical equipment, but also with the natural gas system. Therefore, a simple problem and the temporary disruption of the operations might lead to a loss of interest in biogas production even where there is no gas, firewood is expensive and has to be transported from large distances. Accordingly, first of all, it is necessary to conduct the practical trainings for all able-bodied beneficiary family members (and especially to provide the focal points with enhanced training) to thoroughly introduce and acquaint them with the operation and functioning of the equipment, as well as to demonstrate potential problem solution options. The existence of complex unites/parts of the equipment that requires the involvement and knowledge of a qualified engineer should be minimized as much as possible;
- Emergency power supply failuresoutages in Mestia Municipality is an important barrier. Harsh climate conditions, the outdated and dysfunctional electricity system, especially in the winter period, often cause emergency power shut offs for several weeks. This is why it is necessary to equip the biogas digester with the gasoline-powered generator. This will allow the beneficiary to uninterruptedly operate the installation during the power outages. But of course, it makes the biogas generation process more expensive;
- The problems with the heating system. The heating system is the most difficult part in the operation of the equipment in harsh climate conditions. The entire water supply system must be wrapped with the reliable insulation layer and buried deep in the ground to protect it from frosts. In case of power cut-off, the biogas-powered water heating stove should work properly. Solar panels, which increases reliability of the system and reduces the risks, should be installed additionally for heating water and increasing the security of the system. If the heating system is not mounted correctly, its break will drop down the temperature in the device and will halt the process of producing gas. The reactivation of the device is a quite complicated process;
- Because of the lack of internal roads in the high mountainous regions, the transportation of the gas generator and its assembly is a serious problem in the villages and significantly increases the initial cost of the technology;
- The adverse climate conditions increase the danger of frosts and make it impossible to serve the device by qualified engineers in the winter period. Most of the problems have to be solved by the simplification of the component parts of the device and, in part, by the existence of the maintenance team locally;
- As for the technical barriers, it must be stressed that in both Hadishi and Ushguli, soil is rocky that makes it impossible to install the biogas plant in the ground. This increases the risk of physical damage of the installation and freezing the biomass inside the device. In addition, it is necessary to use the high quality and expensive insulation. In addition,

since this is the tourist area, the appearance of the installation and the entire facility must be well-maintained and align with the local environment. All of this further increases the cost of the equipment.

5.7.7. Project Implementation Milestones and Budget

Cost of the Installation of the Biogas Digester in Hadishi Village

#	Activity	Amount	Unit Price (in USD)	Total (USD)
1	Conducting trainings for the selected family members	Twice	500	1 000
2	Preparing the site, supplying the site with and installing electricity and water systems	_	500	500
3	Manufacturing 3 m^3 thermophilic digester (bio-reactor, gasghlder, heating system).	1 unit	9 000	9 000
4	Purchasing the solar heating system for maintaining the temperature of 37^{0}C for 150 l water a day	1 unit	1 700	1 700
5	Purchasing autonomous fuel generator (3 kw)	1 unit	400	400
6	Bringing the gas system to the house, installing the gas oven	_	300	300
7	Transportation	_	800	800
8	Supervision after the installation	At least twice	450	900
9	Overhead expenses	_	1 000	1000
	Grand Total			15 600

Cost of the Installation of the Biogas Digester in Ushguli Village

#	Activity	Amount	Unit Price (in USD)	Total (USD)
1	Conducting trainings for the selected family members	Twice	500	1 000
2	Preparing the site, supplying the site with and installing electricity and water systems	_	500	500
3	Manufacturing 6 m^3 digester (bio-reactor, gasholder, heating system).	1 unit	10 000	10 000
4	Purchasing the solar heating system for maintaining the temperature of 37^{0}C for 150 l water a day	1 unit	1 700	1 700
5	Purchasing autonomous fuel generator (3 kw)	1 unit	400	400

Annexes

Annex 1. Changes in climate parameters

Table 1.1. Changes in climate indexes between the periods of 1986-2010 (III) and 1961-1985 (II) according to the data provided by 3 meteo stations in Samegrelo-Zemo Svaneti

Station \ Parameter	Winter						Spring						Summer						Autumn						Year					
	T, ^{0}C	P,%	FD0, day	SU25, day	TR20, day	R90, day	T, ^{0}C	P,%	FD0, day	SU25, day	TR20, day	R90, day	T, ^{0}C	P,%	FD0, day	SU25, day	TR20, day	R90, day	T, ^{0}C	P,%	FD0, day	SU25, day	TR20, day	R90, day	T, ^{0}C	P,%	FD0, day	SU25, day	TR20, day	R90, day
Mestia	-0.1	30	-0.2	–	–	–	0.1	18	4.0	3.2	–	–	0.7	-8	-0.1	9.2	–	-0.1	0.5	10	-2.0	2.4	–	–	0.3	10	0	14	–	-0.1
Khaishi**	0.0	12	3.7	–	–	0.1	0.1	22	-0.7	-1.8	–	–	0.4	3	–	7.1	0.2	–	0.8	14	0.3	2.6	0.1	–	0.4	15	1.0	8.1	0.3	0.1
Zugdidi	-0.3	9	0.7	0	–	–	0.0	7	-0.4	0.4	-0.1	0.1	0.9	-14	–	12.2	11.7	-0.5	0.6	7	-0.5	4.4	2.4	0.1	0.3	1	-1.0	17	14	-0.4

Table 1.2 Changes in climate indexes between the periods of 2021-2050 (III) and 1986-2010 (II) according to the data provided by 3 meteo stations in Samegrelo-Zemo Svaneti

Station \ Parameter	Winter						Spring						Summer						Autumn						Year					
	T, ^{0}C	P,%	FD0, day	SU25, day	TR20, day	R90, day	T, ^{0}C	P,%	FD0, day	SU25, day	TR20, day	R90, day	T, ^{0}C	P,%	FD0, day	SU25, day	TR20, day	R90, day	T, ^{0}C	P,%	FD0, day	SU25, day	TR20, day	R90, day	T, ^{0}C	P,%	FD0, day	SU25, day	TR20, day	R90, day
Mestia	1.3	-1	-2.2	–	–	–	0.8	-16	-5.1	2.4	–	–	1.0	30	0.2	7.1	–	–	1.5	-8	-10	8.4	–	–	1.2	2	-15.4	18.7	–	–
Khaishi	1.3	14	-14.0	–	–	-0.1	0.8	-23	5.5	9.3	–	–	1.2	10	–	2.0	17.7	–	1.3	-10	1.8	10.2	1.8	–	1.1	-5	-4.5	21.3	19.6	-0.1
Zugdidi	1.5	33	-12.2	0.2	–	–	1.0	-21	-0.2	5.5	0.9	-0.1	0.2	44	–	-13.6	0.3	1.7	1.4	-2	0.6	4.8	1.7	–	1.0	13	-11.1	-2.7	2.7	1.4

Table 1.3 Changes in climate indexes between the periods of 2071-2100 (V) and 1986-2010 (III) according to the data provided by 3 meteo stations in Samegrelo-Zemo Svaneti

Station \ Parameter	Winter						Spring						Summer						Autumn						Year					
	T, ^{0}C	P,%	FD0, day	SU25, day	TR20, day	R90, day	T, ^{0}C	P,%	FD0, day	SU25, day	TR20, day	R90, day	T, ^{0}C	P,%	FD0, day	SU25, day	TR20, day	R90, day	T, ^{0}C	P,%	FD0, day	SU25, day	TR20, day	R90, day	T, ^{0}C	P,%	FD0, day	SU25, day	TR20, day	R90, day
Mestia	3.7	-11	-13.0	–	–	–	3.1	-10	-15.9	8.6	0.1	–	4.1	16	–	25.7	2.3	–	4.1	-21	-18.1	19.8	0.1	–	3.7	-6	-45.3	54.9	2.4	–
Khaishi	3.5	-2	-25.9	0.3	–	-0.1	2.9	-17	-1.0	16.4	1.7	–	4.4	-14	–	15.2	41.2	–	3.8	-22	-1.7	20.5	7.4	–	3.6	-16	-26.6	52.2	50.3	-0.1
Zugdidi	3.4	-5	-20.9	1.2	–	–	2.8	-10	-2.7	11.0	3.0	-0.1	2.5	-8	–	1.7	28.0	0.8	3.6	-20	-0.5	17.8	10.2	–	3.0	-12	-23.3	32.0	41.2	0.6

Explanations:

T - Average seasonal/annual air temperature, ^{0}C
P -Average sums of seasonal/annual precipitation (change, %)
FD0 - Average number of seasonal/annual days during the period, when the daily temperature comprises minimum $T_{min}<0^0$C
SU25 - Average of seasonal/annual days during the period, when the daily temperature comprises $T_{max}>25^0$C
TR20 - Average of seasonal/annual days during the period when the daily minimum comprises $T_{min}>20^0$C
R90 - Amount of days with anomalous heavy precipitation (≥90mm) during the period

Annex 2. Results of the studies conducted at the Chalaati Glacier in various years

❖ **1959 (D. Tsereteli, R. Khazaradze, et al.)**[45]

In 1959, the observation over Glacier Chalaati movement from July 9 to September 6 with a theodolite was performed in 2 points of the glacier surface at 2 250 and 2 500 meters above the sea level. It has been determined as a result of the study that average rate of the movement of glacier is 38 cm/day. Average values of surface melting over the observation period are provided in Table 2.1.

Table 2.1. The volume of melting on Glacier Chalaati in 1959

Period	Melting mm	Runoff, m^3
9 July- 1 August	1 862	18 417 200
1 August- 1 September	2 294	19 094 400
1 September - 6 September	269	
Total 58 days	4 425	

According to this data, it can be defined that 9.1 thousand m^3 melted water corresponds to melting of 1 mm on Glacier Chalaati surface. Therefore, the melting of 4 42 5mm over 58 days in 1959 has conditioned (4 425 mm X9, 100 m^3=402 67 500 m^3) the formation of about 0.04 km^3 water.

❖ **1960 (R. Shengelia, M. Chizhavadze)**[46]

In the summer of 1960, glacio-hydrological studies of River Chalaati were performed near Chalaati Glacier. It has been identified as a result of the study that the depth of the layer of melted water on site of runoff site organized on the glacier surface over 10 days (10VIII-19VIII) totaled 393 mm, the depth of ice on the runoff site for the same period decreased by 575 mm.

At the same time, the correlation between average daily air temperature and the depth of the melted water layer has been determined (Fig. 2.1), which has shown that 1^0C rise in average daily air temperature results in the melting off of 7 mm daily.

[45]D. Tsereteli, R. Khazaradze, G. Lominadze, Sh. Inashvili, T. Lashkhi, G. Kurdghelaidze, G. Kalandadze, R. Chekurishvili Glaciological observations over Chalaati and Lezkhiri glaciers (Upper Svaneti) in Spring, 1959, Works of the Vakhushti Geography Institute Works, T. 27, 1962, Pg. 223-255

[46]Shengelia, R., Chijavadze, M. Chalaati glacier river runoff in Summer, 1960. Georgia SSR. Academy of Sciences the Works of Vakhushti Institute of Geography, T. 28, 1963, Pg. 245-253.

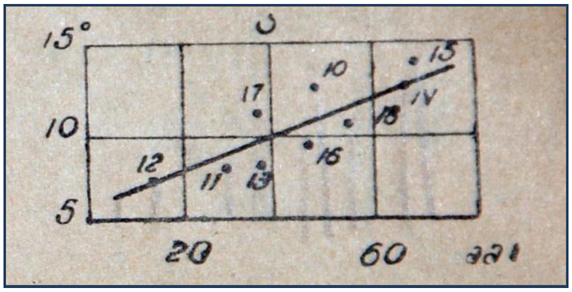

Fig. 2.1. Correlation between air temperature and the depth of the melted water layer, Glacier Chalaati, 1960

- **2000 (P. Janelidze et al.)**[47]

The study carried out in 2000 on Glacier Chalaati was aimed at assessing the role of the glacier in the formation of the river runoff. The observation was performed over 4 months, from June 15 to October 15. It comprised observations over several glaciers of the River Enguri Basin: Lekhziri, Chalaati, Dolra, Kvishi; Although, in the present paper we will focus on the survey conducted on Glacier Chalaati in 2000. River water levels and water temperature, as well as water discharge, air temperature and ablation was measured at hydrological posts installed on River Chalaatitskali. It has been identified as a result of the study that during the study period, from June 16-20 to October 10-15, over 116 days, 762 cm ice layer was melted off on Glacier Chalaati surface. Glacier Chalaati retreated by 253 meters over 24 years (1976-2000). Its speed was 10.5m/year, which is 1.8 times higher than the rate of retreat of the glacier defined in 1963-1983.

- **2011 (R. Gobejishvili, L. Tielidze, N. Lomidze, et al.)**[48]

In 2011, complex glacio-hydrometeorological observations on Glacier Chalaati were carried out for 92 days, over the entire ablation period. In terms of meteorology, the study primarily involved observations over air temperature and atmospheric precipitation. Glaciological observations envisaged the calculation of accumulation of solid atmospheric precipitation and measuring of snow and ice ablation. Snow survey method was used for calculating accumulation; This method includes measuring snow cover depth and snow density on a pre-planned route in specifically designed sections. The section was made in the middle part of the glacier's tongue. While for calculating surface melting off ablation gauging rods were used, which were placed in a section cut at a pre-selected elevation zone above the sea level (1 900-2 800m); Based on this the glacier area and the volume of accumulated snow was determined, while above 2 800m up to 3 300 meters works were performed according to theoretical calculations which are well proven for using in glaciological studies.

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[47] Janelidze, P. Assessing the role of glaciers in the formation of river runoff in Georgia, Project # 2586-03, Glacier -02, Final report, Tbilisi, 2000, Pg. 110.

[48]Gobejishvili R., Tielidze L., Lomidze, N., Glaciers Monitoring in the Context of Climate Change, Publishing House Universal, Tbilisi, 2012, Monograph, 176 pg.

❖ The results of meteorological observations

Table 2.2 has been designed according to the analysis of the data of three stations (Chalaati Lower, Chalaati Upper, Mestia M/S), which provides air temperature data over the observation period: average monthly, maximum and minimum temperatures during the ablation period (June, July, August).

Table 2.2. Air temperature in Mestia area, at upper and lower parts of Glacier Chalaati, 2011.

	Air temperature °C																	
	June						July						August					
	Date	Mestia h=1441	Date	Lower Chalaati 1960m.	Date	Upper Chalaati 2135m.	Date	Mestia h=1441	Date	Lower Chalaati 1960m	Date	Upper Chalaati 2135m..	Date	Mestia h=1441	Date	Lower Chalaati 1960m.	Date	Upper Chalaati 2135m..
Avg.		14.5		10.7		5.1		18.5		14.5		11.1		16.9		12.5		9.6
Max.	29	18.5	30	16.2	28	8.0	29	22.2	31	18.9	30	15.0	2	22.3	1	18.0	2	13.6
Min.	19	12.1	4	7.4	13	3.2	2	13.2	2	9.1	2	3.9	26	13.0	26	7.4	26	5.8

As can be seen from the Table, temperature difference between these three points was the highest in June and amounted 5 °C, in July and August this difference comes down to 3 °C. It is estimated that in June, as in the coldest among summer months, the role of the glacier on the overcooling of the lower layer of air has become vivid. While the glacier effect was relatively less clear in July and August, as in the warmest months of the year. Furthermore, the dates of the occurrence of minimum and maximum temperatures approximately coincided. At all three points (Mestia, two points of Glacier Chalaati) daily course of air temperature is almost (Fig. 2.2) similar to one another, which confirms that Mestia Meteorological Station air temperature multi-year data are representative for Glacier Chalaati (Model Glacier in River Enguri basin).

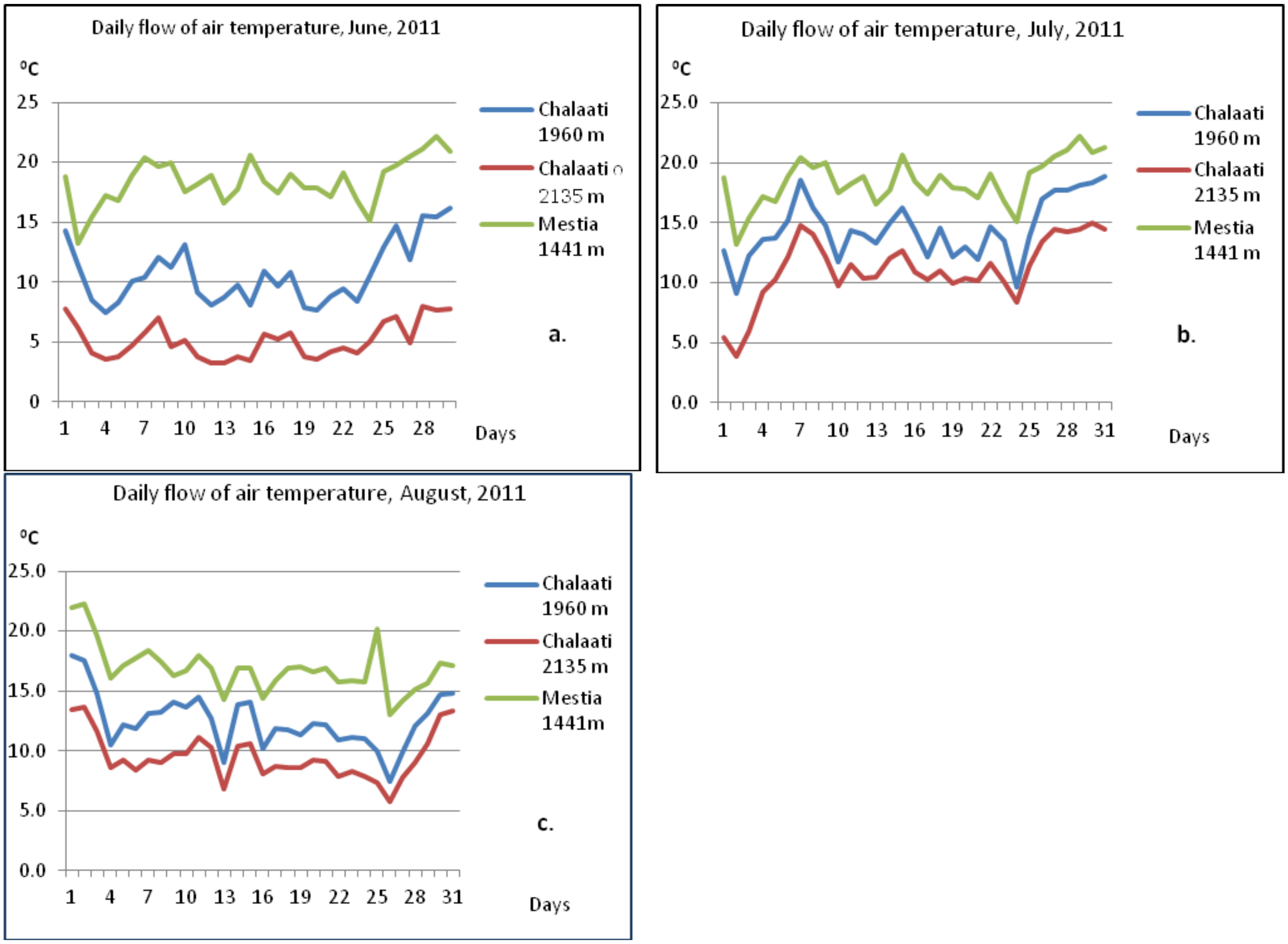

Fig. 2.2. Daily air temperature at Glacier Chalaati and MS Mestia in June, (a), July (b), and August (c), 2011

The comparison of the Mestia MS 2011 air temperature data with 1961-1990[49] and 1981-2010 multi-year data has demonstrated that in 2011 air temperature was almost 1°C higher in June and August, while it was 2 °C higher in July (Table 2.3.) Notably, in July, 2011 similar situation was observed at other meteorological stations of Georgia as well. Specifically, at one of the most reliable meteorological station throughout the country, Tbilisi M/S. This may reinforce the view that on the most part of Georgia's territory there was about 2 °C higher temperature than the norm in July, 2011.

Table 2.3. Average air temperature data of Mestia Meteorological Station

	1961-1990	2011	1981-2010
June	13.6	14.5	14.0
July	16.5	18.5	16.7
August	15.8	16.9	16.6

The comparison of two thirty-year periods has identified that over all three summer months the rise of air temperature is observed, which has been manifested with the highest indicator in August (almost 0.8 °C).

[49] 1961-1990 – Thirty years Accepted by the World Meteorological Organization as a baseline period

Since in 2011 the observation over atmospheric precipitation was performed not specifically on the glacier surface, but 3 km away from it, due to less reliability of these data Mestia M/S data were analyzed (Table 2.4).

Table 2.4. Mestia meteorological station average atmospheric precipitation data

Atmospheric Precipitation, mm		
	2011	**1961-1990**
June	125	105
July	87	96
August	35	100

Therefore, in 2011 more precipitation fell in June in Mestia as compared to multi-year (1961-1990) norm, in July precipitation was relatively closer to climate average, while in August precipitation was much less than the norm. This further confirms that in the context of global warming, not only air temperature rise, but also the fall in the amount of precipitation us taking place.

- **The results of hydrological-glaciological observations**

The distribution of density according to the depth of snow cover is provided in Figure 2.3.

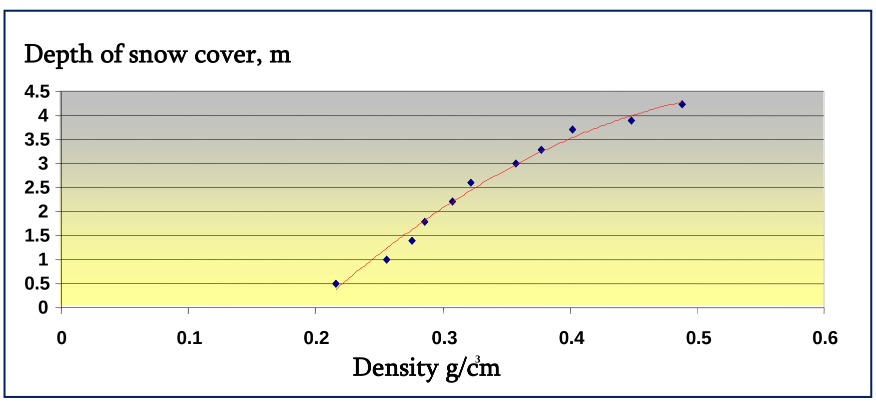

Fig. 2.3. The distribution of snow density according to depth on Glacier Chalaati, June, 2011.

It can be seen from this Figure that there is a distinct correlation between the snow cover depth and density. The obtained data were used for the calculation of snow accumulation.

The curve of correlation between snow cover depth and the elevation of the site is shown on Figure 2.4.

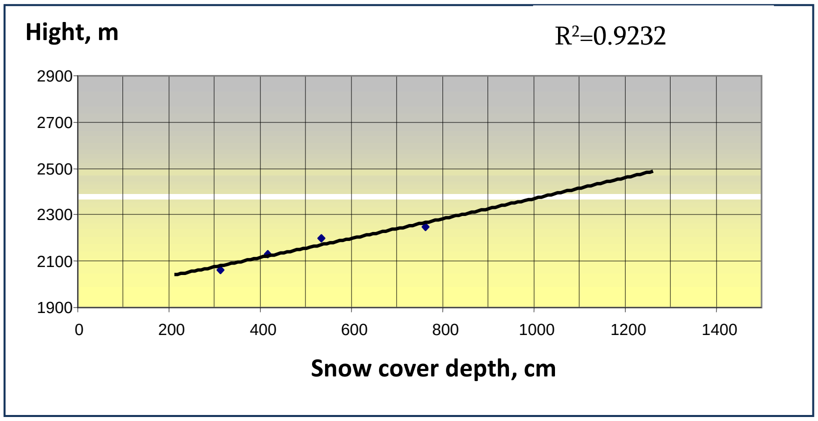

Fig. 2.4. The correlation between Glacier Chalaati snow cover depth and the elevation of the site. June, 2011

Accumulated snow amount in water equivalent was calculated using to the data on the depth of snow cover, its density and the elevation of the site according to the distribution of actual areas, which is given in Table 2.5.

Table 2.5. The distribution of areas according to elevation zones on Glacier Chalaati and the amount of accumulated snow in June, 2011

Accumulation thousand m^3	Area thousand m^2	Elevation
72	265	1900-2000
202	567	2000-2100
332	984	2100-2200
202	1 112	2200-2300
311	1 138	2300-2400
602	1 236	2400-2500
1 416	1 497	2500-2600
1 621	1 385	2600-2700
1 494	1 032	2700-2800
423	106	2800-2900
431	109	2900-3000
239	98	3000-3100
94	91	3100-3200

Annex 3. Potential for utilization of renewable resource

Table 3.1. Mestia Municipality population as of 2012.

#	Name of Village	Number of housholds	Nmber of population
1	Ushguli	70	267
2	Kala	27	107
3	Ipari	90	261
4	Cvirmi	126	484
5	Mulaxi	313	1007
6	Lenjeri	223	1066
7	Latari	390	1104
8	Tskhumari	242	633
9	Becho	368	1003
10	Etseri	226	813
11	Phari	105	316
12	Lakhamula	74	337
13	Nakra	127	332
14	Chuberi	383	1304
15	Khaishi	421	1281
16	Idliani	115	443
17	Mestia	817	2881
	Total	**4 237**	**13 679**

Table 3.2. Amount of Livestock and Poultry in Mestia Municipality in 2013

#	Livestock types	Unit	Becho	Mestia	Etseri	Ipari	Kala	Lenjeri	Latali	Lakhamula	Mulakhi	Nakra	Ushguli	Pari	Tskhumari	Tsvirmi	Chuberi	Khaishi	Total
1	Number of livestock and poultry in Total:	Head	3 579	3 554	2 175	1 246	635	1 029	2 174	479	1 585	620	657	700	1 074	600	4 210	11 535	35 852
2	Cattle in Total:	Head	1 876	1 510	900	600	273	770	930	219	1 035	500	291	400	537	400	1 620	2 165	14 026
3	Cows	Head	586	901	735	188	96	295	580	150	300	300	168	300	358	150	1 250	1 605	7 962
4	Pigs	Head	584	206	130	50	138	50	19	70	110	22	139	60	20	20	15	500	2 133
5	Goats and sheep	Head	891	11	50	50	62	15	56	16	250	20	116	100	-	50	-	105	1792
6	Poultry	Head	228	1 827	1 095	546	162	194	1 142	174	190	78	111	140	517	130	2 575	8 769	17 878

Annex 4. Reforestation and forest management

Assessment of carbon uptake and deposition potential of planted forests in the subsequent years

The increase of the potential of carbon accumulation in the years following the reforestation of the Upper Svaneti eroded slopes (23.3 ha) was assessed using the CO2FIX[50] model.

CO2FIX V 3.1 model is used to determine the volumes of accumulation of carbon in nature, using the so-called accounting method of recording carbon. In particular, it involves the calculation of changes in carbon stocks in all carbon dioxide “reservoirs” (the part of nature where carbon is accumulated, like live biomass, detritus, organic soils as well as wood products) in the forest over the specific period of time.

Carbon sequestration data as a result of reforestation on a project 23.3 ha area calculated using the model are provided in Table 4.2, while graphical representation of accumulation dynamics is oresented on Fig. 4.1. Mg on these figure denotes mega gram, i.e., 10^6g=1 ton.

As can be identified from summary Tables, on selected territory (23.3 ha) in the first year of reforestation 3.5 tC will be accumulated, while in subsequent years, for example, in 5 years from planting, 186.0 tC will be sequestered over the entire area (Table 4.1).

Table 4.1. Absorbtion of carbon dioxide and storage of carbon in various periods of growth (23.3 ha)

Accumulation process starting from the first year of planting							
Years	1	5	10	20	30	40	50
Accumulated Carbon, tC	3.5	23.0	52.0	104.6	143.5	170.8	186.0
Absorbed Carbon Dioxide, Gg CO_2	12.8	84.3	190.6	383.5	526.2	626.6	682.0

[50] http://dataservices.efi.int/casfor/frontpage.htm

Table 4.2. Carbon storage after reforestation of slopes

	Sequestered Carbon reforestatio...		Sequestered Carbon reforestatio...		Sequestered Carbon reforestatio...		Sequestered Carbon reforestatio...		Sequestered Carbon reforestatio...		Sequestered Carbon reforestatio...
year [yr]	carbon [MgC/ha]	year [yr]	carbon [MgC/ha]	year [yr]	carbon [MgC/ha]	year [yr]	carbon [MgC/ha]	year [yr]	carbon [MgC/ha]	year [yr]	carbon [MgC/ha]
1	3.48	25	125.83	49	184.94	73	201.07	97	208.63	122	214.22
2	7.62	26	129.62	50	186.05	74	201.47	98	208.88	123	214.42
3	12.43	27	133.28	51	187.10	75	201.86	99	209.13	124	214.62
4	17.63	28	136.82	52	188.09	76	202.24	100	209.38	125	214.82
5	23.02	29	140.24	53	189.02	77	202.61	101	209.62	126	215.01
6	28.64	30	143.55	54	189.91	78	202.97	102	209.86	127	215.21
7	34.39	31	146.74	55	190.76	79	203.33	103	210.10	128	215.40
8	40.26	32	149.81	56	191.56	80	203.67	104	210.34	129	215.59
9	46.21	33	152.78	57	192.32	81	204.01	105	210.57	130	215.78
10	52.05	34	155.65	58	193.05	82	204.34	106	210.80	131	215.97
11	57.76	35	158.41	59	193.75	83	204.66	107	211.03	132	216.16
12	63.34	36	161.08	60	194.41	84	204.98	108	211.25	133	216.35
13	68.81	37	163.66	61	195.05	85	205.29	109	211.48	134	216.54
14	74.17	38	166.15	62	195.66	86	205.59	110	211.70	135	216.72
15	79.44	39	168.56	63	196.25	87	205.89	111	211.92	136	216.91
16	84.63	40	170.80	64	196.81	88	206.18	112	212.14	137	217.09
17	89.74	41	172.88	65	197.35	89	206.47	113	212.35	138	217.27
18	94.79	42	174.79	66	197.87	90	206.76	114	212.57	139	217.46
19	99.77	43	176.55	67	198.38	91	207.04	115	212.78	140	217.64
20	104.56	44	178.20	68	198.86	92	207.31	116	212.99	141	217.82
21	109.16	45	179.73	69	199.33	93	207.58	117	213.20	142	218.00
22	113.58	46	181.16	70	199.79	94	207.85	118	213.41	143	218.18
23	117.82	47	182.50	71	200.23	95	208.11	119	213.61	144	218.35
24	121.90	48	183.75	72	200.65	96	208.37	120	213.82	145	218.53

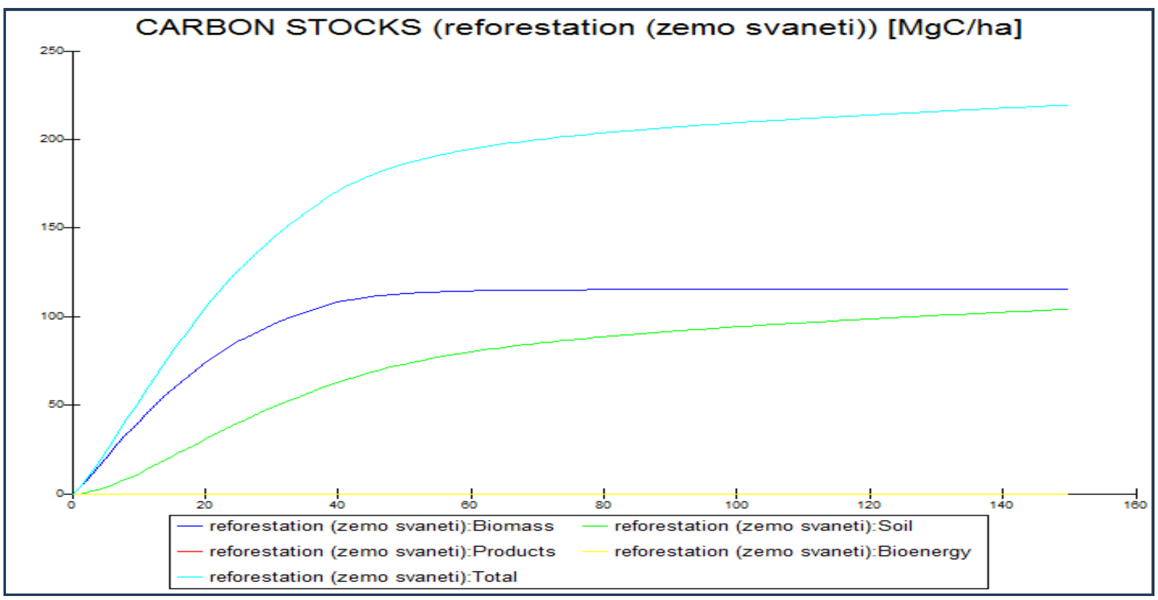

Fig. 4.1. Dynamics of carbon accumulation after reforestation

Table 4.3. Budget of planting works of woody plants (23.3 ha)

№	Description of expenses	unit	Unit cost (USD)	Total quantity	Total cost (USD)
I. Main expenses					
1.	**Purchases**				
1.1	Wooden poles	Units	2.90	1 200.0	3480
1.2	Barbed wire	Meters	0.07	12 500.0	875
1.3	Nails	Kg	2.40	30.0	72
	Total 1:				**4 427**
2.	**Field works**				
2.1	Cleaning the area (cleaning from dried and damaged ligneous plants and bushes)	ha	54.00	23.3	1 258
2.2	Fencing of the area with barbed wire (fastening poles and barbed wire).	Meters	1.32	2 500.0	3 300
2.3	Preparing clear areas and holes for planting – size 0.5mX0.5m	Units	0.31	50 800.0	15 748
2.4	Taking the saplings from the nursery and planting on selected areas	Units	0.16	50 800.0	8 128
2.5	Watering the saplings with an irrigation machine	Units	0.11	50 800.0	5 588
	Total 2:				**34 022**
	Grand total (USD)				**38 449**

Table 4.4. Budget of arranging the nursery of ligneous and coniferous plants (0.3 ha)

№	Description of expenses	Measure unit	Unit cost (USD)	Total amount	Total cost (USD)
I. Main expenses					
1.	**Purchases**				
1.1	Seeds material (coniferous)	Kg	23.00	12.0	276
1.2	Poles wooden	Units	2.90	130.0	364
1.3	Barbed wire	Meters	0.07	1300.0	91
1.4	Nails	Kg	2.40	3.5	8.5
	Total 1:				**739.5**
2.	**Field works**				
2.1	Cleaning the area (from scrubby undergrowth, sprouts, etc.)	ha	100.00	0.3	40
2.2	Fencing off the area (fastening of poles and barbed wire).	Meters	1.50	260.0	390
2.3	Ploughing the area (in autumn)	ha	200.00	0.3	60
2.4	Harrowing the area (in spring)	ha	190.00	0.2	38
2.5	Treating coniferous tree seeds material with anti-fungal preparations	Kg	75.00	0.2	15

	(Fundazole) 3 days prior to sowing				
2.6	Distribution the area into beds in the coniferous nursery 2-3 weeks prior to sowing	Sq. m	0.07	2 000.0	140
2.7	Treating the soil 3-4 days prior to sowing in the mentioned beds with antifungal preparation (Fundazole)	Kg	75.00	15.0	1 125
2.8	Sowing in the beds (in spring)	Sq.m.	0.05	2 000.0	100
2.9	Treating sprouts of coniferous plants with herbicides and shading with the branches	Sq.m.	0.80	2 000.0	1 600
2.10	Spraying irrigation (if necessary)	Sq.m.	0.05	2 000.0	100
2.11	Thinning out of one-year growth	Sq.m.	0.05	2 000.0	100
	Total 2:				**3 708**
	Grand total (USD)				**4 447.5**

Table 4.5. Estimated budget of arranging the nursery of ligneous leafy plants nursery (0.3 ha)

№	Description of expenses	Measure unit	Unit cost (USD)	Total amount	Total cost (USD)
I. Main expenditures					
1.	**Purchases**				
1.1	Seeds (leafy)	Kg	17.0	64.0	1 088.0
1.2	Wooden poles	Units	2.9	130.0	364.0
1.3	Barbed wire	Meters	0.07	1 300.0	91.0
1.4	Nails	Kg	2.4	3.5	8.5
	Total 1:				**1 551.5**
2.	**Field works**				
2.1	Levelling and cleaning the area (from scrubby undergrowth, sprouts, etc.)	ha	750.0	0.3	225.0
2.2	Fenceing of the area (with barbed meter wire)	Meters	1.5	260.0	390.0
2.3	Ploughing the area (in autumn)	ha	200.0	0.25	50.0
2.4	Harrowing the area (in spring)	ha	190.0	0.25	47.5
2.5	Making beds for sowing and drilling the seeds (in spring)	Sq.m.	0.2	2 500.0	500.0
2.6	Treating the new growth with herbicides and watering by spray irrigation (if necessary)	Sq.m.	0.2	2 500.0	500.0
	Total 2:				**1 712.5**
	Grand total (USD)				**3 264**