Ministry of Environment and Natural Resources Protection of Georgia

IFAD
Investing in rural people

gef

ENVIRONMENTAL INFORMATION AND EDUCATION CENTRE

Climate Change National Adaptation Plan for Georgia’s Agriculture Sector

Tbilisi, 2017

This document is prepared by the LEPL "Environmental Information and Education Center" of the Ministry of Environment and Natural Resources Protection of Georgia, under the joint order of the Ministry of Environment and Natural Resources Protection and the Ministry of Agriculture. The project has been initiated by the Ministry of Agriculture within the frameworks of the "Agriculture Modernization, Market Access and Resilience" (AMMAR) project. This project is implementing by the Ministry of Agriculture of Georgia with the support of IFAD / GEF.

LEPL "Environmental Information and Education Center" of the Ministry of Environment and Natural Resources Protection of Georgia thanks to all participants of the project:

Marina Shvangiradze - Sustainable Developmen Center Remissia (project team leader);

Davit Bedoshvili - impact of climate change on wheat and corn;

Salome Gelashvili - Argiculture Policy Research Center (ISET), cost-benefit analysis of the measures for adaptation to climate change;

Gizo Gogichaishvili - National Environmental Agency (impact of climate change on potato);

Vakhtang Goguadze - LEPL Laboratory of the Ministry of Agriculture of the Autonomous Republic of Adjara (citrus, potato and livestock breeding in Adjara);

Medea Inashvili - project expert (guide on preparation of national adaptation plan on climate change for agriculture sector);

Nato Kutaladze - National Environmental Agency (changes in agro-climatic zones and climate change future scenarios);

Lika Megralidze - National Environmental Agency (the current climate change scenarios, climate change impact assessment on water requirement and productivity of non-perennial crops);

Nato Mikadze - project expert (impact of climate change on nut culture in Zugdidi Municipality);

Gia Nakhutsrishvili - professor of Botany Institute of Ilia State University (impact of climate change on pastures);

Ana Rukhadze - project expert (review of the documents for climate change impact assessment on agriculture sector of Georgia & identification of problems);

Tengiz Kurashvili - Director of the Institute of Veterinary Medicine (impact of climate change on livestock breeding);

Natia Javakhishvili - Environmental Information and Education Center (project assistant).

Sector ministries have presented important recommendations and considerations during elaboration and refinement of the document:

Grigol Lazrievi - Head of Climate Change Division (Ministry of Environment and Natural Resources Protection);

Lasha Zivzivadze - Analytical Department of the Ministry of Agriculture.

Table of Contents

Introduction

Traditionally, agriculture is a key economic sector in Georgia employing about 42% of the population though its share in GDP is not so high and in 2015 it was 9.3%[1]. The sector requires rehabilitation and reformation and the ongoing climate change processes should be taken into consideration, Agricultural production heavily depends on climatic conditions. Forecasted climate change significantly increases sector development risks, also it negatively impacts economic and social welfare of the farmers and other vulnerable groups. Though there are positive impacts as well. The above has caused necessity of development of the national plan for agriculture sector adaptation to the climate change. This was initiated by the Ministry of Agriculture of Georgia within the scopes of the project "Agriculture Modernization, Market Access and Flexibility (AMMAR). The mentioned project is implemented by the Ministry of Agriculture of Georgia with IFAD/GEF support and its goal is providing assistance to the large farmers in reduction of risks caused by climate change, increase of incomes of the small farmers and improvement of resistance to climate changes impact through providing the infrastructure, production systems stable to the climate changes and investments into the technologies.

Elaboration of the National Plan for Agriculture Sector Adaptation to Climate Changes (hereinafter National Adaptation Plan (NAP)) was preceded by the analysis of the studies conducted in the country, for assessment of the agricultural sector vulnerability and adaptation. As a result, the available data and information were collected and the gaps and requirements for NAP development were identified. Based on the above there was elaborated the roadmap for NAP preparation and development, setting the stages of Adaptation Plan development, there was assessed also how favourable the existing political, legal and institutional environment was for the document elaboration and adoption.

In preparation of the roadmap the components necessary for agriculture sector development were considered, as well as and how well the impact of climate change on these components was studied in Georgia. The key components considered include the climate and agro-climatic zones, soils, irrigation water and irrigation facilities, agriculture directions (annual crops, perennial plantations, pastures and livestock). Analysis of the available materials showed that almost all of these components have been partially studied, with respect of climate changes, at various times and within the scopes of various projects. Available studies and assessments consider various annual crops, perennial plantations; information about impact of climate changes on the livestock sector and increase of morbidity risks in this sector is relatively scarce; for the conditions of increased demand for the irrigation water and reduction of flows into the rivers the availability of irrigation water in the rivers used for these purposes is not adequately studied. Impact of climate change is more or less evaluated for Dedoplistskaro pastures only; agricultural lands degradation caused by the climate change is basically evaluated in Adjara and partially in Kakheti. It is also significant to assess system adaptability to the climate change and this was done in the third national communication on climate change for 14 municipalities only and in the regional project for assessment of the climate change impact on agro-biodiversity[2], covering only 5 semi-arid municipalities.

One of the most important directions, such as climate change impact on the entire value chain have not been assessed yet though climate change impact was assessed for certain elements of the process and the adaptation measures were developed. In particular, the third national communication provided evaluation of climate change impact on the quality of cereal seeds and the process of sale of perishable vegetables (Kabali market). The adaptation measures were developed.

---

[1] http://geostat.ge/cms/site_images/_files/georgian/agriculture/2016%20wlis%20soflis%20meurneoba.pdf

[2] http://www.rec-caucasus.org/projects.php?id=&lang=en&p=2

Based on the available studies it was established that impact of the current and forecasted climate changes on the agriculture sector includes the following:

- Displacement of the agro-climatic zones; In this respect, within the scopes of this project assessment of the changes ongoing in the agro-climatic zones was planned and such assessments were made as generally, also for each of the crops, individually. To complete this objective, at the following stage the agricultural land areas in these agro-climatic zones and their suitability for the specific crop or specific agricultural branches should be evaluated.

- Reduction of productivity of the most crops resulting from the draughts, strong winds, unevenly distributed precipitation, hail days, heat waves and evapotranspiration growth; In this respect, within the scopes of ongoing project, among the key agricultural cereal crops there were evaluated the wheat and maize, among the perennial crops intended for export – hazelnuts and tangerines, among the annual crops widely consumed as food – potatoes, as well as the livestock sector, together with the pastures. The results are described in the respective chapters. Climate change impact is evaluated for the vegetation period, water demand in this period and the productivity. The remained components of the full cycle value chain (nurslings, seeds, sale, storage in winter etc.) were not considered. To obtain more refined strategy, it is necessary to evaluate the climate change impact for the entire value chain, for each of the crops and agricultural branches and each of the regions where agriculture is a key sector.

- Reduction of the agricultural lands' fertility and degradation intensity growth, frequently aggravated by the intensive extreme phenomena caused by climate change (landslides, mudflows, floods, inundations etc.); Risks of agricultural lands fertility reduction were indirectly considered in relation with certain crops (potatoes in Akhaltsikhe and pastures in Dedoplistskaro and Kazbegi). In the Adaptation Plan this direction is not specifically divided and fully analyzed, even for the municipalities that were considered at current stage of adaptation plan development.

- Loss of productivity, as a result of extreme weather frequency growth (hails, frosts etc.); These phenomena were linked with the agricultural insurance as the adaptation measure, for the tangerines only. This direction is of key significance given the increased frequency of extreme weather and requires greater attention. Against the background of the climate change cost-effectiveness of insurance mechanism should be assessed for each of the products for which the insurance operates (cereals, legumes, vegetables, melons, fruits, hazelnuts, citruses etc.).

- Reduction of irrigated land areas and increase of demand for irrigation water.

In the process of NAP development it was found that within the scopes of single small-scale project all regions, sectors and components of agriculture cannot be evaluated with respect of climate change risks. This should be a permanently updatable process that would stage by stage cover all issues and fill in the gaps already described in the roadmap that were identified in this project and will be further identified in various projects. Ministry of Agriculture should consider impact of the climate change within the process of strategy updating ("climate-smart agriculture" should not be a separate direction in the strategy, as this is a conception that should be reflected in the respective directions of the strategy), as well as in the regional directions development plans and programs.

The following chapters provide assessment of the climate change impact in the pre-selected cultures and directions for this stage, as well as potential adaptation measures, their cost-effectiveness and social effect.

1. Climate Change National Adaptation Plan for Agriculture Sector

1.1. Vision 2030

Climate-smart agriculture is practiced in Georgia, ensuring the country's food security, poverty elimination in the rural areas and sustainability of the agro-ecosystem services through introduction of the highly effective production methods and management of the climate change-associated risks.

1.2. Mandate

National Adaptation Plan of Georgia's agriculture sector to Climate Change (AgriNAP) should become the integral part of Agriculture Development Plan and assist the government in implementation of the agriculture strategy, with due regard of the climate change risks. AgriNAP development process is a long-term one, requiring involvement of all stakeholders and authorities in its preparation process. Based on such broad stakeholder consultations, the document should become the guidance document for all governmental authorities and other parties interested and involved in agriculture sector development and its adaptation to climate change.

1.3. Overview of Current Situation

Introduction of climate-smart agriculture practices is a significant component of Georgian Agriculture Development Strategy (2015-2020)[3].

According to the strategy, development of the climate-smart agriculture should respond to three inter-crossed challenges: ensuring food security through improvement of productivity and incomes, adaptation to climate change and promotion of climate change mitigation.

Impact of climate change on agriculture of Georgia was discussed in all third national communications of Georgia to the UNFCCC. In the process of preparation of the Third National Communication (2012-2014) the study of climate change impact on agriculture was conducted for the two philot regions with drastically different climatic conditions – Adjara and Kakheti municipalities. And for Zemo Svaneti there was evaluated the expected impact of the forecasted climate change on transformation of the agro-climatic zones by the end of this century. Georgian Climate Change Strategy-2014[4], based on the mentioned assessment, provides evaluation of vulnerability of agriculture to climate change in the other regions of Georgia as well and identification of the adaptation priorities; also improvement of the agriculture service centers potential for mitigation of the climate change negative impact risks and improvement of the soil fertility. Climate Change Strategy of Georgia provides recommendations on the measures for adaptation to climate change in 14 municipalities of Adjara and Kakheti, for the purpose of improvement of agriculture sustainability.

The agriculture adaptation strategy provided in the Third National Communication on Climate Change recommends that the certain measures should be integrated into the individual regions development strategies.

---

[3] Approved by the Resolution No: 167 of 11 February 2015 of the Government of Georgia

[4] Prepared within the scopes of the Third National Communication of Georgia on Climate Change

1.4. Key Strategic Directions of the Strategy for Agriculture Development in Georgia

Certainly, the priorities of the AgriNAP are based on the key strategic directions of the strategy for agriculture development of 2015-2020 period:

- Improvement of competitiveness of those engaged in agrarian sector (improvement of the farmers' awareness, vocational training, insurance market development, support to the cooperatives etc.)
- Institutional development (basically implying development and enabling of the Ministry of Agriculture and its subordinated institutions)
- Melioration and soil fertility (improvement of the irrigation and drainage systems, reasonable use of the soils)
- Regional and sector development – support to development of the complete production cycle adding value (production of the seeds and planting materials, their certification, development of the sector programs etc.)
- Ensuring food security (monitoring)
- Food safety, veterinary and plants protection
- Support to introducing of the climate-smart agriculture practices, including, as such, sector adaptation to the climate change, as well as reduction of the processes negatively impacting global warming in the sector.

For the latter the strategy provides for implementation of the following measures:

- Assessment of the climate change on agriculture
- Development of the database of negative impacts resulting from climate change
- Putting in place the system for supply of information on agro-climatic monitoring, analysis, results communication and other data
- Implementation of the relevant re-training programs to improve capacities of the Ministry of Agriculture and municipal information & consultation services in the area of application of the climate-smart approaches in agriculture

2. Changes of the Key Climatic Parameters

For the last 55 years (1961-2015), in the entire territory of Georgia the average annual temperature growth trend was recorded. The maximal increment was registered in the Eastern Georgia – Dedoplistskaro (0.9°C) while in the Western Georgia – Poti this figure was (0.6°C). In Mtskheta-Mtianeti and Kakheti the trend of warming was relatively weaker but yet significant. According to the forecasts, by 2021-2050, the highest increase is expected in Sachkhere (2.1°C), further, along Adjara coastal area and Goderdzi Pass. And by 2071-2100, the highest temperature growth is expected in Batumi (4.2°C). 3.7OC temperature growth is expected in Sachkhere, Ambrolauri and Mestia.

Annual aggregate precipitation growth between two periods (1966-1990; 1991-2015) was the highest in Svaneti low hill zones and Adjara mountain areas (up to 14%), growth was significant as well, in Poti and Imereti mountain areas (up to 10%). In general, in Western Georgia, with few exclusions (significant reduction has taken place in the eastern part of Adjara, at Goderdzi Pass – 17%), precipitation increases, while in Eastern Georgia there is the reduction trend; though there are exclusions as well, and one of the most important ones is Lagodekhi, where precipitation growth in the second period was 7.6%. Stable trend of precipitation growth will be maintained in Western Georgia up to 2050, further the figures will reduce, with certain exclusions (Batumi, Pskhu and Mta-Sabueti in the east). In the Eastern Georgia reduction trend will be replaced by growth and expected average precipitation growth by 2050 is 3.4%. By 20100, significant reduction of precipitation is expected all over the Georgian territory and the highest fall is expected in Samegrelo, Kvemo Kartli and Kakheti (22%).

Average annual wind velocity, all over the territory of Georgia, has decreased significantly and the greatest reduction, with stable trend was observed at the stations (Mta-Sabueti, Poti) selected as the areas of highest potential for wind power generation. In the future, up to the end of the century, wind velocity all over the Georgian territory will further reduce. Though, possibly, in some places some growth will take place. Average wind velocity growth was forecasted in Akhmeta, though by the end of the century the windiest places will be Kutaisi, Batumi and Goderdzi (5.1 m/sec). It should be emphasized that no observations and recording of the high velocity winds were conducted while these are the most dangerous for agriculture and no forecasts can be made.

Reduction of the number of frosty days will take place all over the territory of Georgia in the second period of observation. In the following period the number of frosty days will reduce with growth of the average temperatures though by 50s of this century the frosty days will still persist in the lowlands of Georgia, in winter and especially in spring and by the end of the century the frosty days will be characteristic for the mountain areas only.

More specific information about climate change and its impact on various agricultural crops selected at this stage for the National Adaptation Plan is provided in the relevant sections.

3. Changes in Agro-Climatic Zones of Georgia

Change of agro-climatic zones against the background of the temperature increase and change of precipitation is one of the highest risks caused by climate change for the agriculture sector. Reduction or growth of the agro-climatic zones requires implementation of significant changes in this sector. In the process of NAP development change of the agro-climatic zones spread all over the territory of Georgia was evaluated, regarding changes of the following agro-climatic parameters: total of active temperatures, precipitation in the vegetation period and average absolute minimal temperature. These are the parameters used for agro-climatic zoning of Georgia for the first time in 70s.

Changes of Active Temperature Total

Vegetation of the most agricultural crops lasts for the period where total average daily temperature exceeds 10^{O}C though there are the crops with vegetation period starting earlier, at 5^{O}C or later, at 12^{O}C. In Georgia, in this period, the lowlands are provided with heat best of all with annual total active temperature is 4000OC and higher. With increase of altitude over the sea level total of active temperatures decreases by about 160^{O}C per 100 m height and at 1500 m over the sea level falls to 2000OC. Table 3.1 provides distribution of active temperatures by the altitude over the sea level, respective areas and their change in 1991-2015 and 2071-2100 periods.

Table 3.1. Distribution of active temperatures by the altitude over the sea level and areas in different periods.

Year	<500⁰	500-1000⁰	1000-1500⁰	1500-2000⁰	2000-2500⁰	2500-3000⁰	3000-3500⁰	3500-4000⁰	4000-4500⁰	>4500⁰
Altitude (m)										
1966-1990	>2500	2300-2500	2100-2200	1500-2000	1200-1500	1000-1200	800-1000	500-800	<500	<500
1991-2015	3000	2500-3000	2100-2500	1700-2100	1300-1700	1100-1300	900-1100	700-900	500-700	<500
2071-2100	3500	3000-3500	2500-3000	2000-2500	1500 - 2000	1200-1500	1000-1200	800-1000	<800	<800
Area (km²)										
1966-1990	7745	4943	6626	6944	7078	6998	7351	8389	9557	796
1991-2015	6722	4306	6257	6812	6886	7003	7444	7394	9669	7441
2071-2100	252	3692	4632	5091	6795	10409	8107	9344	10545	12700

Changes in moisture supply / precipitation in the vegetation period

One of the key factors for yielding of the agricultural crops, after heat supply comprise the moisture supply conditions.

By precipitation in the vegetation period the following 3 zones were identified in Georgia:

1. Dry (up to 500 mm);
2. Moderate (500-900 mm);
3. Humid (over 900 mm);

According to the data of 1991-2015, precipitation in the vegetation period was changed only slightly while in 2071-2100 period reduction of precipitation in the vegetation period will be considerable. Table 3.2 provides areas with different moisture supply for two periods. By 2071-2100 the area of humid zone will reduce almost two times and hence, the area of dry zone will increase, mostly on the lowlands of eastern and southern Georgia.

Table 3.2. Areas with different moisture supply (km²)

Year	Dry (up to 600 mm)	Moderate (600-900 mm)	Humid (over 900)
1966-1990	14665	46386	8113
2071-2100	22799	41699	4673

Change in agro-climatic zones

For simple marking of the agro-climatic zones the following signs were introduced: Three zones were distinguished by the total of active temperatures: A (<1000^{0}C), B (<1000-3900^0 C) and (>3900^0 C). Zone A is the coldest and can be considered as a pasture only, zone C us the hottest and the citruses and tea can be grown only here and zone B is the one supplied with the heat sufficient for all other crops.
In these tree zones, the following sub-zones of moisture supply are distinguished: (1) dry (precipitation is lower than 500mm); (2) – moderately humid (with 500-900 mm precipitation); and (3) humid zone (with over 900 mm precipitation).

Table 3.3. provides change of the areas of agro-climatic zones in Georgia in the period of 1966-1990, 1991-2015 and 2071-2100. As can be seen in Table 3.3. in 1991-2015 the area of A2 zone has reduced as the zone with up to 1000 degrees of total active temperatures has moved upwards by 300-500 m and this territory was replaced by zone B. Area of zone B has reduced as well, almost similarly in all sub-zones. Areas of this zone were replaced by zone C. Area of all subzones of zone C has increased and the one of the C3 (humid) subzone, the closest one to the see - most of all and in this period it spreads over the territories up to 800 m height.

By the period 2071-2100, regarding that total of active temperatures growth by up to 100-1000 degrees almost all over the territory of the country and the zones displace upwards by about 500 m and in the entire eastern and southern Georgia the significant lack of moisture will take place in the vegetation period, the following changes of agro-climatic zoning can be expected: in this period area of A2 zone will reduce significantly (with only one third left). B3 zone will not exist at all, area of zone B2 will reduce and B1 will increase significantly. The latter is a dry subzone with up to 3900 active temperature including elevated areas of Imereti, Kvemo Kartli and South Georgia. Areas of c1 and C2 zones will increase significantly as well (almost two times) while area of zone C3 will reduce 3 times. This is the zone favorable for citrus growing, its area is currently the largest and it will reduce significantly in the future.

Table 3.3. Change of the areas of agro-climatic zone (km^2)

1966-1990			
	500-1000^0 (A)	1000-3900^0(B)	>3900-5000^0(C)
Humid>900 mm (3)		4741	4448
Moderately humid 500-900 mm (2)	12636	35502	3752
dry< 500 mm (1)		1356	6772
1991-2015			
Humid>900 mm (3)		3336	5816
Moderately humid 500-900 mm (2)	11012	35639	5034
dry< 500 mm (1)		881	7240
2071-2010			
Humid>900 mm (3)			1910
Moderately humid 500-900 mm (2)	3868	30316	10268
dry< 500 mm (1)		9693	13097

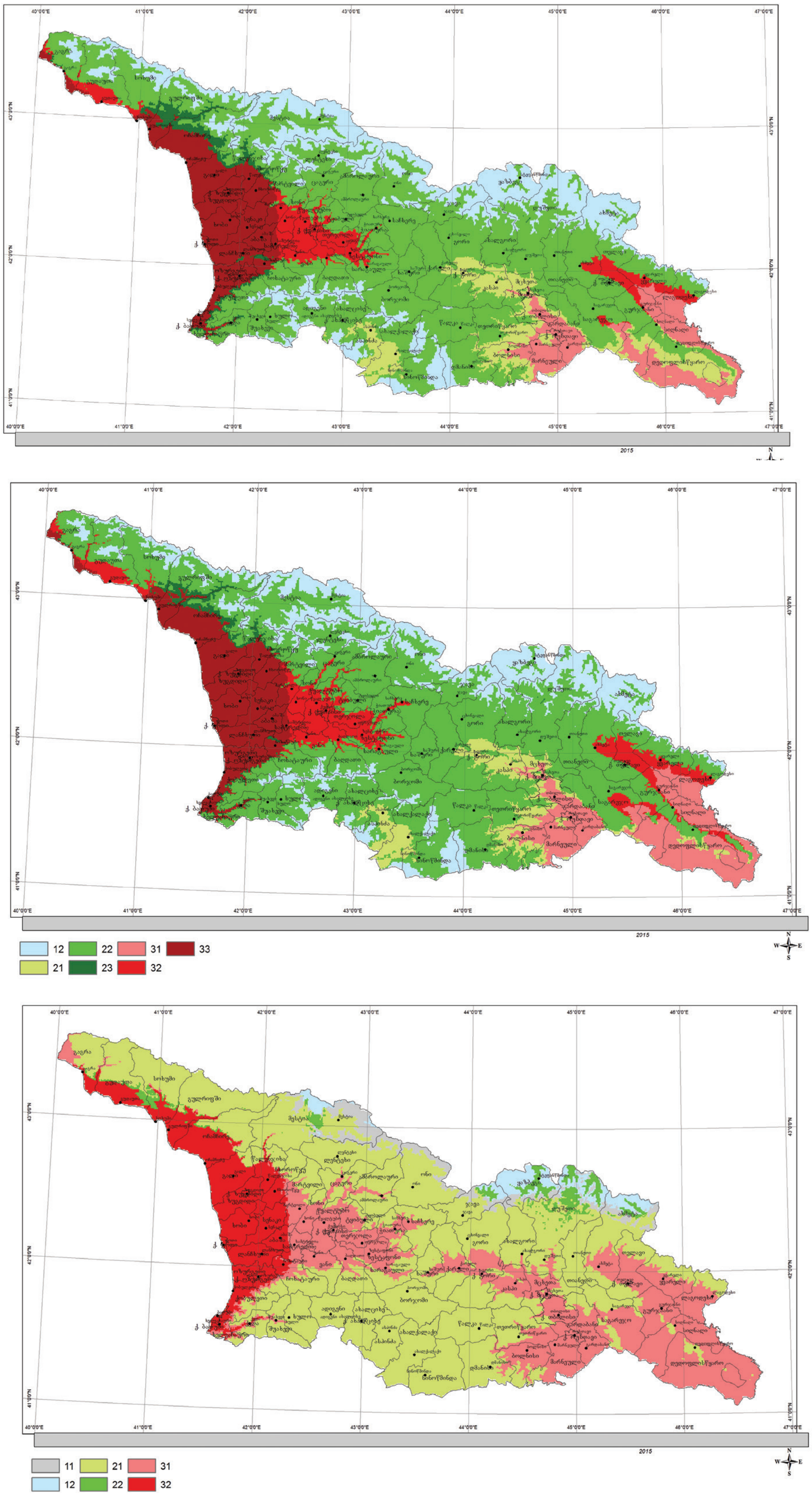


Fig. 3.1. Agro-climatic zones change in 1961-1990, 1991-2015 and 2071-2100 periods

Changes, with respect of agro-climatic zones were evaluated for 6 meteorological stations (Dedoplistskaro, Mestia, Zugdidi, Pasanauri, Khulo, Stepantsminda). Table 3.4 describes change of the agro-climatic zones in the areas of the mentioned stations in the periods 1966-1990, 1991-2015 and 2071-2100.

Table 3.4. Changes in agro-climatic zonality in location of the meteorological stations

	1966-1990	1991-2015	2071-2100
Dedoplistskaro	B1	C1	C1
Mestia	B2	B2	B2
Zugdidi	C3	C3	C2
Pasanauri	B2	B2	B1
Khulo	B2	B2	B1
Stepantsminda	A2	A2	B2

Table 3.5 provides the coefficients of climate parameters change trends in 1966-2015 period. Trend of change of temperature parameters shows that in the vegetation period, the temperature regime will be more favourable with the higher temperature sum and lower number of frosty days. Though, high temperature sum is frequently associated with the increased frequency of the animals and plants diseases, as well as emergence of the new diseases. As for the precipitation in the vegetation period, stable growth trend was identified in Khulo only, number of the days with showers increase in this period as well and this could be regarded as the negative impact for this territory as the showers can cause soil washout and provoke mudflows and landslides in this specific territory that is quite steep. In all other cases the trends are unstable and any changes can be expected in the future.

Table 3.5. Coefficients of trends of the climatic parameters changes in 1966-2015 period [5]

#	Parameter	Akhaltsikhe	Dedoplist-skaro	Mestia	Zugdidi	Khulo	Pasanauri	Stepants-minda
1	Absolute temperature maximum, ^{0}C	0.049	0.081	0.033	0.029	-0.017	0.043	0.011
2	Absolute temperature minimum, ^{0}C	0.067	0.072	0.043	0.046	-0.003	0.002	0.011
3	Total of active temperatures, ^{0}C	6.093	9.918	4.866	8.269	0.396	4.645	2.181
4	Hot days' (T max >25^{0}C) number (SU25)	0.496	0.802	0.514	0.625	0.232	0.528	0.14
5	Hot days' (T max >30^{0}C) number (SU30)	0.468	0.768	0.271	0.62	0.133	0.221	0.015
6	Frosty days' (T min<0^{0}C) number (FD0)	-0.314	-0.37	-0.009	-0.107	0.167	-0.01	0.291
7	Frosty days' (T max<0^{0}C) number (ID0)	-0.16	-0.066	0.276	-0.005	0.229	-0.092	0.003
8	Total precipitation in the vegetation period, mm	-0.035	0.297	4.078	2.633	6.611	0.826	1.68
9	Number of sequential dry days (CDD, period duration)	-0.176	0.117	-0.055	-0.049	-0.097	0.038	-0.028
10	Number of days with precipitation ≥20 mm (R20)	-0.002	0.017	0.043	0.045	0.156	0.04	0.08
11	Aridity index	-0.005	-0.049	-0.011	0.023	0.032	0.005	0.005

[5] *Coefficients of the stable trends are specified in black and those of unstable trends are in red.*

Impact of Climate Change on Wheat Production and Recommended Adaptation Measures

4.

4.1. Wheat Production in Georgia

In 1909-1913, cereal growing was at the first place by product value in Georgian agriculture. According to the statistical data of that period, area under autumn wheat was no less than 180 thousand hectares with 132 thousand tons of average productivity. In early 20th century the spring wheat area was about half of that of the autumn wheat (about 90.000 ha) and the productivity was respectively half of the one of autumn wheat. In 1913 Georgian population was no more than 2.6 million and per capita wheat production was 104 kg. Currently this figure is much lower, amount to 36 kg[6]. It should be noted that in 1909-1913 period, Georgia imported great quantities of wheat flour from Russia (about 97.000 tons[7]) as yielded wheat was not sufficient to meet local demand for the wheat flour.

12 of 24 varieties of cultivated wheat are currently available in Georgia and five of them are endemic varieties originated in Georgia and grown only there. These include: Gvatsa Zanduri, Chelta Zanduri, Dika, Kolkhuri Asli and Makha.

Currently, only soft wheat is sown in Georgia. According to GeoStat data for year 2016, almost entire areas under wheat are occupied with the autumn wheat (95.6%) and spring soft wheat fields are very rare (4.4%). Soft spring wheat is usually sown in the areas of the destroyed q autumn wheat.

In Georgia, the leading region producing autumn wheat is Kakheti, by both, the sown areas and productivity per ha/ In Kakheti Region, Dedoplistskaro and Sighnaghi municipalities are distinguished with high wheat production.

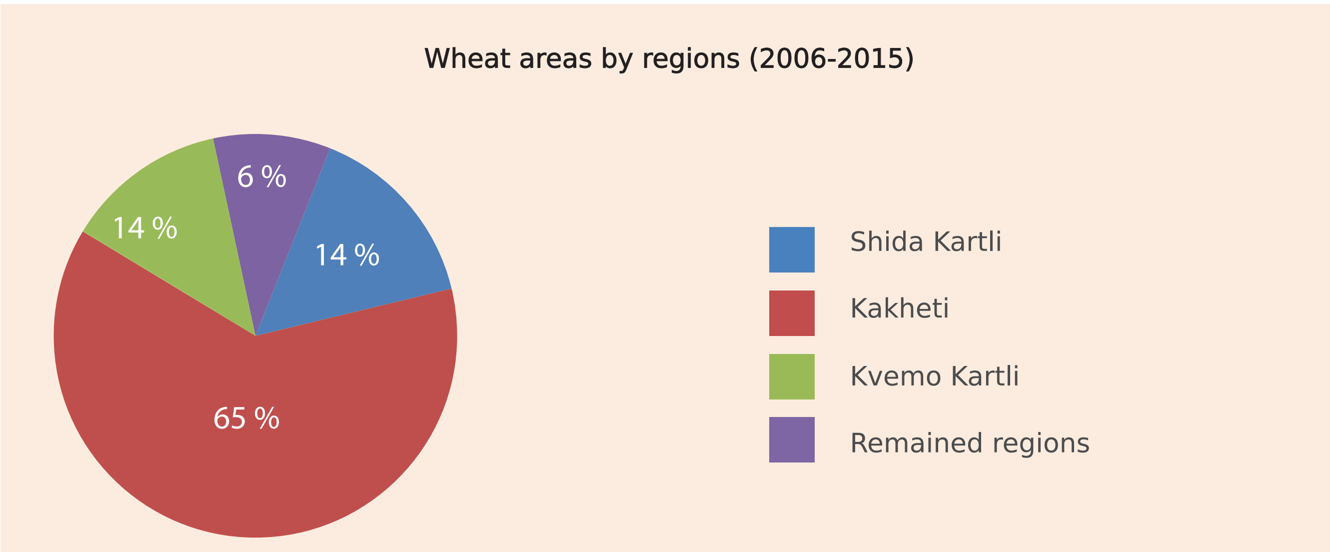


Fig. 4.1. Areas under the wheat by regions (Source: GeoStat)

---

6 *For comparison: according to GeoStat data, in 2015, Georgian population was 3.713 thousand people and wheat output was 133 thousand tons*

7 *Statistical reference book, 1909-1921 Tbilisi 1923, p. 78-79.*

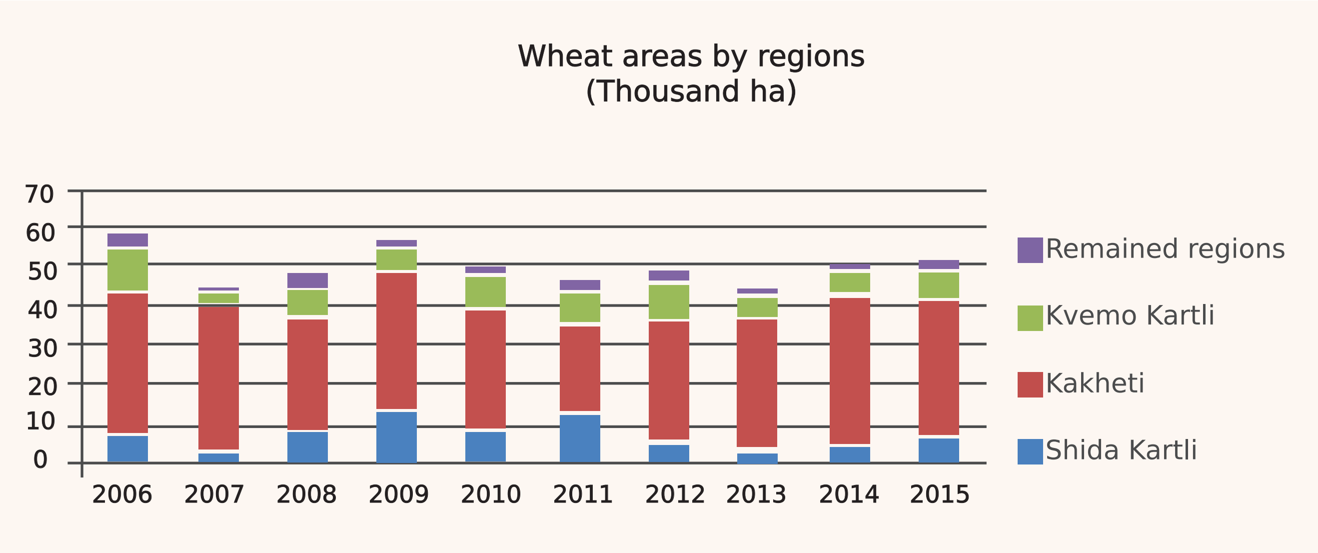


Fig. 4.2 Areas under the wheat by regions, in ha (Source: GeoStat)

In Georgia, wheat areas are almost non-irrigated, resulting in significant fall of the productivity in the droughty years. In the non-irrigated areas, the choice of wheat fore crops is very limited. In Dedoplistskaro, on non-irrigated areas, the sunflower is used most frequently as wheat fore crop though its area gradually decreases (2.700 ha in Dedoplistskaro). Therefore, in the most part of the wheat areas are the single-crop ones and this negatively impacts the soil fertility.

To illustrate dynamics of the wheat productivity in the soviet period Fig. 4.1 provides the plot for five-year intervals based on the data provided by V. Kevkhishvili[8]. While this plot cannot be used for evaluation of the climate impact of on wheat production it clearly shows the trend of growth of the wheat productivity due to improvement of the varieties and agricultural technologies.

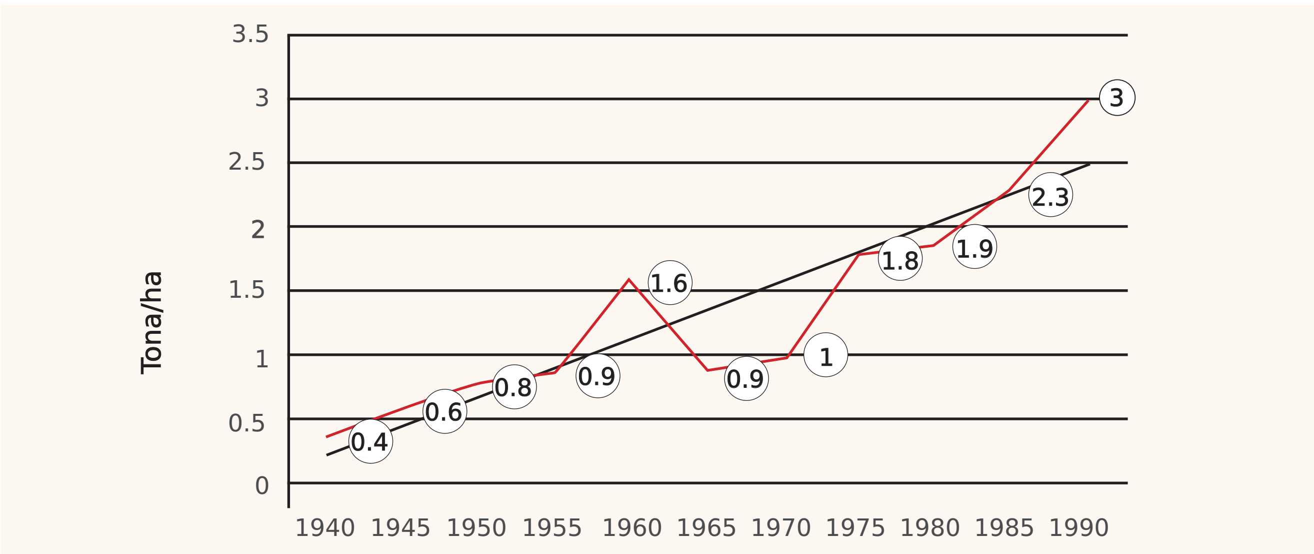


Figure 4.3 Dynamics of wheat productivity in the period 1940-1990

[8] *V. Kevkhishvili (2001) Wheat. Agrarian Engineering. Tbilisi, Publishing House "Akhali Sakartvelo", p. 399*

In 1992-2016 (see Fig. 4.5) the wheat productivity varied significantly and no apparent growth or reduction trend compared with the previous period was seen at that stage. First fall of wheat productivity occurred in 1991-1994. Georgia Agriculture and Food Sector Review[9] published by the World Bank in 1996 and dealing with the period from 1985 to 1994 states that the key causes of low wheat productivity included non-compliance with the agrarian terms, low quality of performing of the agrarian measures, low quality seeds, lack of the fertilizers, ineffective methods against the weeds, diseases and vermin, losses at harvesting and low productivity species.

In 1990, in Georgia, wheat productivity was higher than in those Azerbaijan, Armenia and average global productivity. Since then the productivity in Georgia has not increased while Azerbaijan, Armenia and average global productivity have improved. In 2012-2014, average wheat productivity was two times lower than world average and far behind those in the neighbouring countries. With respect of quality of agrarian technology measures and their performing in the optimal terms Georgia was far behind the developed countries even in the best years of the soviet epoch and this gap has further increased. These processes are plotted on Fig. 4.4.

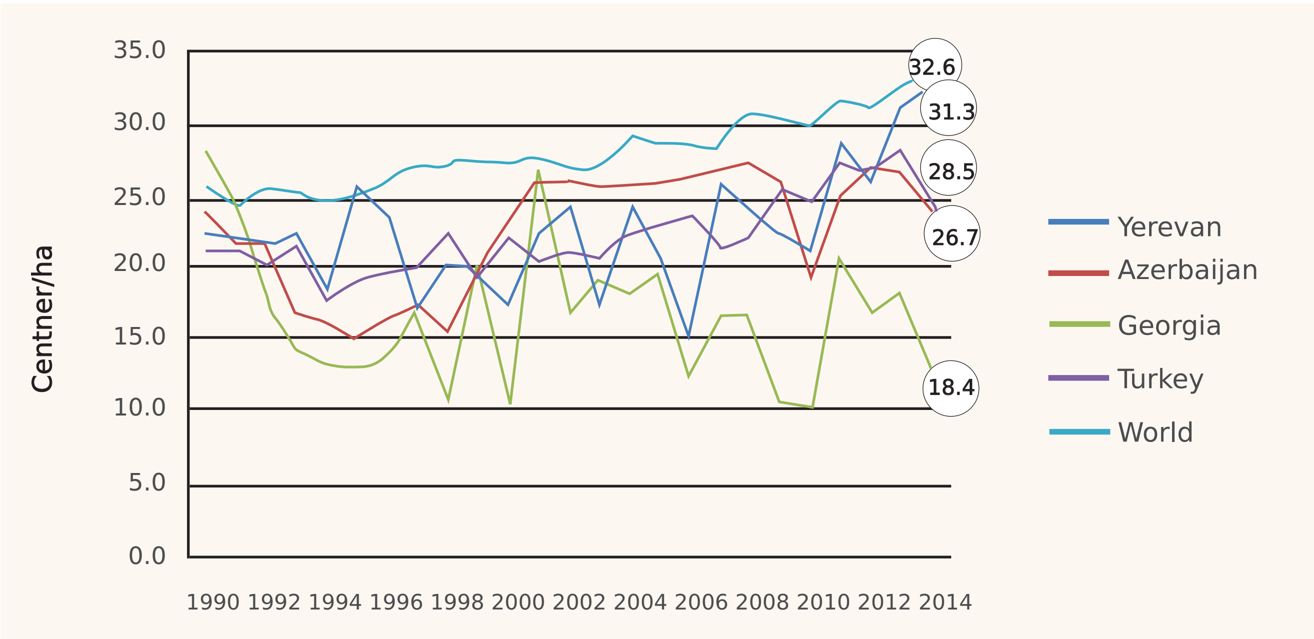


Fig. 4.4 Dynamics of wheat productivityin 1990-2014

Such situation can be caused by severe climatic conditions in Dedoplistskaro District further aggravated by ongoing climate changes.

In the process of NAP preparation of for agriculture sector evaluation of climate impact on the wheat productivity was conducted by Kakheti Region.

[9] World Bank Report: Georgia Agriculture and Food Sector Review (in two volumes). January 24, 1996. No. 14659-GE. Volume I: Main Report. Volume II: Sub-sectoral Analysis.

4.2. Impact of Ongoing Climate Change on Wheat Productivity

Between periods 1966-1990 and 1991-2015 increase of average annual temperature in Dedoplistskaro was 0.9°C. Warming takes place in all seasons, with highest increment (+1.6°C) in summer and the lowest – in spring (+0.4°C). Between these two periods annual aggregate precipitation has slightly decreased (9 mm, -1%). Precipitation has decreased significantly in summer (-16%) and increased in autumn (+14%). Reduction of the absolute values of the daily precipitation was 40 mm in spring though the maximal value is still in summer. Growth of relative air humidity seasonal and annual values between two periods was 3-4%. Between two periods average wind velocity has decrease in all seasons by 0.2-0.4 m/sec and average annual value has decreased from 1.6 m/sec to 1.3 m/sec.

Among the extreme phenomena, frequency of moderate, as well as severe and extreme draughts has apparently increased causing substantial damages to the agricultural sector and requiring application of the suitable adaptation measures. There was identified also certain growth of frequency of extremely high precipitation (> 40 mm) (0.1 day per year).

Since 90s, the lowest wheat productivity (10.2 c/ha) in Dedoplistskaro were recorded in 2010. That year the highest average annual temperature (13.3°C) was recorded in 1961-2015 period. In 2010, the average temperature in June was the highest for the same period as well. In addition, winter 2009-2010 was unusually warm as well as no average temperature below 0° C was recorded in any of the months. In such temperature conditions, irrespective of maintaining of the average annual precipitation, one can suppose that the soil has rapidly dried in spring thus hindering growth and development of the wheat.

Year 2000 was one of the worst harvest years (10.4 c/ha) due to “great” drought. According to the data of Dedoplistskaro meteorological station, aggregate precipitation in the wheat vegetation period was 238 mm, the lowest value in 1961-2015 period. The drought was further aggravated by increased temperatures. Average temperature for June in 2000 was as much as 26.2°C, the highest temperature in 1961-2015 period.

Cause of poor wheat productivity in 1998, supposedly was the high temperature as well. According to the data of Dedoplistskaro meteorological station, sum of active temperatures for that year was 4038°C. Normally, in Dedoplistskaro territory sum of the active temperatures varies within 3000-3700°C. Together with the above, one of the causes of poor harvest is the high speed of the winds in spring, “sweeping” the seeds and humus from the fields. Low productivity in 2000 result from such wind that was earlier controlled by the windbreakers.

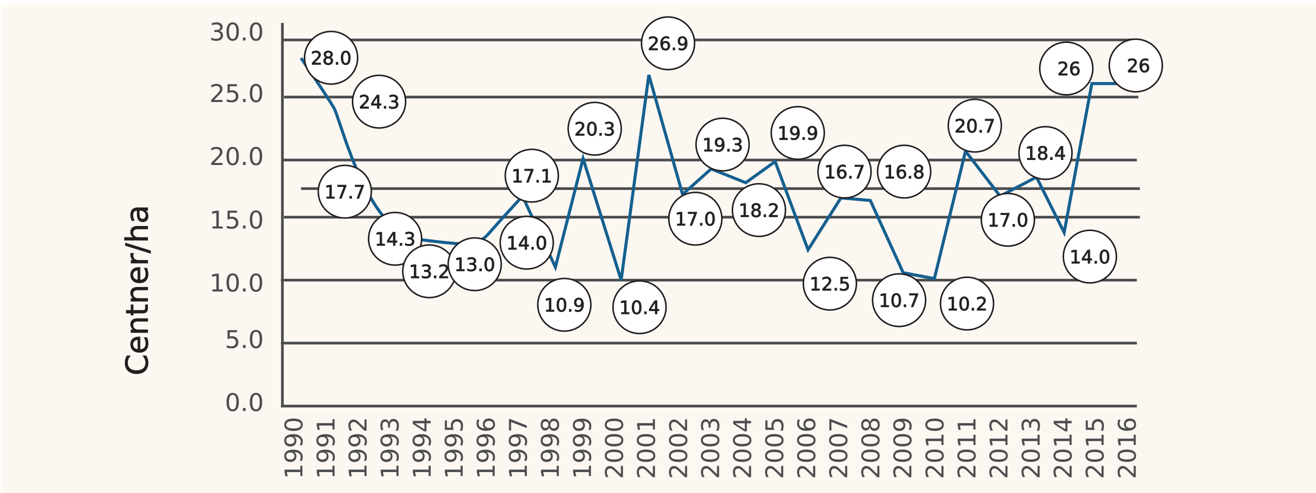


Fig. 4.5 Wheat productivity in 1990-2016 in Dedoplistskaro

Fig. 4.5 shows drastic growth of the productivity in 2001 (26.7 c/ha) and in 2015-2016 (26.0 c/ha). In autumn 2000, high quality wheat seeds imported from Turkey within the scopes of international assistance program were sown widely and the precipitation was very favorable for the wheat in the vegetation period. In 2015-2016, increased productivity was associated with the activities of state assistance programs providing affordable credits, high quality seeds and other production factors to the farmers.

Among the wheat diseases, the stripe rust is the most widespread one in Georgia. In 1987-99 stripe rust was a serious disease of wheat and it was regularly monitored. According to (Naskidashvili et all. 2001)[10] there were recorded the cases of significant epidemics of stripe rust in Georgia. In Georgia there are perfect conditions for infection with stripe rust: cool nights in second half of May (11-13^{O}C) and relatively humid weather (leaves with the dew).

Development of the brown rust and stem rust requires higher temperature and usually shows up in the hotter and more humid season. Brown rust has not been the problem until 1990s at all but in the recent years it has gradually became more significant. Stem rust is still localized in Akhaltsikhe District, Southern Georgia. Supposedly, with warming, spread of the stripe rust will reduce but impact of brown rust will increase. In case of severe infections with this disease the productivity will reduce extremely (almost 100% in the recipient species) and under-sized seeds are formed that are unsuitable for bread baking.

In Dedoplistskaro, wheat is produced without irrigation. Therefore, the greatest impact is caused by increased frequency of agricultural type droughts. Negative impact of the drought is maximal after sowing, in spring and in the period of grain maturation.

In many cases, in Kakheti, sowing takes place in the draught period. The soil rapidly dries die to warm weather. Frequently the wheat sown in October cannot sprout before winter and sprouts only afterwards (February-March) when sufficient moisture accumulates in the soil. Due to the late sprouting the plantation is sparse, resulting in low productivity.

April is traditionally the driest month in Kakheti and one of the most significant periods for wheat development as in early June wheat sprouting commences and in late April or beginning of May – formation of whearears and further flourishing. In this period, drought suspends growth of stems and the wheat height is low. Low height is almost always caused by high dryness in the sprouting period. In the conditions of reduced humidity and high air temperature, the plant vegetation period becomes shorter; the plant rapidly passes the development stages resulting in underdevelopment. Lack of moisture after flourishing reduces number of kernels in the ear, naked kernels and seedless ears.

At the stage of ripening 22-27^{O}C temperature is favourable. High air temperature (35-40^{O}C) in the period of filling negatively affects the kernel quality. In the conditions of lack of moisture the grains cannot normally ripen due to early drying of the stem and leaves.

[10] Naskidashvili J., Aptsiauri N., Sikharulidze Z., Natsarashvili K. (2001) Virulence structure of thepopulation wheat yellow rust causing Puccinia striiformis West f. sp. tritici Eriks. Bulletin of theGeorgian Academy of Sciences. V 163 (2), 364- 366.

4.3. Ongoing and Forecasted Changes in Agro-climatic Zones Relevant for Wheat Production

For growing of the autumn wheat sum of active temperatures of 2100-2200°C and 600 mm aggregate precipitation is required in the vegetation period. Vegetation period of this crop commences from September, it halts from late November, up to the end of March and further continues development up to the harvesting (late June). As a result of evaluation of agro-climatic zoning the following three zones were distinguished:

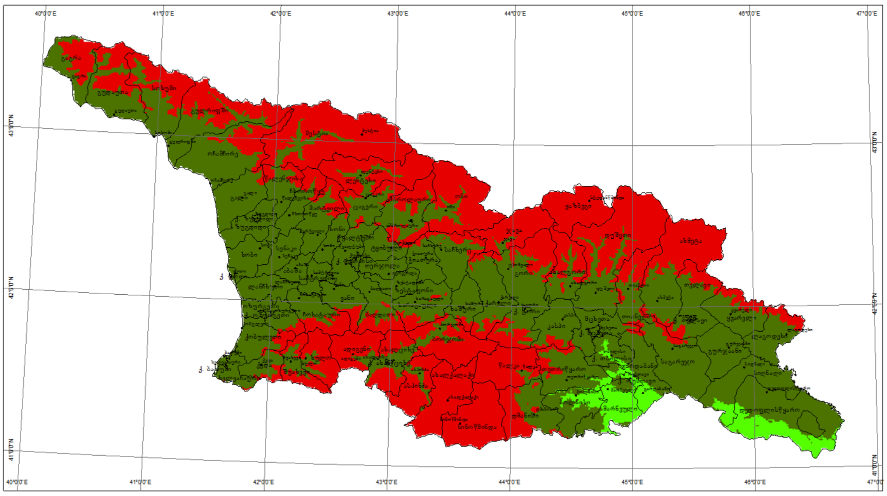
Zone 1 - heat is not sufficient for wheat growing (red on Fig. 4.6)

Zone 2 - wheat can be grown if irrigation is provided (light blue on fig. 4.6)

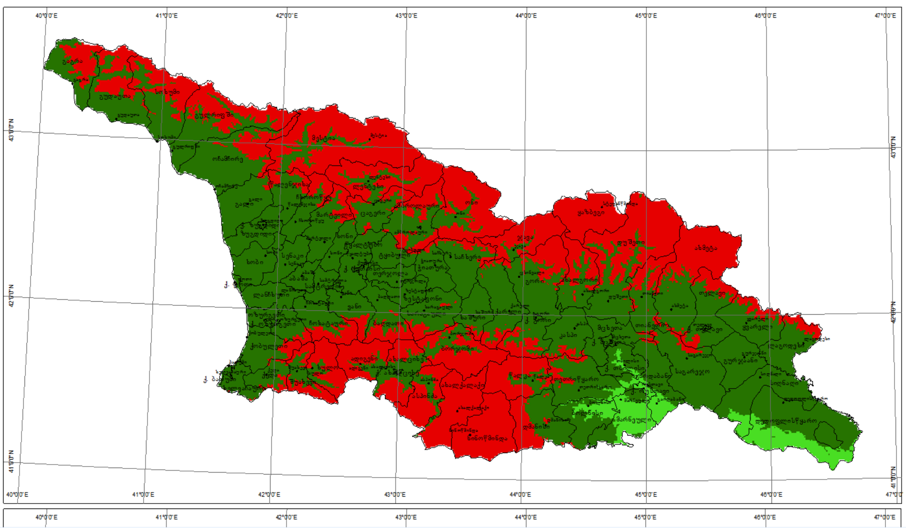
Zone 3 - favorable climatic conditions for growing of the autumn wheat (dark blue on Fig. 4.6).

1966-1990

1
2
3



1991-2015



2071-2100

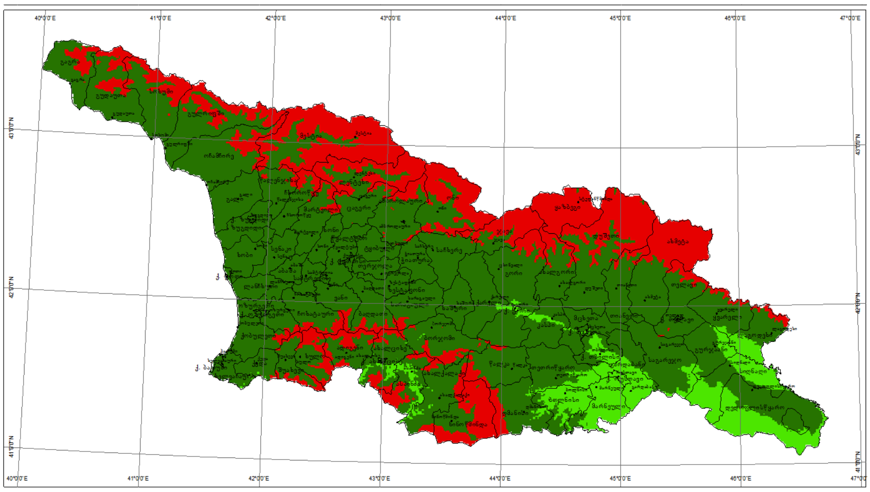


Fig. 4.6. Changes in wheat agro-climatic zoning 1966-90, 1991-2015 and 2071-2100.

Table 4.1. Areas of the zones favorable for wheat growing in different periods

	1966-90 (ha)	1991-2015 (ha)	2071-2100(ha)
Zone 2	844200	846900	594600
Zone 3	3171800	3365300	4675600

Areas of the zones favorable for growing of autumn wheat where this crop can be grown in case of irrigation are currently increased by 212.200 ha and will increase by 1.254.200 ha in the future and this will occur basically due to temperature growth, when sum of active temperatures achieve 2100-2200°C at 1.200-1500 m altitude above the sea level. This is the mountain zone of average altitude distinguished with complex orography, extensively fragmented and represented with small land plots. The soil is favorable for wheat growing. Most part of the territories is currently covered with the forests and pastures.

It should be noted that in the current period, in Georgia, only part of the areas favorable with respect of climate is used for production of the autumn wheat, due to the following circumstances:

- In Kvemo Imereti (Tskaltubo, Samtredia, Khoni), Kakheti and Kartli, in the same heat and moisture conditions they grow much more profitable crops: vine in the east and culinary herbs and melons in the west
- The other municipalities of Western Georgia are characterized with abundant rainfall causing lodging down of the grains and therefore they do not grow wheat there

4.4. Assessment of Climate Change Impact on Wheat Productivity and Irrigation Water Demand

Impact of the current and future climate changes on wheat productivity and irrigation water demand was evaluated based on Aquacrop (FAO) model and experts' evaluations[11] . 4 different periods were simulated by means of the model: two ongoing 25-year (1966-1990; 1991-2015) and two forecasted 30-year periods (2021-2050; 2071-2100).

[11] *http://www.fao.org/land-water/databases-and-software/aquacrop/en/For simulation of future climate change IPCC climate change A1B scenario was used. Climatic parameters (atmosphere precipitation, maximal and minimal temperatures, reference evapotranspiration) were obtained from global circulation model (ECHAM4.1) adjusted for the region by means of (RegCM).*

Climatic parameters of the vegetation period used in the model and those for each of the regarded periods, together with the simulated productivity are provided in Table 4.2.

Table 4.2. Values and changes of the climatic characteristics and productivity between the periods 1966-1990 (1) and 1991-2015 (2), 2021-2050 (3) and 1991-2015 (2), 2070-2099 (4) and 1991-2015 (2) (Dedoplistskaro) taking into account the carbon dioxide growth effect

Period / Parameter	Precipitation, mm	Evapotranspiration mm	Sum of active temperatures 0C*day	CO_2, ppm	productivity (t/ha) (non-irrigated)	productivity(t/ha) (irrigated) (RAW50)	productivity(t/ha) (irrigated) (RAW30)
1966-1990(1)	467	494	2185	336	2.4	6.2	6.2
1991-2015(2)	441	505	2329	375	2.7	7.5	7.5
2021-2050 (3)	449	385	2544	442	5.4	8.5	8.3
2070_2099(4)	356	349	3018	540	4.5	11.5	11.5
Abs. change_21	-25	11	144	40	0.2	1.2	1.2
Abs. change _32	8	-120	215	66	2.7	1.0	0.9
Abs. change _42	-85	-156	690	164	1.8	4.1	4.1
Rel. change_21	-5%	2%	7%	12%	9%	20%	20%
Rel. change _32	2%	-24%	9%	18%	102%	14%	12%
Rel. change _42	-19%	-31%	30%	44%	67%	54%	54%

Table 4.2. provides the version where CO_2 effect is included into the modelling process and Table 4.3. provides the results obtained without taking into consideration CO_2 effect.

Table 4.3. Values and changes of the climatic characteristics and productivity between the periods 1966-1990 (1) and 1991-2015 (2), 2021-2050 (3) and 1991-2015 (2), 2070-2099 (4) and 1991-2015 (2) (Dedoplistskaro) without taking into account the carbon dioxide growth effect

Period / Parameter	Precipitation, mm	Evapotranspiration mm	Sum of active temperatures ⁰C*day	CO_2, ppm	productivity(t/ha) (non-irrigated)	productivity(t/ha) (irrigated) (RAW50)	productivity (t/ha) (irrigated) (RAW30)
1966-1990	467	494	2185	336	2.4	6.2	6.2
1991-2015	441	505	2329	366	2.6	7.3	7.3
2021-2050	449	385	2544	369	4.6	7.5	7.3
2070-2099	356	349	3018	369	3.3	9.2	9.2
Abs. change_21	-25	11	144	30	0.2	1.1	1.1
Abs. change _32	8	-120	215	3	1.9	0.2	0.0
Abs. change _42	-85	-156	690	3	0.7	1.8	1.8
Rel. change_21	-5%	2%	7%	9%	7%	17%	17%
Rel. change _32	2%	-24%	9%	1%	75%	3%	0%
Rel. change _42	-19%	-31%	30%	1%	25%	25%	25%

Comparison of tables 4.2 and 4.3 show that in Dedoplistskaro District, wheat productivity have growth potential in both cases – taking into consideration of CO_2 growth effect and without it, up to 2050 (provided that all circumstances, with the exclusion of climatic parameters remain unchanged) but the difference emerges by the end of the century and while with CO_2 growth effect the wheat productivity can potentially grow, without this effect, in non-irrigated conditions, almost 30% fall is expected, compared with the first prognosis period but this will be still 27% greater compared with the current period.

In comparing the productivity simulated by the model and actual statistical data one should bear in mind that the model does not take into consideration impact of such significant factors as extreme phenomena, like floods, hail, strong winds etc. on the productivity. In addition, temperature growth and heat waves results in increase of the fire risk, increase of the vermin propagation and the frequency of diseases and, what is most important, the model regards proper and timely implementation of the agrarian technological measures and use of the high quality certified seeds. Hence, the simulated productivity show the region's potential, rather than actual situation though in ideal conditions the coincidence could be good. Within the project there were cross-checked the productivity in Dedoplistskaro and Sighnaghi, in 2016-2017. Local large farmers[12] conformed that productivity in 2016 were very good – 4 t/ha without irrigation and in 2017, due to high winds in the spring the productivity was 3 t/ha. Naturally, not all farmers have such good outputs but this clearly demonstrates the region's potential that is much higher than the modeled average one. As shown on Fig. 4.5, in 2015 and 2016, in Dedoplistskaro, average productivity are really high and very close to the modeled values though as mentioned, few farmers were able to productivity even better harvests. According to the forecasts obtained from the model by 2050 doubling of the productivity can be expected, even without irrigation, provided that all other conditions are fulfilled. As for the statistics of the previous years, low productivity was caused by almost full negligence of the agrarian technological processes, aggravated with the droughts in some years and sum of the active temperatures much higher than required in the vegetation period, as explained above.

As for the demand for irrigation water, Table 4.4 provides irrigation water requirements of the autumn wheat according to scenarios of easily available water (RAW[13]). Orange background shows irrigation water demand increase and green – its decrease.

Table 4.4. Autumn wheat demand for irrigation water (mm) and its changes between the periods: 1991-2015 (2) and 1966-1990 (1), 2021-2050 (3) and 1991-2015 (2), 2070-2099 (4) and 1991-2015 (2)

Period / change	Kakheti (Dedoplistskaro)	
	RAW50	RAW30
1966-1990(1)	126	140
1991-2015(2)	154	168
2021-2050 (3)	60	73
2070_2099(4)	87	100
Abs. change_21	28	28
Abs. change _32	-93	-95
Abs. change _42	-67	-68
Rel. change_21	22%	20%
Rel. change _32	-61%	-57%
Rel. change _42	-43%	-40%

[12] Expert-farmer George (Bondo) Bolashvili, Sighnaghi

[13] Two scenarios of readily available water in the roods zone where acceptable drying degree of the roots zone is 50 and 30% (RAW50, RAW30).

It is significant to mention that irrigation water demand depends on irrigation technology as well as different irrigation systems are characterized with different effectiveness of water spending. The model relies on so called sprinkler irrigation technology for calculation of the total irrigation water demand.

Analysis of the modeling results showed that:

- According to the selected scenario of climate change (A1B[14]), potential productivity of the autumn wheat will grow, both, with and without irrigation. Irrigation effect is particularly significant for the cultivated areas on saline soils in current 25-year period while in the first prognosis period the effect is relatively lower.

- In the conditions of non-irrigated agriculture, by the end of the century, increased but yet, unstable productivity are expected. The forecast is optimal for the first prognosis period, implying increased and stable productivity of the autumn wheat. In the conditions of irrigation, both, the productivity and stability grow significantly. Due to sufficient irrigation the autumn wheat productivity can be increased 2-3 times. In the current period such growth means 6-8 t/ha productivity in average while by the end of the century this figure will exceed 10 t/ha.

- For the autumn wheat that belongs to the crops moderately sensitive to soil water content stress, effect of precipitation reduction is apparent only for the plantations on saline soils. In the other territories water deficiency caused by reduction of precipitation is compensated by reduction of physical evaporation of water from soil surface and hence reduction of evapotranspiration and improvement of effectiveness of water consumption by the plant. According to the scenario for the future, this trend will be maintained up to the end of the century and irrespective of significant trend of precipitation reduction in the second prognosis period, in the studied territory, even in case of dry-land cultivation improvement of the productivity could be expected. Hence, during both prognosis periods, to maintain maximal productivity for both prognosis periods, water requirement will be 40-60% lower, compared with the current period.

- Increased CO_2 concentration will positively affect the autumn wheat biomass production. Positive effect of CO_2 can be covered by unfavorable changes of climate parameters in the vegetation period and it is specific, depending on the type of soils in the studied territories.

4.5. Recommendations on Adaptation Measures in Wheat Production

- Irrigation of the arable lands of Dedoplistskaro Municipality;

- Performing the following agrarian technological measures for dry-land wheat production: Semi-fallow land working; Compliance with the sowing terms (October in Dedoplistskaro); Sowing depth should be 4-5 cm. In less humid soils the sowing depth should be greater (6-8 cm); Soil fertilization; Soil compaction after sowing; Retaining the snow in the land plots by means of the snow ploughs; Sowing of the autumn wheat fore crops, such as legumes, silage maize, maize for the green fodder, dredge maize sown in wide rows, annual legumes and grains (mixture of oats and peas or vetch), mixture for green fodder, perennial grasses and sunflowers; Production of dry-land wheat with zero land work i.e. with no-tile technology; Use of the improved species.

[14] IPCC Special Report: Emissions Scenarios. WMO/UNEP. 2000: www.ipcc.ch/pdf/special-reports/spm/sres-en.pdf: IPCC special reports about future emission scenarios: „A1B – balanced consumption of all fuels (in this case the balance means that full/excessive dependence on any fuel type should not be accepted, with the assumption that technology development coefficient is similar for different production and end use technologies for different fuels.

- For irrigated wheat production the following agrarian technological measures should be applied: Autumn wheat should be irrigated immediately after sowing. First vegetation irrigation should be provided at the sprouting stage – in April and second vegetation irrigation should be provided at a time of laden kernels – in June. Introduction of sprinkler irrigation technology; soil fertilization; Crops rotation: in the conditions of irrigation, the most desirable forecrops for the autumn wheat include dredge maize (with short vegetation period), silage maize, vegetables and melons, perennial grasses, plowed stubble crops and legumes sown on the fallow land. Use of the improved species with irrigation; Wheat sowing on the on padas.

4.6. Cost-Benefit Analysis of Wheat Production Adaptation Measures

At this stage, for adaptation to climate change in wheat production, the following two activities were identified: irrigation of the arable lands of Dedoplistskaro District and application of agrarian technological measures. For both cases two scenarios were considered – for existing drought conditions and for increase of agriculture acceleration. Costs for the first case amount to GEL 26.6 million for 11-year period and for the second case amount to GEL 11.9 million with irrigation and GEL 8.9 million without irrigation.

Currently, in the territory of Dedoplistskaro Municipality dry-land agriculture dominates. Climatic modeling showed that in Dedoplistskaro District, autumn wheat suffers from lack of water and irrigation water demand for the black soils is 100-150 mm. This deficiency will somewhat reduce in the nearest future (2021-2050) bit later (2070-2099) it will increase and return to the currently existing level. In addition, the forecasts show the stable trend of the sum of active temperatures and carbon dioxide concentration growth and this positively affects the autumn wheat productivity. The activities seemingly are in contradiction with the changes expected up to 2050 but reduction of water deficiency does not mean that there will be no deficiency at all.

For the last decade the autumn wheat productivity is quite low in the territory of Dedoplistskaro municipality, varying between 2 and 3 tons and frequently this is basically caused by lack of water (though, in many cases this is caused by high, so called fitful winds in spring). If autumn wheat is supplied with sufficient moisture, the productivity will increase 2-3 times and reach 6-8 t/ha. Therefore, the main recommendation is irrigation of the arable lands in Dedoplistskaro.

This analysis does not include the state costs for rehabilitation/installation of the irrigation systems as the analysis deals with the farmers' costs and benefits only.

Assumptions and other details of the cost and benefit analysis are provided in Annex 1.4. Evaluation period covers standard 11-year period (2018-2028). Analysis covers the territories of Dedoplistskaro and Sighnaghi municipalities only.

Costs basically include the additional expenditures for irrigation, such as water and other costs directly related to irrigation process. For the entire period these costs amount to GEL 26.6 million. As for the benefits, these include: incomes from increased productivity resulting from irrigation and difference between prices for irrigated and non-irrigated lands. Irrigation increases productivity from 2.5 t/ha to 5.5 t/ha and non-irrigated land, normally, is 2.3 times cheaper than the land equipped with irrigation system.

Irrigation positively affects the productivity and land prices and regarding the effective tariffs, benefits from these measures are much higher than costs.

Profit, with low discount rate (R=4.76%) amounts to GEL 179.2 million and with high discount rate (R=9.98%) – amounts to GEL 131.9 million.

In the second scenario for the same measures, the droughts' frequency increases and in such case, wheat productivity' reduction, without irrigation, is 5% per annum (assumption). In 2017, productivity on non-irrigated lands is 2.5 t/ha and regarding 5% annual reduction, by 2027 this figure will be 1.3 t/ha/ In case of the second scenario the benefits of the measures are higher, compared with the basic scenario, amounting to GE 71.5 million, in case of 7.37% discount rate (in the first scenario, benefit with such discount is GEL 153 million).

Second activity provides timely implementation of the agrarian technological measures in a timely manner and at high level. Proper agrarian technological measures positively affect the wheat productivity. Analysis provides discussion of the agrarian technological measures' effect for two cases: wheat growing without irrigation and with irrigation.

Agrotechnical measures applied within nonirrigated conditions include: soil semi fallow cultivation, keep optimum timing for sowing, determining the optimum depth of sowing, soil fertilization, packing the soil after sowing, snow retention within the plots, crop rotation, no-till and improved crop varieties.

Agrotechnical measures of wheat production applied within irrigated conditions include: irrigation, soil fertilization, crop rotation and identifying the relevant varieties depending on the irrigation conditions.

The details concerning agrotechnical measures and cost-benefit analysis are presented in annex 1.4.

Net current benefits are positive in both cases, with and without irrigation, use of the modern agrarian technological measures provide positive effect. And it is greater where the modern agrarian technological measures are used with irrigation, in such cases the profit reaches GEL 8.7 million, while in absence of irrigation, by the end of period the expected profit is GEL 7 million. If the farmer applies modern agrarian technological measures, it is more beneficial to produce wheat with irrigation as these two activities, jointly, are much more effective. In the second scenario the droughts frequency increases and if the farmers fail to apply modern agrarian technology measures, the productivity will reduce, in particular: it is implied that in case of use of the basic methods, without irrigation, annual reduction of the productivity will be 5% while with irrigation the annual reduction is 2.5%. If the frequency of draughts increases, the benefit almost doubles and profits reach GEL 17 million with irrigation and GEL 14.6 million – without it, demonstrating the significance of agrarian technological measures given the climate change.

4.7. Social Impact of Recommended Measures and Role in Implementation of Agriculture Development Strategy of Georgia

The considered adaptation measures recommended for wheat production can have the social impact as well, though the beneficiaries are large and medium farmers and enlargement of these type of farms is envisaged in future but these measures can contribute to improvement of reliability of food security.

Melioration, construction of the irrigation and drainage systems, their operation and management comprise one of the priority directions in agriculture development strategy to ensure creation of the environment required for intensive and effective agricultural production in the country. As a result of effective measures (rehabilitation and operation works) performed by the Ministry of Agriculture of Georgia in 2012-2014, the areas supplied with irrigation water have increased by 88 thousand ha. Three-fold increase of the irrigated and dried areas is planned up to 2020.

Purpose of modernization of the melioration systems is improvement of water supply to the irrigated lands, expansion of the melioration service area and providing of the conditions required for growth and development of the plants in the soil that would ensure, together with application of the modern agrarian technologies, high and guaranteed productivity of the agricultural crops.

These measures would contribute to achievement of the strategy goals as competitiveness of the melioration systems depend on existence of demand for water.

5. Impact of Climate Change on Maize Productionin Zugdidi Municipality and Recommended Adaptation Measures

5.1. Maize Production in Georgia

In 2016, Dredge maize fields' area in Georgia was 95.9 thousand ha. 70% of the areas of maize fields are located in Western Georgia. Samegrelo-Zemo Svaneti Region is one of the leaders in maize production.

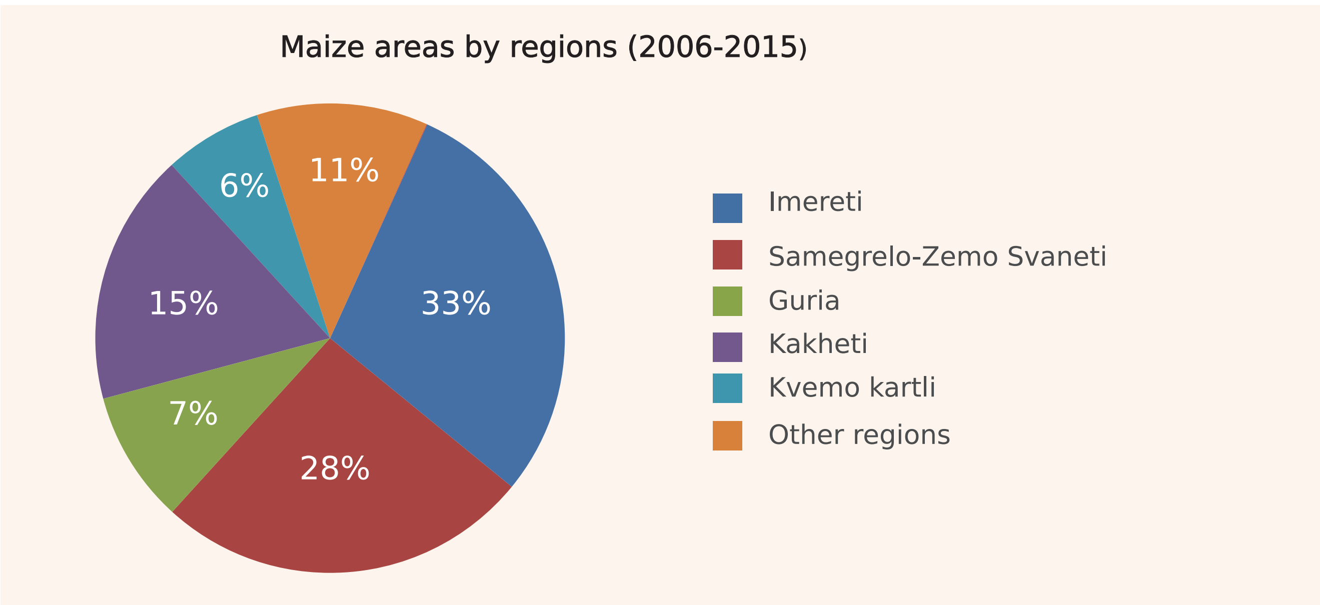


Fig. 5.1 Maize areas by regions (source: GeoStat)

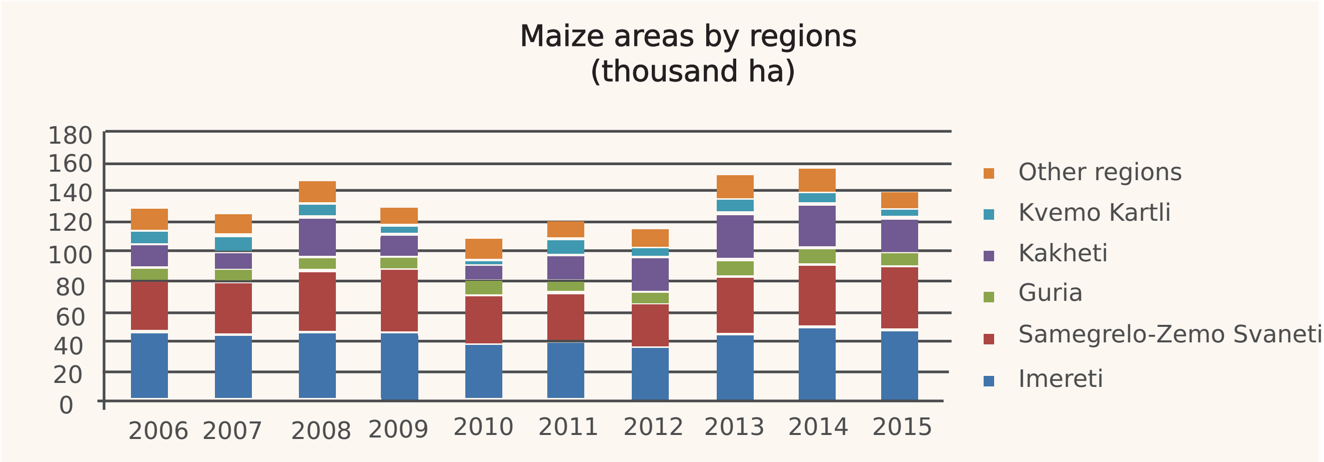


Fig. 5.2 Maize areas by regions (ha)

In 80s of the past century, in Georgia, basically the maize species developed nearly 20th century were sown (Ajametis Tetri, Iodal Tetri Nakhevarkbila, Local Tetri Kzhovana etc.) These species were intended for food but they could be used as the fodder as well. In that period the hybrid varieties occupied less than 5% of the sown areas. From 2007, in Georgia and especially in Western Georgia spreading of the "Pioneer" hybrids started. Currently the "Pioneer" hybrids are most widespread on the irrigated lands, in Lagodekhi, Gori and Bolnisi regions. "Pioneer" late-season (130-145 days) and medium late-season (110-120 days) hybrids are popular among Georgian farmers.

In Western Georgia the local varieties of food production significance are more popular.

In the process of NAP preparation of for agriculture sector evaluation of climate impact on the maize productivity was conducted for Samegrelo-Zemo Svaneti Region.

5.2. Impact of Ongoing Climate Change on Maize Productivity

In Zugdidi Municipality, in 1998-2015, compared with 1961-1993 period, increase of average annual, average annual minimal and average annual maximal temperatures is about 1°C. In 1998-2015, the period without frosts has increased by 9 days. Aggregate annual precipitation has not actually changed. Strong wind that can cause lodging down of the maize is still characteristic for July. It should be admitted that average month temperature is almost the same in April (+0.2) and May (+0.4) and has increased only slightly in July (+1.6), warming effect is more significant in August (+1.8), September (+2.0) and October (+0.5). This means that the temperature conditions are almost the same at a time of maize sowing and at the first stage of vegetation. Though in the 2nd half of vegetation period and at the ripening stage the temperature is significantly higher and this can impact the productivity formation and ripening.

In Kolkheti there is sufficient moisture and there is no necessity of irrigation for the maize. Hence, dependence of the maize productivity on precipitation is insignificant, with the exclusion of very hot or dry years.

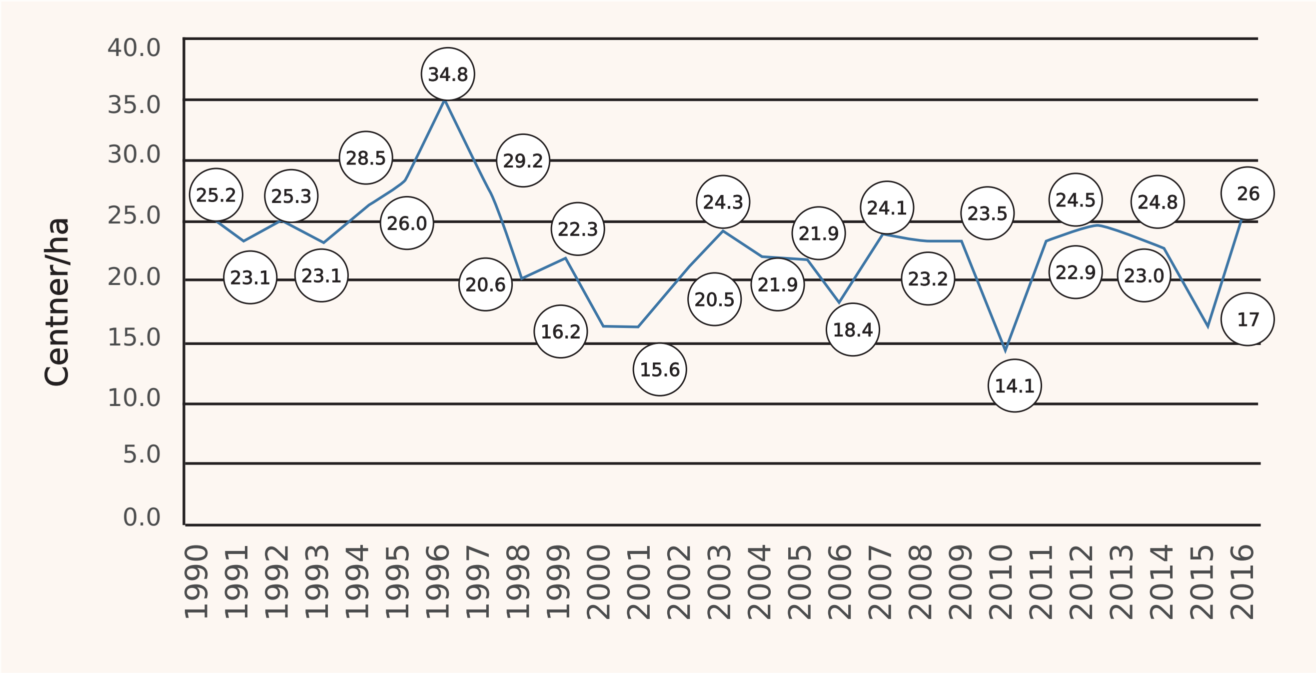


Fig. 5.3. Maize productivity in 1990-2016

In the current period, the lowest maize productivity (14.1 c/ha) were recorded in 2010. In studying of Zugdidi meteorological data it was apparent that in 2010, the active temperatures' (>10^{o}C) sum (5368) was very high. This is the highest figure in 1961-2015 period. Sum of active temperatures has not exceeded 4995 in any other year. In 2010, average month temperatures for June, July and August (as well as average maximal temperature) were the highest for the last half century. Maize, tolerant to high temperatures is able to freely ensure photosynthesis at temperatures close to 45^{o}C, lacked moisture. For the maize, year 2001 was also droughty and productivity have reduced to 15.6 centners.

The highest maize productivity was recorded in 1996. That year was not distinguished with the precipitation or temperatures and it is hard to explain what the cause of such growth was, supposedly it was not related to climate and more detailed researches are required for each of the vegetation stages.

In addition, it should be noted that compared with 80s, in Zugdidi Municipality, period of maize sowing and hence the development stages take place almost one month later. IN many areas the maize is sown in late May and sometimes early June. Late sowing is not supposedly related to climate factors, as according to the analysis of meteorological data, temperature has not actually increased in April and May.

There were not found any changes in spreading of the maize fungous diseases or weeds. Among the insects, the maize is damaged by the stem moth and bollworm and for recent few years the Asian tortoise beetle.

5.3. Ongoing and Forecasted Changes in Agro-Climatic Zones Relevant to Maize Production

Sum of active temperatures required for maize growing, for the early and late species, is 1700-2800°C and for the averagely ripened maize – 2200°C. Required aggregate precipitation, for both, early and late species, is 800 mm. Agro-climatic zoning was performed for the averagely ripened maize.

After agroclimatic zonation, following three zones were identified:

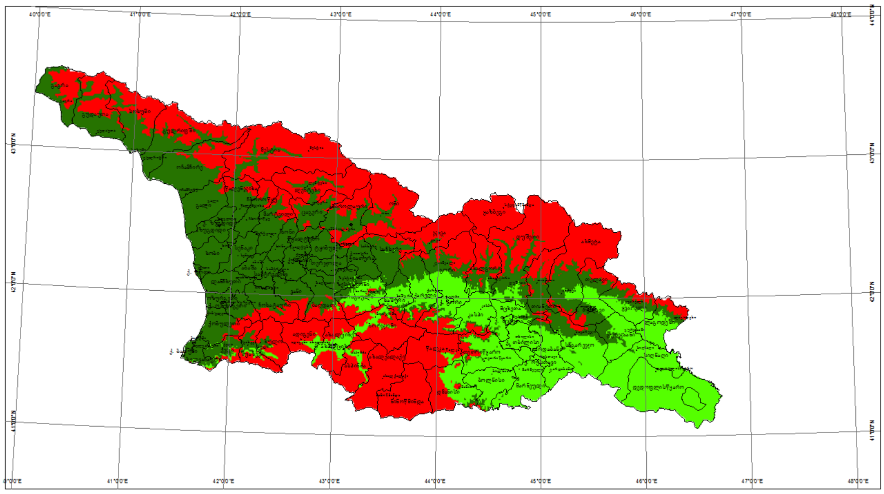
Zone 1 - heat is not sufficient for maize growing (red on Fig. 5.4)

Zone 2 - maize can be grown if irrigation is provided (light green on fig. 5.4)

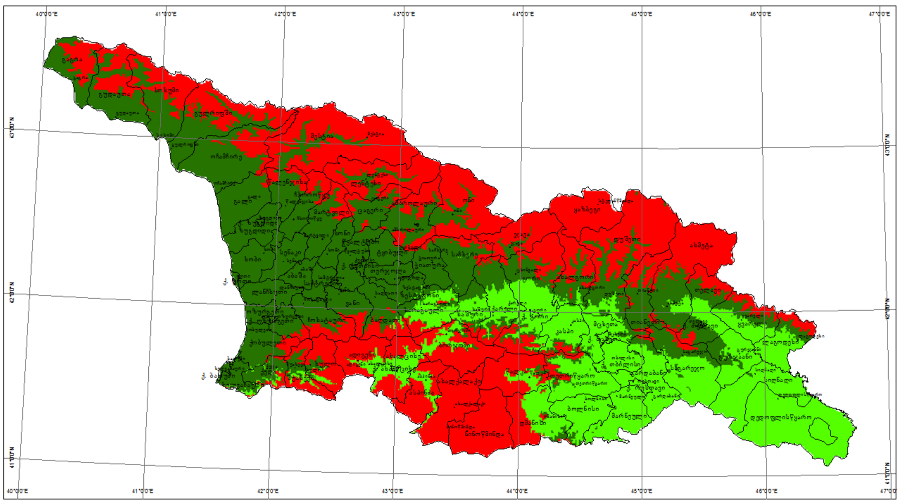
Zone 3 - favorable climatic conditions for maize growing (dark green on Fig. 5.4)

1966-1990

1
2
3



1991-2015



2071-2100

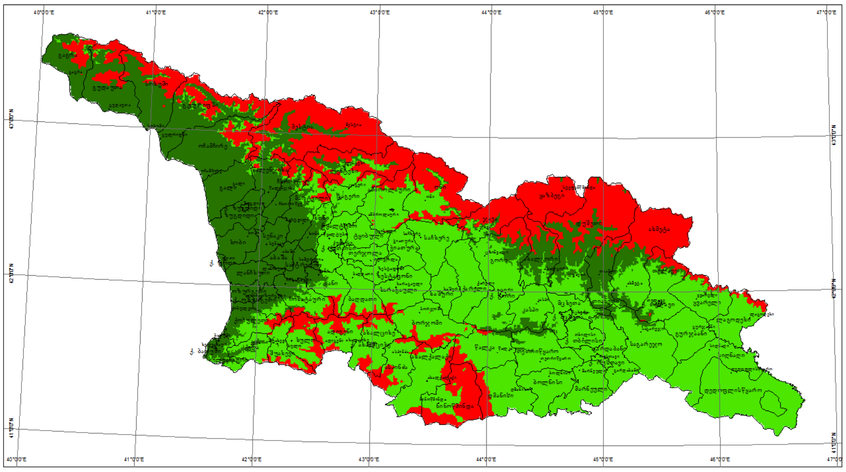


Fig. 5.4. Changes in agro-climatic zones relevant for maize production in 1966-90, 1991-2015 and 2071-2100.

Table 5.1 . Areas of the zones favorable for wheat growing in different periods

	1966-90 (ha)	1991-2015(ha)	2071-2100(ha)
Zone 2	1601500	1643400	3528000
Zone 3	2414600	2568800	1742200

According to Fig. 5.4 and Table 5.1, in the current period, the areas favorable for maize growing are increasing. In the future, the area favorable for maize growing with irrigation will increase significantly while the areas where the maize can be grown without irrigation will decrease. Part of the territories warm enough to grow maize is mostly the highlands where, supposedly, the precipitation will be sufficient for maize growing without irrigation. Thus, in these areas, maize growing can be more reasonable in economic respect.

In the current period, the area under maize is smaller, compared with the territories with favorable climatic conditions for maize growing. Similar to the autumn wheat, this is caused by the economic and cultural factors.

5.4. Assessment of Climate Change Impact on Maize Productivity and Irrigation Water Demand

Impact of the current and future climate changes on maize productivity and irrigation water demand was evaluated based on Aquacrop (FAO) model and experts' evaluations[15]. 4 different periods were simulated by means of the model: two current 25-year (1966-1990; 1991-2015) and two prognosis 30-year periods (2021-2050; 2071-2100).

Climatic parameters of the vegetation period used in the model and those for each of the regarded periods, together with the simulated productivity are provided in Table 5.2.

[15] http://www.fao.org/land-water/databases-and-software/aquacrop/en/in simulation of future climate change IPCC climate change A1B scenario was used. Climatic parameters (atmosphere precipitation, maximal and minimal temperatures, evapotranspiration) were obtained from global circulation model (ECHAM4.1) adjusted for the region by means of (RegCM).

Table 5.2. Values and changes of the climatic characteristics and productivity between the periods 1966-1990 (1) and 1991-2015 (2), 2021-2050 (3) and 1991-2015 (2), 2070-2099 (4) and 1991-2015 (2) (Zugdidi)

period/parameter	Precipitation, mm	Evapotranspiration mm	Sum of active temperatures ºC*day	CO_2, ppm	productivity(t/ha) (non-irrigated)	productivity(t/ha) (irrigated) (RAW50)
1966-1990(1)	742	470	1740	2.03	2.10	2.09
1991-2015(2)	677	492	1891	1.99	2.16	2.14
2021-2050 (3)	910	506	1912	1.94	2.21	2.17
2070_2099(4)	630	487	2153	2.07	2.24	2.21
Abs. change _21 [16]	-65	22	152	-0.04	0.06	0.05
Abs. change _32	233	14	21	-0.05	0.05	0.03
Abs. change _42	-47	-5	262	0.08	0.09	0.07
Rel. change_21	-9%	5%	9%	-2%	3%	3%
Rel. change _32	34%	3%	1%	-3%	2%	1%
Rel. change _42	-7%	-1%	14%	4%	4%	3%

Table 5.2 provides the version where CO_2 effect is not included into the modelling process, as according to FAO[17], CO_2 effect on maize is negligible.

In comparing the productivity simulated by the model and actual statistical data one should bear in mind that the model does not take into consideration impact of such significant factors as extreme phenomena, like floods, hail, strong winds etc. on the productivity. In addition, temperature growth and heat waves results in increase of the fire risk, increase of the vermin propagation and the frequency of diseases and, what is most important, the model regards proper and timely implementation of the agrarian technological measures and use of the high quality certified seeds. Hence, the simulated productivity show the region's potential, rather than actual situation though in ideal conditions the coincidence could be good. Statistical data on Fig. 5.3 show that actual productivity in Zugdidi District is 10% higher than the modelled figure, with the exception of few years where productivity was relatively poor due to various climatic or human factors. The causes are discussed in the relevant subsections. The figure also shows the productivity reduction trend in the second period that will persist up to 2050 if the same conditions are maintained (while in case of introduction of the high-productivity species can change the situation).

As for the demand for irrigation water, Table 5.3 provides irrigation water requirements of the maize according to scenarios of easily available water (RAW[18]). Orange background shows irrigation water demand increase and green – its decrease.

[16] *Change between 2nd and 1st periods.*

[17] *Increased temperature and CO2 concentration are regarded as the key mechanism of climate change that will affect crops productivity significantly through increased effectiveness of water consumption and biomass accumulation though in comparison with the other crops the increment for maize is relatively low and this can be explained by high ability of carbon dioxide fixation.*

[18] *Two scenarios of readily available water in the roods zone where acceptable drying degree of the roots zone is 50 and 30% (RAW50, RAW30).*

Table 5.3. Maize demand for irrigation water (mm) and its changes between the periods: 1991-2015 (2) and 1966-1990 (1), 2021-2050 (3) and 1991-2015 (2), 2070-2099 (4) and 1991-2015 (2)

Period/change	Samegrelo-Zemo Svaneti (Zugdidi)	
	RAW50	RAW70
1966-1990(1)	17	6
1991-2015(2)	30	16
2021-2050 (3)	41	18
2070_2099(4)	50	22
Abs. change_21	14	9
Abs. change _32	11	2
Abs. change _42	20	7
Rel. change_21	82%	148%
Rel. change _32	37%	14%
Rel. change _42	66%	42%

It is significant to mention that irrigation water demand depends on irrigation technology and different irrigation systems are characterized with different effectiveness of water spending. The model relies on so called sprinkler irrigation technology for calculation of the total irrigation water demand.

Analysis of the modelling results showed that:

- According to the selected scenario of climate change (A1B), during the period in question potential productivity of the maize will remain quite stable from year to year, both, with and without irrigation and change if productivity between the periods is insignificant (+4%), amounting, in average, to 2-2.5 t/ha

- For the maize that belongs to the crops sensitive to soil water content stress, effect of precipitation reduction was not apparent due to high moisture content in the studied territory. Due to this, no any significant effect of irrigation on productivity was identified.

- Simulation results show also that the stress factors affecting the plants for the entire studied territory (temperature, leaves shooting, closing of the plant’s labella) are insignificant and were indicated in few cases only.

- In the studied region, the conditions favorable for maize growing exist now and will exist in the future and low average productivity (compared with the global figures) are supposedly caused by the crop varieties or some other reasons (vermin, diseases, ineffective management).

5.5. Recommendations on Adaptation Measures in Maize Production

- Introduction of the improved species: dissemination of the maize hybrids; though the measures should be taken for mitigation of the negative impact (e.g. ensuring isolation distances for prevention of the danger of genetic pollution of local populations, adaptation of the intensive technologies required for growing of the hybrid varieties to the conditions of Western Georgia with abundant precipitation and their introduction);

- Improvement of profitability of local species by using of the enhanced technologies and dissemination of local hybrids. The plantations of local species and those of hybrids should be separated from one another by 300-400 m distance to prevent pollution of the local species and populations with the pollen on the other maize species;

- Sowing of the fore crops, such as soy;

- Agrarian technological measures: improvement of land working technologies and their differentiation by zones.

5.6. Cost - Benefit Analysis of Maize Production Adaptation Measures

In the territory of Zugdidi Municipality, for the purpose of adaptation of maize production process to the current climate changes there were identified two measures and analysis of their cost-effectiveness was performed. Each of the measures two scenarios were evaluated.

Maize is more resistant to the high temperature, compared with the other field crops and the conditions currently existing in Zugdidi Region are quite favorable for maize production. In Kolkheti, aggregate annual and vegetation period precipitation is quite sufficient for maize production and this situation will persist up to 2050. Though in certain months of the year maize suffered lack of moisture in the past and this affected the productivity and this will take place in the future as well. With climate change the danger of moisture deficiency will increase significantly (12%) in the second half of the century.

In the first prognosis period (2020-2030) expected reduction of the precipitation in spring is 21% and this will impact vegetation of this crop. In these conditions, it is necessary to use the highly productive varieties well adaptable to local conditions. There are numerous hybrids at domestic and international markets that are highly productive compared with the local species. But together with the climatic conditions, it should be taken into consideration that n Western Georgia maize is the basic crop and the taste of the variety is of great significance for local population. Currently available foreign hybrids are mostly intended as fodder for animals and their use for food is excluded due to poor taste qualities. Range of such hybrids expands gradually, with development of livestock production.

Analysis includes Zugdidi Municipality only. It considers white maize that is used in the west for both, as the food and as fodder for the animals, as well as Georgian and foreign hybrids used as fodder only. It was implied that certain part of the farmers would switch from common Georgian species of maize to Georgian hybrids and part of the farmers would switch to the foreign ones. Analysis covers standard 11-year period (2018-2028). Detailed assumptions and calculations related to the activities are provided in Annex 1.5.

The basic benefit from the first measurement (testing of the hybrids in local conditions) is the value of additional productivity. In case of use of Georgian hybrid the productivity grow from 3.5 t/ha to 7 t/ha while in case of the foreign hybrid the productivity grow from 7 t/ha to 10 t/ha. As for the costs, these include the difference between costs of production of the common species and hybrids. In case of use of Georgian hybrids costs increase from 1.230 GEL/ha to 2.043 GEL/ha while for the foreign hybrids – from 1.230 GEL/ha to 2.523 GEL/ha[19]. Total costs for the entire period amount to GEL 505 million (4.877 ha). Net current value of the benefit by the end of the period is GEL 469.368 with high discount rates implying that the activities are profitable.

Second scenario of this activity considers reduction of productivity in case of use of the basic technologies (non-hybrid species). If, due to climate change, the temperature increases gradually, this will cause reduction of the maize (common specie, not hybrids) productivity from 3.5 t/ha to 1.1 t/ha[20]. By the end of the period profit from these activities amounts to GEL 777.579.

Second measure includes agrarian technological measure of plowing of the frozen land. As a rule, in Western Georgia, the soil intended for the maize should be plowed in late November-early December. Plowed soil accumulates moisture during the winter, low temperature causes loosening of the soil and in spring, before sowing only soil cultivation (surface working) is required, the exclusion are the lands located on the coastal lowlands where, due to the abundant and heavy showers the soil is compacted and requires plowing early in spring. Soil plowed in spring dries rapidly (due to high temperature) negatively impacting germination and development. Therefore, in the rainy lowlands it is plowing should be provided later, in late February or March. In such case the soil will maintain moisture before sowing and no plowing will be required. Therefore, it is significant to comply with the optimal terms of plowing what is not done currently.

This activity implies comparison of two technologies of growing of white food maize: comparison of two options: the one most widespread in the farms currently and improved technology tested at Abasha test station of Georgian Agrarian University.

Analysis covers standard 11-year period (2018-2028). The main benefit of this activity is income from excessive productivity. The basic maize production technology widely applied by the farmers provides 3.5 t/ha productivity while enhanced technology allows yielding of 5 tons per ha. Difference provides additional benefit for the farmer. As for the costs, these include difference between the costs of basic and enhanced agrarian technological measures. While enhanced measures provide greater productivity, they are more expensive and total costs for the entire period amount to GEL 2.9 [million] while by the end of period the benefit is GEL 2.5 million (788 ha). The profit is gained in case of high, 10% discount rate as well.

The second scenario of the same activity considers increase of costs in case of use of the basic agrarian technologies in the conditions of climate change.

If the temperature increases due to climate change, for yielding the same harvest, the basic agrarian technological measures will be more expensive. This implies that the annual increase of costs will be 5%. For both scenarios the benefits of these activities exceed the costs and the activities are quite profitable.

[19] *Due to lack of the data, the case where the farmer switches from Georgian hybrid to the foreign one is not considered*

[20] *Based on the statistical data, 1.1 t/ha is the lowest productivity in Samegrelo Region in the period from 2006 to 2013*

5.7. Social Impact of Recommended Measures and Role in Implementation of Agriculture Development Strategy of Georgia

The social effect of the activities is not calculated in monetary units but improvement of the maize productivity and its quality will have significant social effect as this crop is widespread among the small farms and population and is used as food, as well as fodder for the animals, thus, these activities will positively affect livestock production as well. According to the statistical data, Samegrelo-Zemo Svaneti Region is at leading position with respect of cattle breeding. In case of use of hybrids the necessary safety zones should be provided.

Measures for improvement of productivity in maize production, fully compliant with the climate-smart agriculture development direction, contributes to implementation of agriculture development strategy, in particular, with respect of improvement of awareness in agrarian technologies, promotion of local production of the seeds and planting materials and their certification.

Both of recommended adaptation measures of maize production toward climate change must be carried out by active participation of extension centres of Ministry of Agriculture of Georgia as well as farmers.

6. Impact of Climate Change on Potato Production in Certain Regions of Georgia and Recommended Adaptation Measures

6.1. Potato production in Georgia

Potato is relatively new culture in the agriculture of Georgia. It had been completely unknown to the local population until the 19th century. The first potato crops appeared in Georgia in the second decade of the 19^{მაზრა} century (1818-1819). From the second half of the 19th century, local population, particularly in Akhaltsikhe and Gori Mzda (Uyezd), started growing their potato. In 1913 in Georgia, the area of potato crop did not exceed 6800 hectares, however, by the end of 1970 it had quadrupled and surpassed 32,000 hectares. 80 % of potato crops are situated within the eastern part of Georgia and, particularly, in the mountainous municipalities of Akhalkalaki, Tsalka, Dmanisi, Ninotsminda, Tetritskaro, Tianeti, and Dusheti. In western Georgia potato-growing is relatively well spread in intra-mountainous Ajara –the municipalities of Khulo and Shuakhevi; also, in Upper Svaneti and Lower Svaneti, to a smaller extent in Upper Imereti and Racha. Early crop is grown in Lower Kartli – the municipalities of Bolnisi, Marneuli, and Gardabani.

At present, the leading regions in potato production are Samtskhe-Javakheti, Lower Kartli, and Adjara, though, the tradition of potato-cultivation practice has long history in Mtskheta-Mtianeti region. In Dusheti, Mtianeti, and Kazbegi potato potato-cultivation is one of the major agricultural sectors.

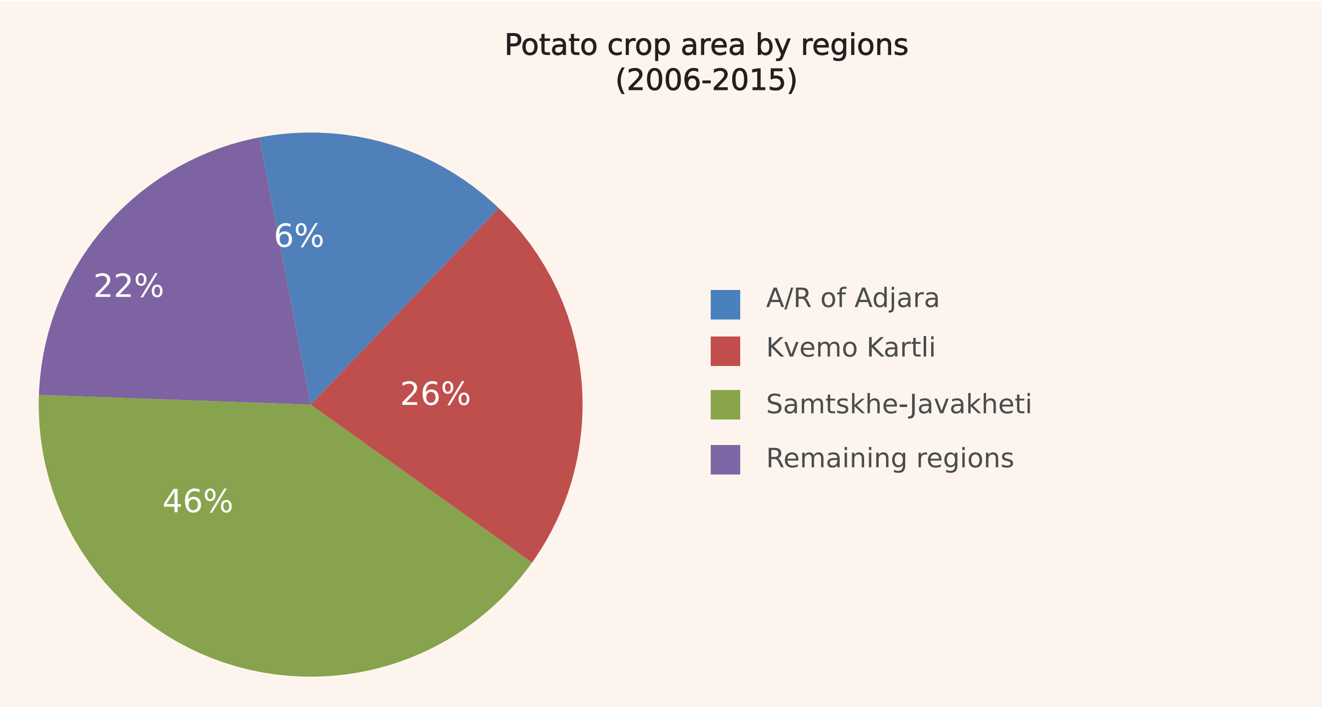


Figure 6.1. The Area of Potato Crops by Regions (source: the National Service of Statistics)

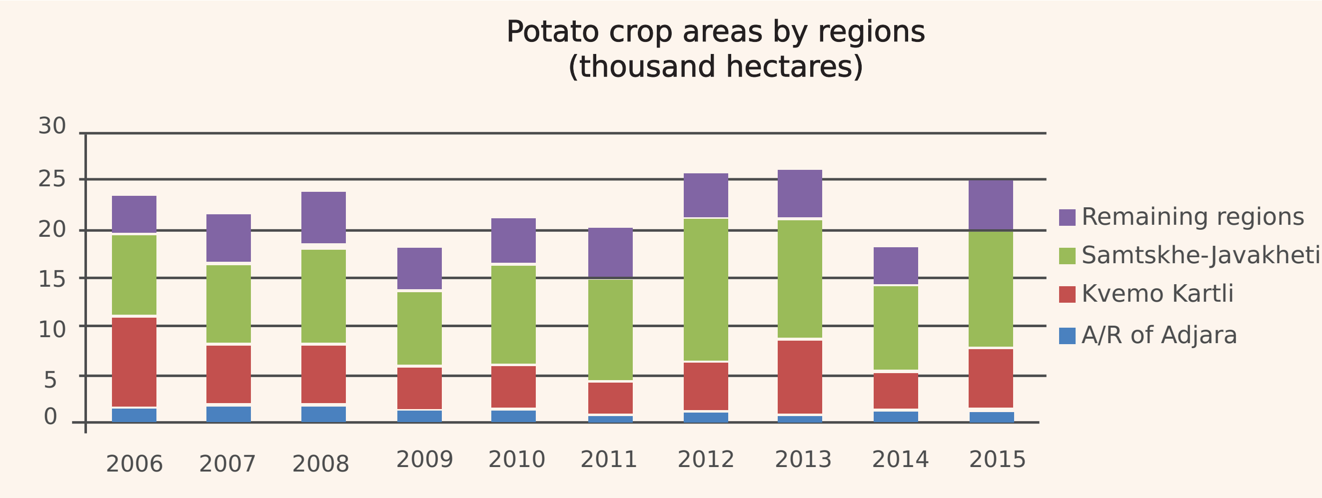


Figure 6.2. The Areas of Potato Crops by Regions (thousand hectares)

This culture is important for the agriculture of Georgia as it is highly resilient to the mountain climate and can be grown on the altitude too high for the most cultures.

Potato productivity in Georgia on the whole is low by global standard; this is mainly due to less developed agricultures and climatic conditions.

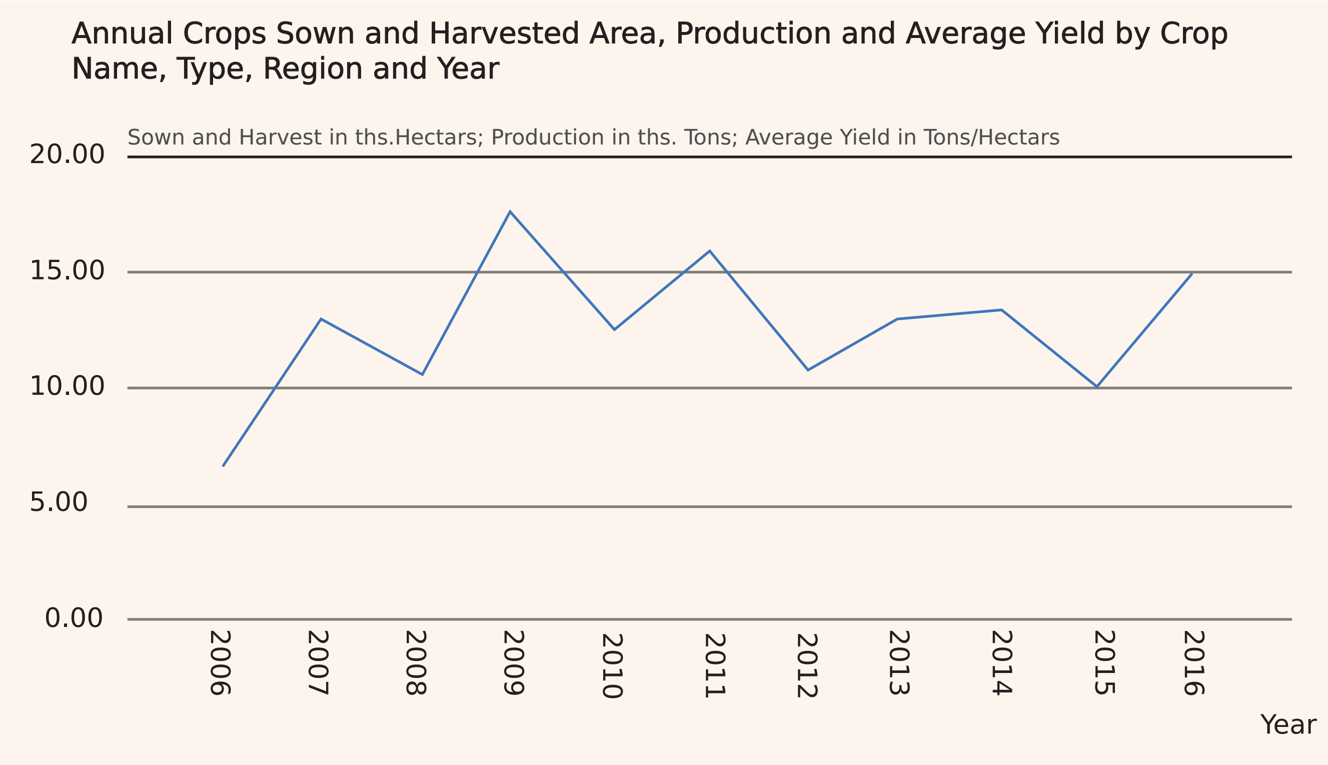
The most common varieties of potatoes in Georgia are white tuberous colour ones. However, red and blue tuberous types of potatoes are not completely uncommon. The donor organisations supplied many varieties of potatoes to regions of Georgia, Adjara being one of them, and 15 best varieties have been distributed throughout regions. The varieties being: Agria, Desire, Santé, Majestic, Nevsky, Marpona, Picasso, Velox, Álvara, etc.

In the process of preparation of the Agricultural National Adaptation Plan of Georgia with regard to climate change the impact of climate change on potato crops has been monitored in the regions of Samtskhe-Javakheti, Adjara, and Mtskheta-Mtianeti.

6.2. Impact of Ongoing Climate Change on Potato Productivity

In Akhaltsikhe Municipality in the period between 1970 and 1990 potato crops occupied 1,000–1,600 hectares. Between 1993 and 2000 the area of potato crops decreased dramatically and hardly exceeded single hectare, in 2000 the area grew up to 2,300 hectares. In 2016 the area of potato crops in entire Samtskhe-Javakheti was 10,800 hectares.

In Akhaltsikhe Municipality the average potato productivity in the periodbetween 1970 and 2000 was 7.7 t/ha, however, between 2013 and 2015 the productivity more than doubled up to 16.6 t/ha. In the region, the number of days with the temperature exceeding 30⁰C in summer has increased by 15. This is not a positive development for the potato culture as it halts vegetation/development of the plant In the municipalities of Akhaltsikhe, Aspindza, and Adigeni, only 40% of potato crops, situated in lowland zones, are watered 3-4 times on average. Crops in highlands are not watered. The lack of irrigation water (scheduled water supply) forces farmers to perform irrigation in the daytime and this increases the risk of potato blight/powdery mildew



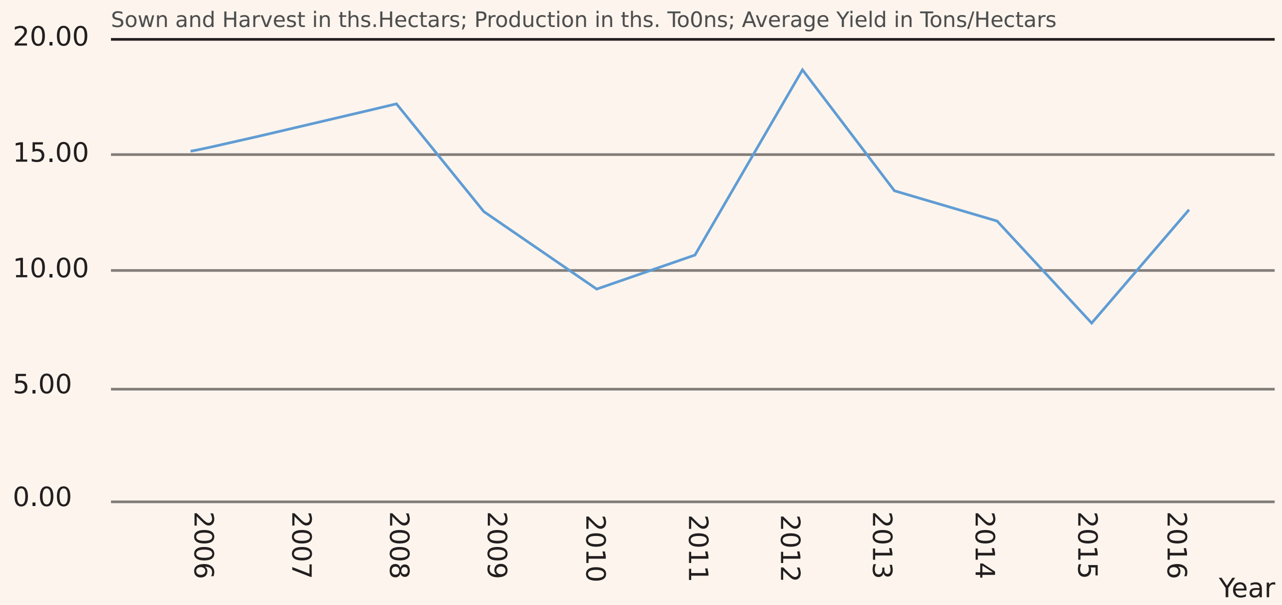
Source: National Statistics office of Georgia (Geostat)

Figure 6.3 Potato productivity (t/ha) in Samtskhe -Javakheti

Apart from the increase of days with high temperature, there has also been an increase in precipitation in May-June by 10% in the last ten years, even though the precipitation in the entire period of vegetation has decreased by 6%. As mentioned above, the increase of precipitation in May-June poses problems for potato crops. In the last five years the precipitation in May and July has increased by 17% and this causes potato fields to flood and crops to rot. The number of days with torrential rainfall (more than 25 mm of precipitation per day) has also risen. In recent years, this particular event has caused greater damage to the agricultural lands of the municipalities of Akhaltsikhe and Adigeni: approx. 120 ha in Akhaltsikhe and 140 ha in Adigeni. Due to excess rainfall, potato fields flood (especially in Vale) destroying 70% of crops.

In Adjara potato is grown in every municipality with the highest productivity in Khulo. Since 1990 the largest area cultivated for potato in Adjara was 2,370 ha in 2010. Following this year, the cultivated area has been declining with the total of 2,024ha in 2015[21]. In recent years in Adjara, especially, in Khulo Municipality there have been favourable climatic conditions that resulted in increase of the potato productivity. In Adjara, between 1980 and 2010 the potato productivity increased nearly 3-fold.
The average potato productivity in 2007 and 2008 was 17-18 t/ha. The general decline in the total potato productivity is rather due to its substitution with alternative cultures that farmers find more expedient.

Annual Crops Sawn and Harvested Area, Production and Average Yield by Crop Name, Type, Region and Year



Source: National Statistics office of Georgia (Geostat)

Figure 6.4. Potato Productivity (t/ha) in Khulo (Adjara)

The optimum temperature for potato and tuber formation is 13-15⁰C. At high temperature 25-30⁰C tuber does not grow well and 30⁰C prevents potato growth. 350C halts vegetation. It is due to high temperatures that in summer on the plains of Adjara potato crop suffers significantly, while in mountain regions on the altitude of 1,200-2,000 m above sea level potato does much better, with more productivity and less diseased.

The precipitation in May-June has increased here as well by 9% in the last five years. However, the population do not face the problem with storage in winter time. The probability of days with torrential rainfall (50mm and over)) has also increased: between 1966 and 1990 this type of event only occurred once, but in the last five years it happened twice. In the recent period (between 2000 and 2015) the days with the precipitation of more than 100 mm more than doubled since between 1966 and 2000 and this has increased the risk of spread of fungal diseases (late blight and early blight).

[21] *These figures are supplied are supplied by an expert, however, the statistics show half of this, 1000 ha, in 2016 in entire Adjara.*

With the advance of climate warming it will be possible to cultivate potato in higher mountain zones by 2015 (it has already started). However, the process should be properly organised and planned to make sure that it does not have an adverse effect on one of the leading sectors of agriculture – animal husbandry as spontaneous growth of potato crop areas could infringe on pastures and hay-fields. In Adjara this development could also raise the risk of erosion due to steepness of the terrain.

In Dusheti Municipality the areas of potato crops between 1970 and 1981 covered 76 ha. Over the following years they decreased dramatically to 1-4 hectares. In 2016 on the entire Mtskheta-Mtianeti territory, the cultivated area for potato covered 500 ha. In Dusheti, between 1970 and 1980 the average potato productivity was 5.5 t/ha while between 1993 and 2000 it was 2.9 t/ha. In Dusheti Municipality, between 2013 and 2015 the productivity increased and made up 19.1 t/ha. In general, the decrease in the productivity of this culture is due to both lack of agrotechnical activities and climate change. Namely, almost on the entire territory of Georgia, including Dusheti Municipality, there was 13% increase in May-June precipitation during in the period over ten years (2006-2015) as compared to the average May-June precipitation between 1966 and 2015; and during the last five years (2011-2015) there has been 22% increase. The excess precipitation during those months causes rotting of the potato seed and affects the long-term storage.

At present in the mountain villages of Dusheti Municipality, specifically in the Barisako community, there has been observed dry rot in the potato tubers stored for winter. It is difficult to tell, at the moment, any specific causes. However, it is possible that the increased May-June precipitation has caused it. There is a higher number of days with torrential rainfall (over 40mm) within these periods. In the second 25 year period it increased by six days; and in the last five years it has been occurring annually. Otherwise, no other visible signs of effects of climate change on potato have been observed in Dusheti region.

On the territory of Dusheti Municipality, the temperature during vegetation period of potato has increased by 2.5 ^{0}C in the second period (1991-2015) as compared to the first period. This is caused by the increase in days with high temperature (>30 ^{0}C), by 10 days within the second period.
In the villages on the plains of the municipality some diseases have occurred and special agrotechnical measures have been taken by local population to address the issue. These diseases have not troubled the population of mountain area yet. However, in near future, in the light of the rising temperatures in mountain regions (by 2050 the temperature is expected to rise by 8 ^{0} C during vegetation period, and the number of hot days – by 14), it is anticipated that potato diseases will spread to this part and it will require similar agrotechnical measures to fight them.

6.3. Ongoing and Forecasted Changes in Agro-climatic Zones Relevant for Potato Production

For growing potato the total of 1500-2800⁰C active temperature is required[22]. Figure 6.5 shows the changes in agro-climatic zones favorable for growing potato within the periods of 1966-90, 1991-2015 and 2071-2100

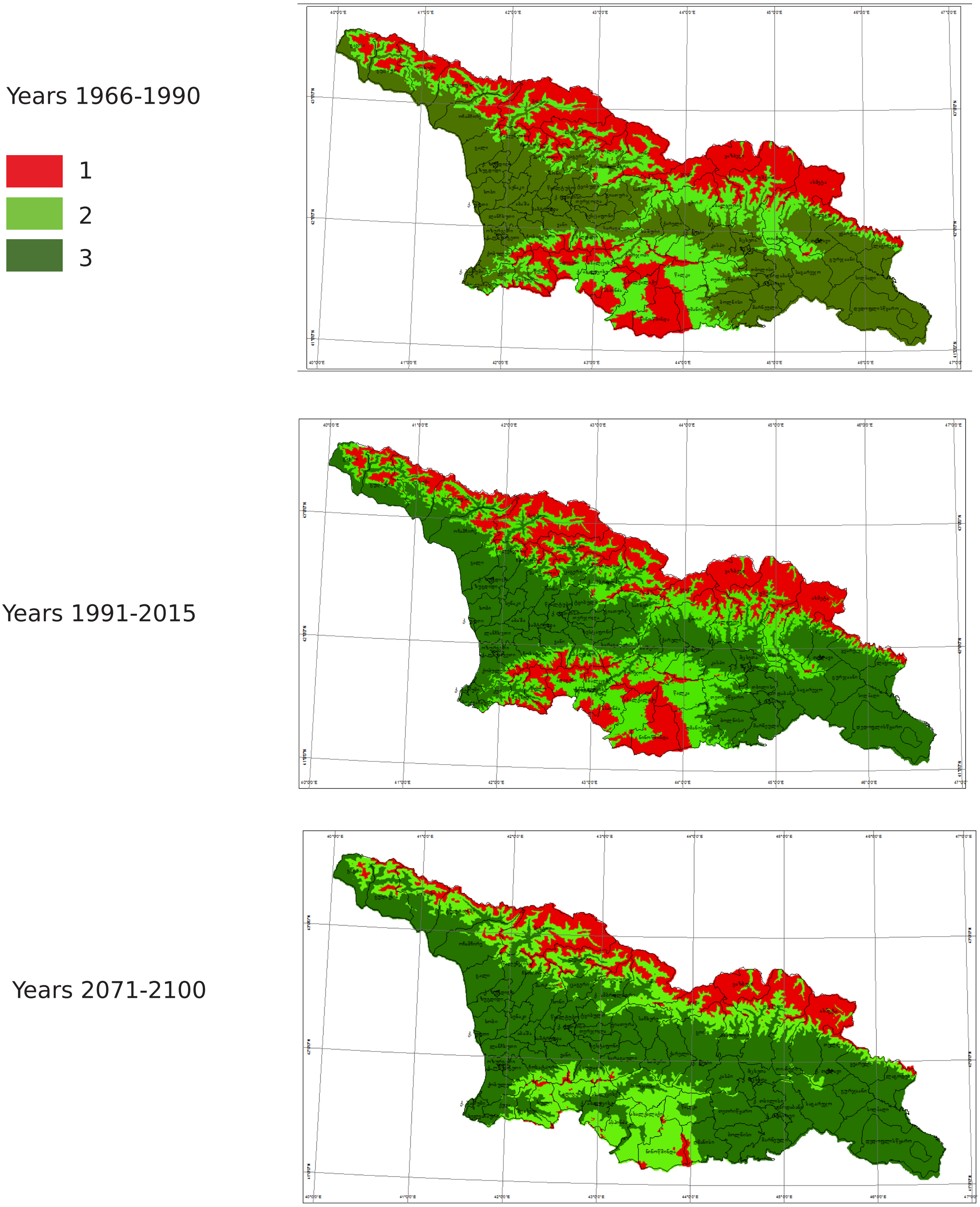


Figure 6.5. Changes in potato Agro-climatic Zones within the Periods of 1966-90, 1991-2015 and 2071-2100

---

[22] Naturally, it is possible to grow potato on the territory with active temperature total over 28000C, however, in this zone more profitable cultures are grown.

Table 6.1 depicts the change in the areas of agroclimatic zones favourable for growing potato within the above periods. The areas of the agroclimatic zones presented in the table are based on the combinations of climatic parameters and do not reflect actual potential, which requires the areas of the existing agricultural lands within these zones to be assessed, suitable soil types for potato growing to be determined, etc., but have not been carried out at this stage. The potato cultivation is more cost-effective in zone 2, with less precipitation and relative coolness, as potato is intolerant to high temperatures and excess water. It can also be grown in zone 3, which is expanding, but its cost benefit analysis vis-à-vis existing cultures should be carried out first.

Table 6.1. Changes in Agroclimatic Zones Favourable for Growing Potato

	1966-90 yy (ha)	1991-2015 yy(ha)	2071-2100 yy(ha)
Zone 2	4467500	4360900	4139900
Zone 3	7954500	8366000	10901200

On the territory of Georgia, in recent years the largest area, 26,000 ha, was planted in 2013 and Samtskhe-Javakheti territory made up 47% of total.

6.4. Assessment of Climate Change Impact on Potato Productivity and Irrigation Water Demand

The impact of the present and expected climate changes on potato productivity and irrigation water demand has been evaluated in three regions of Georgia (Akhaltsikhe, Dusheti-Pasanauri, Khulo) based on joint assessment by Aquacrop (FAO) model and experts[23]. Four different periods have been simulated for each above regions: two current 25-year periods (1966-1990 yy; 1991-2015 yy) and two prognostic periods (2021-2050 yy; 2070-2099 yy).

The climate parameters of the vegetation periods included in the model for all the above periods and respective simulated productivity are presented in tables 6.2.; 6.3 and 6.4.

It is obvious that when comparing simulated productivity with the realistic statistics one should consider that the model does not take into account extreme phenomena affecting crop productivity: frequency and intensity of the growth of occurrenceof diseases and spread of parasites caused by rising temperature and escalating thermal waves; and flooding. Most importantly, the model implies that all agrotechnical activities are carried out thoroughly and promptly and the seeds supplied are of high reflects its potential rather than actual situation. In ideal circumstances the two can come quite close Within the framework of the project, average statistical productivity[24] and the best examples of local productivity have been re-examined in all the three above regions.

[23] *http://www.fao.org/land-water/databases-and-software/aquacrop/en/ when simulating future climate, A1B scenario of IPCC climate change has been used. Climate parameters (atmospheric precipitations, maximum and minimum air temperature, standard/ actual evapotranspiration) have been determined by means of calibrating global circular model (ECHAM4.1) to regional dynamic climatic model (RegCM).*

[24] *http://geostat.ge*

Tables 6.2, 6.3 and 6.4 show the version of modelling process that considers CO_2 effect.

Table 6.2. Climate Indices and Productivity Values and Change of Potato Vegetation Period between the Periods of (1966-1990 (1) and 1991-2015 (2), 2021-2050 (3) and 1991-2015 (2), 2070-2099 (4) and 1991-2015 (2) (Akhaltsikhe)

period / parameter	Precipitation, mm	Evapotranspi-ration mm	Active tempera ture total ºC*day	CO_2, ppm	Productivity t/ha (non-irrigated)	Productivity t/ha (irrigated) (RAW50)	Productivity t/ha (irrigated) (RAW70)
1966-1990(1)	294	581	2016	336	7.4	38.2	37.2
1991-2015(2)	278	571	2094	376	6.9	42.4	41.4
2021-2050 (3)	283	573	2174	442	9.5	47.7	46.3
2070_2099(4)	215	519	2375	540	5.2	52.5	50.8
Abs. change_21 [25]	-17	-10	78	40	-0.5	4.2	4.2
Abs.change_32	5	3	80	65	2.6	5.4	4.9
Abs. change_42	-63	-52	281	163	-1.7	10.2	9.4
Relative change _21	-6%	-2%	4%	11%	-7%	10%	10%
Relative change _32	2%	0.4%	4%	17%	38%	13%	12%
Relative change _42	-23%	-9%	13%	43%	-25%	24%	23%

According to the existing official statistics, the lowest average productivity (6.7 t/ha) in Samtskhe-Javakheti region between 2006 and 2016 was registered in 2006 and in the following year the average had been 10-21 t/ha reaching a record 15 t/ha in 2016. The main contributing factor to this has been setting up an irrigation system (canals and water pumps) ensuring that 60% of crop is watered while 40% still is not. Besides, the farmers are thoroughly adhering to all agrotechnical measures. Despite this, if the actual productivity for non-irrigated year (2006) coincides with the average value of the model estimate for the period (7.4 -6.9 t/ha), the productivity with irrigation should reach 38-42 t/ha with increasing productivity up till 2050. Such Productivity has not been registered in this region yet. The local information centre gives a figure of 14.5 t/ha as the average productivity and 25 t/ha as maximum one, in case of more efficient farmers. According to the model, the productivity will further increase within the future prognostic period in both irrigated and non-irrigated years. There are big losses in this region in case of torrential rainfall; causing flooding of potato crops with 70% of them rotting; and, also, degradation of land, which can be considered as one of the contributing factors to relatively low productivity.

[25] *Denotes the change between second and first periods. The same applies to all other periods*

In order to study the problem in depth, it is necessary to re-examine all the above data locally.

Table 6.3. Climate Indices and Productivity Values and Change of Potato Vegetation Period between the Periods of (1966-1990 (1) and 1991-2015 (2), 2021-2050 (3) and 1991-2015 (2), 2070-2099 (4) and 1991-2015 (2) (Khulo)

period / parameter	Precipitation, mm	Evapotranspi-ration mm	Active tempera-ture total °C*day	CO_2, ppm	Productivity t/ha (non-irrigated)	Productivity t/ha (irrigated) (RAW50)	Productivity t/ha (irrigated) (RAW70)
1966-1990(1)	317	470	1837	336	19.5	36.1	35.4
1991-2015(2)	344	463	1849	376	24.7	39.9	39.2
2021-2050 (3)	312	478	2015	441	21.5	43.7	42.5
2070_2099(4)	250	484	2388	539	14.3	49.8	47.8
Abs. change_21	28	-7	12	40	5.2	3.9	3.9
Abs.change _32	-33	15	166	65	-3.2	3.8	3.3
Abs. change _42	-94	21	540	163	-10.4	9.9	8.5
Relative change_ 21	9%	-1%	1%	12%	21%	10%	10%
Relative change _32	-9%	3%	9%	17%	-13%	10%	8%
Relative change _42	-27%	4%	29%	43%	-42%	25%	22%

According to the existing official statistics the average potato productivity in Adjara between 2006 and 2016 was 15-16 t/ha, although, there are years (2015) when the average productivity was halved (7 t/ha). The highest productivity is in Khulo Municipality reaching 20-25 t/ha at times. This statistics corresponds to the picture drawn by the model with regards to the non-irrigated potato scenario with marked increase in productivity in the second period. Though, after 2021 potato productivity in Khulo Municipality will start to decrease; and in order to achieve high productivity, and according to model Khulo Municipality has potential for this, watering will become essential here. At the moment, with a few exceptions, potato crops are not watered in Adjara mountain zone.

Table 6.4. Climate Indices and Productivity Values and Change of Potato Vegetation Period between the Periods of (1966-1990 (1) and 1991-2015 (2), 2021-2050 (3) and 1991-2015 (2), 2070-2099 (4) and 1991-2015 (2) (Dusheti-Pasanauri)

period / parameter	Precipitation, mm	Evapotranspiration mm	Active temperature total °C*day	CO_2, ppm	Productivity t/ha (non-irrigated	Productivity t/ha (irrigated) (RAW50	Productivity t/ha (irrigated) (RAW70)
1966-1990(1)	472	457	1626	336	24.1	27.5	27.4
1991-2015(2)	462	444	1676	376	26.4	30.5	30.4
2021-2050 (3)	480	469	1772	442	27.9	34.3	34.1
2070_2099(4)	380	433	1958	540	29.0	37.6	37.3
Abs. change_21	-10	-13	51	40	2.4	3.0	2.9
Abs.change_32	18	25	95	65	1.4	3.8	3.8
Abs. change_42	-82	-11	281	163	2.6	7.1	7.0
Relative change_21	-2%	-3%	3%	12%	9%	10%	10%
Relative change_32	4%	6%	6%	17%	5%	13%	12%
Relative change_42	-18%	-2%	17%	43%	10%	23%	23%

In Mtskheta-Mtianeti and, namely, in Dusheti, the actual productivity has at no time reflected high productivity suggested by the model (24 t/ha the lowest). The pat trend, discussed in Chapter 6.2 states that between 1970 and 1980 the potato productivity was 5.5 t/ha (2016 official statistics confirms this figure while other years are not included), but between 1993 and 2000 period it dropped to 2.9 t/ha as hardly any respective agroclimatic measures were carried out and the seed was of poor quality. Between 2013 and 2015, according to the local information, productivity in Dusheti Municipality increased to 19 t/ha. This figure is not confirmed by official statistics, as it seems, this was just one of the isolated cases. According to the Information Services of the Ministry of Agriculture, recently Aragvispiri section has stood out for it high productivity 20-25 t/ha, but this, also, seems to be just one of the isolated cases. According to the above Services the productivity in mountains is 12 t/ha, the figure that has not been confirmed by official statistics[26]. According to the model, in future prognostic period the productivity will increase in both irrigated and non-irrigated conditions. It is essential to re-examine maximum productivity in this region and determine the best suited agrotechnical measures.

As to the irrigation water demand, table 6.5 gives irrigation water demand for potato culture in the three above regions with regard to two scenarios for accessible water (RAW[27]). Orange background indicates growing demand, while green - falling demand.

[26] *In this project, at this stage it was not considered to go to localities and collect more accurate information directly from farmers.*

[27] *Two scenarios for accessible water stored in root zone (RAW) with the permissible dehydration of root zone being 50 and 30% (RAW50, RAW30).*

Table 6.5. Potatoes' demand for irrigation water (mm) and its changes between the periods: 1991-2015 (2) and 1966-1990 (1), 2021-2050 (3) and 1991-2015 (2), 2070-2099 (4) and 1991-2015 in three regions

Period/change	Samtskhe-Javakheti (Akhaltsikhe)		Adjara (Khulo)		Mtskheta-Mtianeti (Pasanauri)	
	RAW50	RAW70	RAW50	RAW70	RAW50	RAW70
1966-1990(1)	251	235	153	134	63	50
1991-2015(2)	250	235	133	119	65	52
2021-2050 (3)	233	218	138	124	70	57
2070_2099(4)	232	216	175	160	83	62
Abs. change_21	-1	1	-20	-16	3	2
Abs.change_32	-17	-17	5	6	5	5
Abs. change_42	-18	-19	42	42	18	10
Relative change_21	-0.4%	0.3%	-13%	-12%	4%	3%
Relative change_32	-7%	-7%	4%	5%	8%	10%
Relative change_42	-7%	-8%	32%	35%	28%	20%

The analysis of the model results shows that:

- According to the chosen scenario of climate change (A1B), in the conditions of non-irrigated agriculture, over the entire prognostic period, potential potato productivity will, probably, only increase in Mtskheta-Mtianeti part; and will significantly decrease in the highland of Adjara (by 10-40%). In the case of irrigation, productivity increases everywhere, the effect of irrigation is especially high in Akhaltsikhe and is relatively insignificant in Mtskheta –Mtianeti, which is explained by different precipitation regimes (Akhaltsikhe has low precipitation, while Pasanauri there is little water deficit); and, also, the granulometric composition of soil.

- In Khulo, according to the future scenario, potato productivity is going to decrease significantly and become irregular, while in Pasanauri the prognosis is most optimal with increased and regular potato productivity. The picture in Akhaltsikhe is different as without irrigation even increase in productivity will not guarantee its stability.

- The effect of change in precipitation with regard to irrigation water demand for potato culture, which is one of the cultures sensitive to soil water content, is particularly evident in Khulo and Dusheti municipalities. Within the prognostic periods, especially towards the end of century, all three above regions show tendency for decrease in precipitation. In the conditions of water deficit the influence of precipitation on potato productivity increases and becomes one of the defining factors for the productivity reduction. According to the results of modelling, irrigation water demand in Khulo and Dusheti by mid-century will grow on average by 10%; and by the end of the century water demand for maintaining maximum productivity will increase by 20-40%. In Samtskhe –Javakheti, the present largest potato producer in the country, prognosis is the most optimistic and in future water demand is expected to drop.

- Increased concentration of CO_2 will have positive effect on potato productivity, although, in certain cases, it will be overshadowed by unfavourable changes in climate parameters during vegetation season dependent on particulars of a region.

- In the case of expected warming, it will be possible to extend potato cultivation to higher mountain region by 2050 (it has already started), however, this process should be well organised and planned to make sure that it does not have an adverse effect on one of the leading sectors of agriculture – animal husbandry as spontaneous growth of potato crop areas could infringe on pastures and hay-fields.

6.5. Recommendations on Adaptation Measures in Potato Production

In the case of potato, three main measures have been identified: to carry out agro-technical measures to protect potato from disease in highland zones of Dusheti region; set up special cellar to store harvest in winter period; and arrange water collectors and watercourses in potato fields of Samtskhe-Javakheti.

The farmers of the mountain villages in Dusheti Municipality need to very closely adhere to the agrotechnical measures on potato cultivation in order to address possible increase in diseases caused by potential climate change. The fathers must start to control parasites and diseases as soon as they manifest themselves, while using the recommended dosage for adequate plant protection.

Most farmers in Dusheti lowland use means for plant protection, as the cases of diseases there are relatively high. In the mountain the cases are low and, respectively, at present the need for plant protection is low. However, in future in the light of climate change the diseases are likely to rise in number in the mountain as well, in which case more thorough agrotechnical measures are recommended and this will cause costs to rise.

In Dusheti Municipality, in winter period 6% of potato harvest is lost in the cases when farmers do not have special storage cellars
The cause of the problem is not clear yet, however, there are two possible reasons for that: increase in frosty days that causes potato to freeze in case they are not stored properly; and dramatic rise in May-June precipitations that damages crop and decreases potato's durability. The above problems still need to be studied and researched, but at this stage, within the framework of the adaptation programme, it has been proposed that potato producers should set up special storage cellars and select healthy, un-diseased potato for storage.

In Meskheti (Akhaltsikhe and other municipalities), in the last five years in the light of climate change May-June precipitation has risen by 10%. Similar increase is observed in Dusheti municipalities and in Khulo. In future the total of annual precipitation and precipitation during the vegetation period drops, however, the trend for growth of rain intensity will stay. This means that flooding of potato fields will continue and this will have adverse effect on the amount and quality of the productivity. In order to adapt to the above process, it is essential to replicate in Samtskhe-Javakheti the methods tested and approved in the western municipalities of Georgia. This means arrangement of arrange water collectors and watercourses in potato fields. This will ensure that surface water from short rainfalls is collected and is channelled away from field. The furrows should be dug during spring ploughing and its cost is included in the cost of ploughing. The two activities are to be carried out simultaneously.

6.6. Cost-Benefit Analysis of Potato Production Adaptation Measures

The first measure is protection of potato from parasites in mountain zone of Dusheti. The analysis covers 11 years over the standard period of 2018-2028. All assumptions and calculation to do with adaptive measures with regard to potato are presented in appendix1.6.

The main benefit from the first measure is additional income from increased productivity. The improved technology will allow the productivity to increase to 22.5 t/ha as compared to 9 t/ha from the traditional technology. As to the costs it includes the difference between the improved and traditional agrotechnical measures and reaches total of 9.3 m Lari for the entire period of its implementation.

This measure is cost-effective. The minimum profit at the end of 11 years (in case of high discount interest rate) is expected to be 9.2 m Lari.
The second scenario of the same measure assumes reduction in productivity when using basic technology in the case of high cases of diseases due to climate change. In this scenario minimum profit at the end of the period is relatively small (8.5m Lari), but still positive.

The second measure is to do with setting up potato storage cellars and it is not cost-effective. In case the price is 0.70 Lari a farmer should be in danger of losing at least 1.8 t of potato in order to invest 1,250 Lari in improvement of his cellars. The benefit of this measure mainly is the value of the potato that is saved from rotting and costs include the price of the cellar.

The second scenario of this measure assumes that, by the end of the period, in case of lack of proper storage facility the productivity loss will increase by 6% to 15% (due to increase in days with abundant rainfall or increase in frost, although the latter is less likely to happen). The second scenario envisages is even bigger financial loss – in the case of low discount interest rate net loss will be 7.6 m Lari.

The third measure envisages fight with abundant rainfall in Akhaltsikhe and the main financial benefit from it will come from productivity spared by flooding and expense is zero as it requires water collecting furrows and this is included in the sort of ploughing and requires no additional costs. This measure is unequivocally cost-effective as incurs no costs.

6.7. Social Impact of Recommended Measures and Role in Implementation of Agriculture Development Strategy of Georgia

Potato is widely spread culture in Georgia and is one of the agricultural products that meets 90% of local demand. Share of cottage industry in potato production is 99.8% (according to 2015 data). Most favourable conditions for potato growing are in mountain and highland regions, where it constitutes staple food for the population, especially in winter months. In the factors such as climate change and change in distribution of rainfall in the potato vegetation period; also increase in very hot (over 30^{0}C) days, it is very important to determine the risks involved when cultivating good quality potato and storing it in winter and to communicate information to population and farmers in order to ameliorate those risks. It is essential to make the information available to smallholder farmers through extension centres and information centres and create environment that exposes them to the knowledge and helps them to apply the knowledge. The above measures are not sufficient for fully protecting this sector from risks of climate change. However, the social consequences in case of their implementation will be highest among all the measures considered in adaptive plan at this stage because, as it has already been stated, potato is widely used as staple and its crops occupy significant areas among all non-grain annual cultures. The three municipalities considered here (Akhaltsikhe, Dusheti, Khulo) are part of large potato producing regions of Georgia (Adjara, Mtskheta-Mtianeti, Samtskhe-Javakheti). These regions comprise 57,373 potato smallholder farms which accounts for 41% of the entire farming in this sector. The above municipalities comprise 15,438 farms and makes up 27% of farms for the three regions[28].

The measure for setting up storage cellars should be singled out. The social consequences of this measure is very insignificant as it is unprofitable as far as the information available to experts is concerned. It should, first of all, be determined how many families will suffer as a result of this problem and whether the loss incurred increases or decreases.

As to the place and contribution of the above measures within agricultural strategy (2015-2020), they will contribute the following way: will help to raise knowledge of farmers and to provide efficient agricultural extension service; will help to develop agricultural sectoral programmes, to facilitate production-certification processes for seed and planting materials, to protect plants and provide phytosanitary conditions, as well as melioration and rational use of soils.

The following are main stakeholders involved in the process of implementing the recommendations concerning potato production: Extension and Information Centres of the Ministry of Agriculture (obtaining and providing the information), National Food Agency, Scientific-Research Center of Agriculture (identifying the reasons to the problems regarding storing the potato within the winter period, revealing other possible negative impacts of climate change and provide recommendations), local community (direct implementing actors), Ltd. Georgian Amelioration (recommendations concerning drainage systems).

7. Impact of Climate Change on Tangerine Production in Adjara and Recommended Adaptation Measures

7.1. Tangerine production in Adjara

In the process of developing National Adaptation Plan for agricultural sector in the light of climate change impact of climate change on tangerine production in Autonomous Republic of Adjara has been evaluated. In addition actual and projected changes in tea agroclimatic zones were identified.

Subtropical horticulture development in Adjara started in 19 the century. Citruses – tangerine, orange and lemon became popular from the very beginning. Large state and co-operative citrus growing farms were established during Soviet period. By 1985 more than 8000 ha of lands were under citrus crops. Later the area of lands under citruses were reduced. Presently they total to 5800ha in Adjara. Total productivity of citrus in 1985-2015 years fluctuated from 40 000 tons to 150 000 tons.

[28] *Agricultural Inventory 2014*

Presumably tea was introduced in Georgia in 30-ies of XIX century. 20-ies of last century were noted with boom of tea growing. By 1980-ies tea plantation occupied more than 7500 ha. Of lands. Average annual productivity was 65-70 000 tons of tea leaves. Four main varieties were grown in Adjara: Chinese (65%), Indochinese (15%), Japanese (10%) and Georgian selection variety " Kolkheti Clone" (10%). Economic crisis of 90ies of the last century had especially heavy impact on tea growing. Owners of privatized land plots started to eradicate tea plantations in order to plant some new crops of their plots. Big part of remaining tea plantations are covered with weeds. The Ministry of agriculture of Adjara plans to only retain 1000 ha of tea plantations in the future.

7.2. Impact of Ongoing Climate Change on Tangerine Productivity

Tangerine remains to be the main agricultural crop for subtropical zone of Adjara based on presence of relevant climatic – soil conditions and opportunity to receive the largest income per unit of land area. Subtropical zone of Georgia is located in the utmost North part of subtropical belt; its climatic peculiarity is conditioned by two main factors: Black Sea, which accumulates large volume of warmth in summer, gradually releasing it along coastal line during the winter; and high mountains of the Caucasus, preventing cold masses of air to penetrate into the region. Subsequently, winters in Ajara are moderately warm, though with high snowfalls.

From the multi year data (1961-2015) of Adjara meteorological stations it becomes clear, that there has been no critical temperature, fatal for tangerines close Batumi in the above period; though basic branches were frozen in 1964, 1971, 1983 and 1993. In Kobuleti there was extremely strict winter in 1985 (-13.8 degrees), which should have caused total drying of citrus plants, but fortunately frosts ere preceded by heavy snowfall, snow cover reaching 1.5-2 m. largely preventing plants from drying. It should be noted that extreme frost frequency indicators are decreasing in various periods; e.g. in 1960-1085 extreme frosts took place five times, in 1985-2000 – 3 times, in 2000-2015 only once which means that frost hazard is gradually dropping.

From observing various periods we can also note decrease of number of frosty days and decrease absolute minimal temperature. In 1966-1990 number of frosty days in Batumi was 7.1. In 1991-2015 - 8.2; In 2071-2100 it is anticipated that number of frosty days will drop to 0.4. In 1966-1990 absolute minimal temperature was -7.5^{0}C; in 1991-2015 -6.6^{0}C, in the future, according to forecasts, due to climate change absolute minimal temperature will drop to just -0.60C. Similar data are received for Kobuleti municipality. Here number of frosty days (0.4) and absolute minimal temperature (-1.1^{0}C). are decreased for different periods.

In future (by 2100) climate change will cause increase of temperature by 4.0^{0}C- on average, and total of active temperatures will be increased to 4900^{0}C, which will fully meet citrus plants' need for warmth. In future estimations monthly, seasonal, vegetation and annual totals of precipitations are insignificantly changed.

Presently tangerines are especially exposed to light autumn freezing or hail. This is when fruit is still not full ripe. Based on Batumi and Kobuleti meteorological stations' data it becomes clear that autumn freezing (October, November) or hail take place every other year in Kobuleti zone, which is directly related to partial or substantial damage of fruit. Such occasions are more rare in Khelvachauri municipality, adjacent to Batumi. Light freezing and hail took place 10 times in 1985-2015. Damaging of fruit by hail has almost become systematic in recent years. Namely in 2016 hail significantly damaged citruses on November 2. If frost frequency trends are decreasing during recent years, we cannot say the same for autumn hails; hails frequency has significantly grown.

Future climate change will have positive impact on autumn and spring freezing's, decreasing hazard of frost and hail damaging plants.

For full ripening of tangerine total of active temperatures should equal to minimum 4000-4200^{0}C , which is achieved in Adjara by end of November, beginning of December. Forecasts of climate change indicates that total of active temperatures will be increased by 1000C 0 in 2071-2100 on average and ill ensure full ripening of fruit by October. On the other hand in the process of developing third National Warning of Georgia for Climate Change it has been stated that increase of totals of active temperatures will be accompanied by invasion of alien diseases destructive for citruses, which farmers and local communities find difficult to adequately respond to.

Adjara subtropics are characterized by intensive precipitations; though in May-June when tangerine especially requires moisture, are rather droughty, subsequently plans drop their flowers. Precipitations in Batumi district are decreased by 9%. Therefore citrus plant need to be irrigated during dry periods, which so far is not done because of lack of relevant infrastructure.

By 2015 anticipated increase of annual average temperature, particularly, increase of average temperatures in warm period of year will significantly change quantitative and qualitative indicators of citrus crops productivity. It is known that Western Georgia is located at the extreme North border of Mediterranean Sea basin and other adjacent citrus growing territories. Here orange, grapefruit, lemon and other warmth loving varieties often lack required quantity of totals of active temperatures in their vegetation period. According to available data, full ripening of orange and grapefruit in Adjara is only feasible 5-6 times every 10 years (4500^{0}C required). By 2015 it is expected that average annual temperature will be increased by 1.5^{0}C in the coastal line of the region; by 2100 subtropical zone of Adjara lowlands will be equaled (from climatic point of view, average annual temperature 18.3^{0}C) to coastal regions of Mediterranean Sea, where average annual temperature presently fluctuates around 18^{0}C. The above will create favorable environment for having high quality and stable productivity of citrus crops in Ajara subtropical zone provided there are appropriate agro-technical conditions. It also should be mentioned here that according to forecasts, moisture, needed for citrus production will substantially drop by 2100 (see agro-climatic zones), thus zones favorable for tangerine (citrus) production will be reduced by three times. In order thee areas to be retained they need to be irrigated.

7.3. Ongoing and Forecasted Changes in Agro-climatic Zones Relevant for Tangerine Production

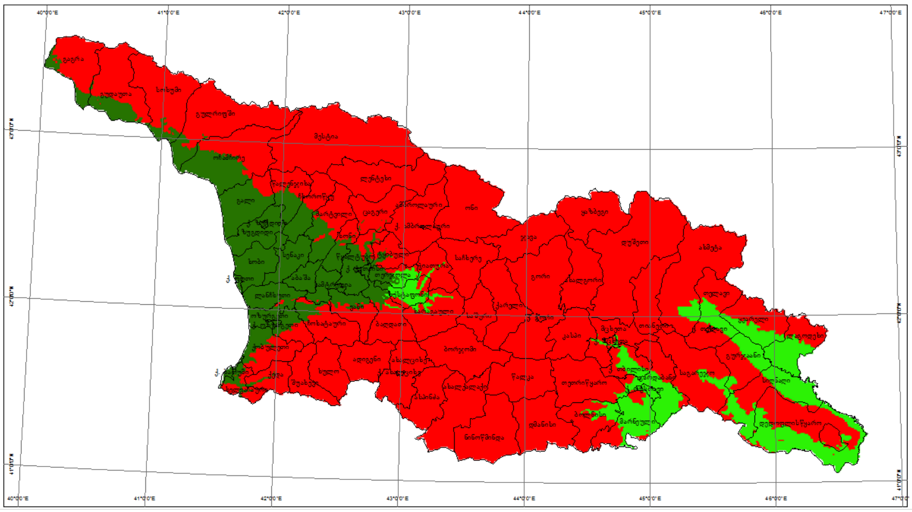
Total of active temperatures required in the period from opening of buds of tangerine till its blossoming is 400-560^{0}C, in the period from blossom to ripening is - 3500-3700^{0}C. Overall total of active temperatures required for tangerine equals to 3900-4260^{0}C. The same temperature modules are required for tea. Tangerine needs humid subtropical climate whereas tea can be produced in conditions of moderate humidity.

1966-1990 Years

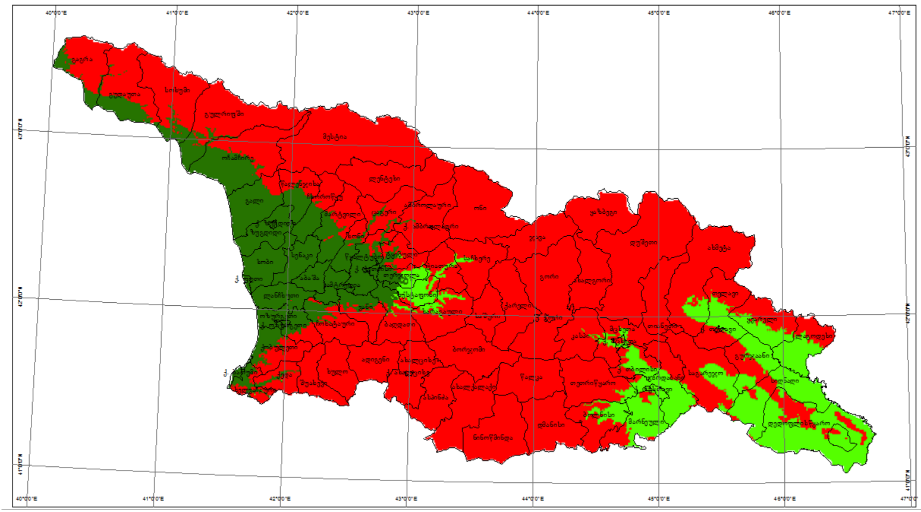
1

2

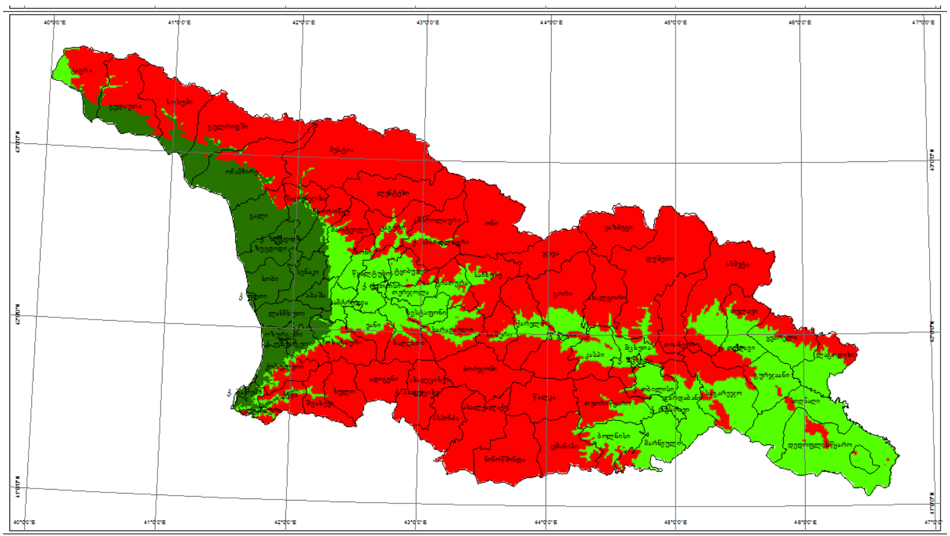
3



1991-2015 Years



2071-2100 Years



Picture 7.1.Changes in citrus agro climatic zoning 1966-90, 1991-2015 and 2071-2100 years[29]

[28] Dark green color (zone 3) notes agricultural zone favorable for citruses. Light green (zone 2) notes the one where citrus may only be produced if lands are irrigated; and red color (zone 1) indicates the zone which is incompatible with conditions favorable for citrus production.

Table 7.1 Areas of zones favorable for citrus production in various period

	1966-90 years. (ha)	1991-2015 years (ha)	2071-2100 years (ha)
Zone 2	598000	820600	1 762800
Zone 3	899200	988400	765500

Citrus can only be produced in zone three, whereas tea in zone two as well. Currently the zone favorable for citrus production is the largest, but it is decreasing in the future. Zone three is significantly decreased in the future; but territories favorable for tea production will be increased almost by three times. Territories where favorable climatic conditions will be created for tea and citrus production in the future, are presently covered by forests ad pastures. They should be cultivated based on economic feasibility.

Based on expert opinion, considering climate change and provided rathe ripe crops are planted in the future, it will be possible to plant citruses on 50 000 ha including Abkhazia and Kolkheti lowlands. This assessment is realistic provided there is demand on the product. In 80-ies land area under tangerines in Georgia (including Abkhazia) equalled to 27000 ha, according to census of 2014 it was 7400 ha [30].

7.4. Recommendations on Adaptation Measures in Tangerine Production

Two measures have been identified for protecting tangerine production process from climate change hazards: Development and support of introduction of high productivity and high quality tangerine varieties – Unshiu and Tiakhara Unshiu in Adjara subtropical zone and large scale application of agroinsuranceby tangerine producers.

Adaptation of high productivity and high quality tangerine varieties – Unshiu and Tiakhara Unshiu in Adjara subtropical zone is rather prospective from economic point of view, based on opportunity to prolong tangerine harvesting and trading season (October-January). The above excludes peak seasonality in trade of harvested product, leading to stable prices of tangerine.

Unshiu and rathe ripe Tiakhara Unshiu should be co-cultivated in accordance with zones, terrain and exposition in order to ensure productivity and high quality fruit. This will enable farmers to enter export markets a month earlier and consequently to enjoy longer sale period. Most importantly cultivation of rathe ripe variety reduces hail and freezing related risks for farmers; hails have become particularly frequent recently2 and in the light of ongoing climate change they may become even more frequent. Freezings used to be the main hazard for tangerines[31] so far, but they will become less frequent with the increase of the temperature, though risk of hails will become higher. Cultivation of rathe ripe varieties is one of the adaptation measures recommended in Adjara.

Considering that success in agricultural activities largely depends on weather conditions and changes in climate, agro insurance is second recommended measure for farmers.

---

[30] http://census.ge/files/results/agriculture/AG%20 Census%20Release.pdf

[31] In Adjara hail events are majorly observed throughout the period of the end of October - November.

[32] Frost events are mainly observed starting from the second half of November.

7.5. Cost- Benefit Analysis of Tangerine Production Adaptation Measures

Dissemination of rather ripe variety Tiakhara Unshiu in Adjara is to be very first activity.

Analysis covers 11 years covering standard period (2018-2028). Assumptions and estimates needed for cost effectiveness analysis are given annex 1.7. Main benefit in case of implementation of the above activity is value of productivity surviving hail; since rathe ripe variety provides opportunity to avoid hail, we can consider that 60 % of productivity, which normally would have been lost as a result of hail in case of traditional varieties, will not be lost any more if new varieties are planted. Benefit will only be received in years when hail would be observed. As for costs, they are related to planting of rathe ripe Tiakhara Unshiu and broad leaf Unshiu; this implies loss of income generated from traditional Unshiu plants, when old trees are replaced by new ones but young trees still do not bear fruit. According to planned activity new variety will be planted on 107 ha (100 ha is already cultivated) and total cost equals to 1.4 million GEL during the whole period, net present value of the benefit (profit) is 335 000 GEL by end of the period in case of (7.37% discount rate).

According to second scenariohail frequency will grow and it will take place every year, meaning that benefit of the above activity will be even higher. Therefore the activity is profitable in case of both scenarios and in conditions of high discount rate (9.98%). Second measure implies support of agro insurance development. Analysis covers Adjara region and implies agro insurance program[33], implemented by Agricultural Projects Management Agency; beneficiaries of the above program are farmers insuring less than 5 ha land plots. This category of farmers are offered 70 percent of policy cost co funding by the state in case they cultivate tangerine. Full policy cost for tangerine is 1000 GEL/ha, and small farmers have only to pay 300 GEL, the remaining 70 % is paid by the state. Large farmers pay the whole amount. Analysis covers 11 years covering standard period (2018-2028). Assumptions and estimates are given annex 1.7

In case of successful implementation of the activity main benefit will be received from loss claims settled by the insurance company, which depends on insured area, policy cost and loss ratio. 55 % loss ratio implies that on average 55 % of premiums received by insurance companies are spent on claim settlements (compensation of losses). Main costs of the activity: Premium paid by farmers and the state to the insurance companies. This amount depends on policy cost, state co funding percent and land area. Small farmers will have to pay less money since 70 % is covered by the state. Total insured area will equal to 14 % of overall lands under citruses by end of the period; 5.8 belonging to small farmers and 8.1% to large farmers.

This activity is detrimental for large farmers, having to cover the full cost of insurance policy, though profitable for small farmers, since 70 % of insurance policy cost is paid by the state. Majority of full cost payers are large farmers, who pay 100 % of the premium. According to this scenario this activity is non profitable even in case of low discount rate (4.76%).

According to the second scenario it is implied that frequency of hails is increased and in this case insurance companies will have to compensate losses more frequently than they had to in the past. If loss ration used to be 55%, in the light of more frequent hails it may become 75 %.

This scenario demonstrates that if loss ratio is increased from 55 % to 75 % than benefit for all groups (both small and large farmers) will exceed costs.

[33] *http://apma.ge/projects/read/agroinsurance/4:parent*

7.6. Social Impact of Recommended Measures and Role in Implementation of Agriculture Development Strategy of Georgia

In case of both activities related to tangerine, social effect is rather high, since it is related to well being of up to 2000 farmers. 60 % of harvest of these farmers may be lost in case of hail. In cost effectiveness analysis monetary value of social effect is only implied in the second activity -insurance package.
Since citrus crops and particularly tangerine is main source of income for Adjara population, both these activities will have serious impact of well being of the local communities; though on the other hand they will be rather difficult to be implemented, since they require profound changes to take place in the mentality of the population, particularly regarding insurance packages. At this stage only 5,7% of plantations are insured. Social effect of the second activity will be especially high in case of more frequent hails and freezings in light of climate change; though in this case there is probability that private insurance companies will not undertake risks for the same conditions, thus changing economic pattern. In order to comprehensively implement these activities it will be important that information centers of the Ministry of Agriculture and extension services are fully engaged in the process, so that information about threats caused by climate change is communicated to the population in appropriate way and, most importantly, more surveys and monitoring should be carried out to identify additional adverse impacts anticipated in various directions of agriculture of Adjara, including citruses in the light of climate change.

Funds, injected by the state in this segment, in addition to social effect, will substantially reduce risks related to production if this export product. The above activities will reflect and largely contribute to development of agro insurance market, facilitation of production and certification of seed and planting materials, support of climate prudent agricultural practices, increase of farmer skills and providing effective agricultural extension services in the most strategic directions of agriculture.

The activity is supported by the Ministry of Agriculture of Adjara through the earmark program and farmers are also rather interested. Citrus is considered to be a priority crop for agricultural strategy of Ajara both in means of population income and as a main export product.

8. Climate Change Impact on Production of Hazelnut and Adaptation Measures

8.1. Hazelnut Production in Georgia

The leading position in hazelnut production in Georgia belongs to Samegrelo-Svaneti, where is grown over 50% of the hazelnut produced in Georgia[34].

[34] *National Statistics Office of Georgia, Agriculture of Georgia, 2016*

Table 8.1 Hazelnut production by regions (thousand, ton)

	2014	2015	2016
Georgia	33,8	35,3	29,5
Adjaria	-	-	1,5
Guria	6,2	6,2	7,2
Imereti	3,2	4,2	3,4
Kakheti	-	-	1,2
Mtskheta-Mtianeti	-	-	0,1
Samegrelo-Zemo Svaneti	20,7	18,8	15,3
Kvemo Kartli	-	-	0,5
Shida Kartli	-	-	0,1
Other regions	3,6	6,1	0,0

There are lots of types of hazelnut spread in Georgia, mostly native, including "Anaklia","Shvelkisera", "Dedophlistiti" (Corylus avellana), "Nemsa", "Gulshishvela", "Khachapura", "Vanis Tetri". Types of Georgian hazelnut are characterized with high quality properties, competitiveness and are one of the important export products, realization of which is mainly in Europe.

Production of hazelnut has been especially developed for the last 10-15 years. Hazelnut is basically produced on small gardening and personal plots, the area of which is ranging between 0.1 ha – 0.5 ha. Because of the increased demands growing of hazelnut has been started on larger areas (10 ha – 300 ha) lately. On the personal plots 400-700 hazelnut trees are grown.

In the regions of Georgia, where there are favorable conditions for the development of the hazelnut culture, productivity per hectare is 2.50-3.50 ton.
Hazelnut has strong roots, set in the upper layers of soil, by which it strengthens and protects soil from erosion. Accordingly, it is recommended to grow hazelnut trees on unused slopes.

8.2. Impact of Ongoing Climate Changes on Hazelnut Productivity

In Samegrelo there are favorable agroclimatic conditions for growing hazelnut for industrial purposes, however its yielding ability is negatively affected by the following climatic changes:

- Increase of power and duration of hot winds
- Increase of precipitations at the beginning of hazelnut vegetation
- Prolonged droughts in July-August

In Samegrelo 40-45% of precipitations are in the vegetation process of hazelnut. Within the last period there were observed some changes in the annual distribution of precipitations. The increase of precipitations in spring (in the blooming period of hazelnut) favors spreading of harmful diseases of hazelnut, because spraying with pesticides is getting hard and as a result of it yielding of hazelnut is decreasing. For the last five years redundant precipitations have hampered carrying out agrotechnical measures in hazelnut gardens timely, in terms, because of which harmful insects, such as ticks, dung beetles, and snout beetles have been spread, there were also different diseases increasing, such as gray rot, brown rot and pink rot. Abundant participations are impeding the plant development. The plant is turning weaker; it is withering and finally is drying up. Abundant participations are causing extreme humidity of the soil and bogging up of the territory, because of which it is necessary to arrange vertical and horizontal drainage systems.

In general Samegrelo region is characterized with hot winds (hot and dry winds). Frequency, duration and velocity of hot winds have been increased for the last five years. Hot winds not only damage the harvest of the current year, but its negative influence is also observed on the harvest of the following year. In the period of droughts plant's new growth is weak, poorly developed and is easily damaged by winter frosts. In 2015-2016 in Samegrelo hot winds, the velocity of which exceeded 15 m/sec, destroyed the harvest in well kept gardens by 80-90%. There were also spread harmful diseases, which in the following years negatively influenced on yielding. Strong winds especially negatively influenced on hazelnut in the period of blooming, because of which it is necessary to arrange windbreak zones.

In Samegrelo frosts are ceased in the middle of March, though for the last few years there have been observed frosts in April and first frosts in autumn at the end of November. At -7-9^{0}C temperature fruiting branches are damaged, but spring frosts damage fruiting buds.

In climatic parameters changes have negative influence especially on small gardens of hazelnut, where proper agrotechnical measures are not taken, such as: pruning, cutting of damaged branches, replacing of outgrowths, cutting buds swollen with ticks, cutting branches damaged by dung beetles, fertilizer application, spraying with pesticides, digging weeds out. Under unfavorable climatic conditions in smart gardens the harvest loss is only 20-40%, but in the unformed garden the hot wind can damage the whole harvest.

If in a hazelnut bush there are 20-50 mother branches (instead of 4-9), the plant grows in height, bearing of the tree is increasing at the top, and treating and cutting the diseased branches are getting hard. In such gardens hot winds ravages the most part of the harvest.

The necessary agrotechnical measures are not mainly taken in hazelnut gardens arranged on personal plots, the owners of which were satisfied with such little harvest (400 g – 1.5 kg on each tree) given by an unkempt garden. It was basically caused by the lack of knowledge and experience in caring for hazelnut gardens. With this approach and because of changes of climatic parameters (the increase of frequency and duration of strong hot winds, redundant precipitations, long drought periods) pests became active and hazelnut diseases were spread. As a result of the above mentioned situation in 2016 yielding of hazelnut declined, the production was of low quality, the plants were weakened and there was danger of drying out.
In the table below, there is given the average of hazelnut yielding by regions and main reasons of yielding difference in kempt and unkempt gardens.

Table 8.2 The average hazelnut productivity by regions

Region	Average yielding, t/ha Unkempt garden	Average yielding, t/ha Kempt garden)	Reason of difference
Samegrelo	1.5-1.8	2.0-2.5-3.5	By drainage canals redundant moisture is being removed, soil is being fertilized
Guria	1.3-1.6	1.7-2.0	Age of trees
Imereti	1.5-1.7	1.8-2.0	Lack of moisture
Adzharia	1.3-1.5	1.5-2.0	Low agro-background
Kakheti	1.9-2.3	2.5-3.0	High productivity of soil

8.3. Ongoing and Forecasted Change in Agroclimatic Zones Relevant for Hazelnut Production

For growing hazelnut the necessary sum of active temperatures on average is 3900-49000C and the annual amount of atmospheric precipitations is 1400-1720 mm; zoning of favorable climatic conditions for hazelnut was just made by this principle. The results are given in Picture 8.1. Area changes of agroclimatic zones, in which it is possible to grow this culture, are given in Table 8.3.

Picture 8.1 Changes in agroclimatic zoning of hazelnut in 1966-90, 1991-2015 and 2071-2100 1966-1990

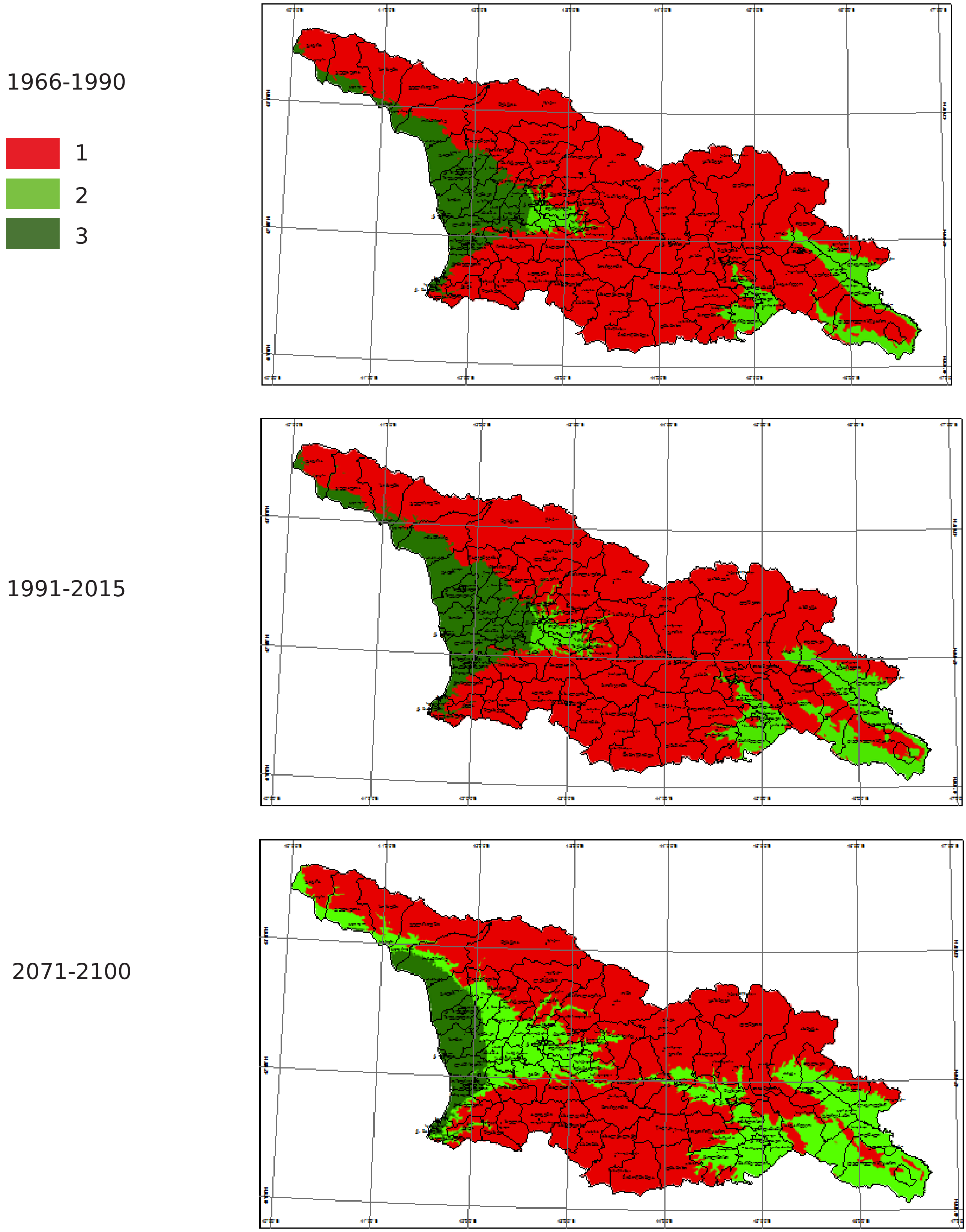


Table 8.3. Zones Areas Favorable for Growing hazelnut in Different Time Periods

	1966-90 (ha)	1991-2015 (ha)	2071-2100 (ha)
Zone 2	548099	760736	1838121
Zone 3	773237	859469	467510

Naturally favorable conditions for hazelnut growing are in zone 3; in zone 2 for this culture only the temperature is favorable, this zone is not provided with precipitations and requires watering. In the current period, where the sum of temperatures and amount of precipitations are increased, areas of zone 2 and zone 3 are nearly unchanged; there are optimal climatic conditions for growing of hazelnut. In the future zone 3 will be decreased 2 -times, in return the area of those territories where because of the temperature growing of hazelnut will be possible, will be increased 2.5 –times, though additional study is required to state on which from these two zones watering will be possible and profitable economically.

8.4. Recommendations on Adaptation Measures in Hazelnut Industry

In hazelnut gardens the following agrotechnical measures must be carried out:

- Arranging drainage canals for removing redundant water
- Arranging windbreak belts
- For the purpose of water provision arranging boreholes and irrigation systems
- Planting of hazelnut bushes on creeping rock layers (by horizontals “like a chessboard”)
- Taking preventive measures against spreading of pests

Gardens of intensive type must be arranged with saplings from nursery garden. For getting pure species saplings must be taken from the nursery bed.

In young gardens of hazelnut plants should be formed (in standard bush forms). The old plants of hazelnut should be rejuvenated. In the vegetation period sprouts must be replaced 3-4 times.

8.5. Cost- Benefit Analysis of Hazelnut Industry Adaptation Measures

For reasonable adaptation of hazelnut industry to climate there were chosen two main measures: carrying out agrotechnical measures in unkempt hazelnut gardens and provision of the hazelnut gardens with windbreak belts. Each measure is for standard 11 years (2018-2028).

In case of the first measure the main benefit is the income received from the productivity increased as a result of carrying out improved agrotechnical measures. In smart gardens the productivity from 1 hazelnut tree is 4-5 kg, while the same index in the unkempt garden is only 1 kg. As for expenditures it is the difference in expenditures in kempt and unkempt gardens. The proper management of the garden requires more expenditure. The difference in expenditures depends on the tree whether it is fruit-bearing or not. Handling of a fruit-bearing garden costs 6 000 Gel/ha, while handling of non fruit-bearing garden is less by 13% (5 291 Gel/ha). The total expenditure in 21 790 ha gardens for modern agrotechnical measures is 292 million Gel.

Net present value or profit at the end of the period is 402 million Gel. Analysis of sensitiveness was performed for different rates of discount and the measure is profitable in all cases. The second scenario of the same measure discusses decrease of the productivity in unkempt gardens as a result of climate changes. In this scenario it is meant that those farmers, who spend minimal money on their gardens and don't increase their expenditures, will not be able to get even 1 kg from one hazelnut tree and yielding might be decreased by 50% (admission). It is meant that in the first 5 years the harvest is 1 kg from 1 tree, during the following 5 years - 0.5 kg. The average profit by the end of the period is 465 million Gel. In case of both scenarios the benefit received by this measure exceeds its expenditure.

The second measure means supplying of hazelnut gardens in Zugdidi municipality with windbreak zones. This analysis was also conducted for standard 11 years (2017-2027). In case of this measure the basic profit is the value of the harvest, which will not be lost, if a windbreak zone is built; in the expenditure only expenses on building of the windbreak zone is meant, which is 5.6 million Gel for building 500 ha windbreak zone. Under conditions of a high or low discount rate the net benefit is positive and in case of the mean discount rate (7.37%) it is 1.6 million Gel. From the point of view of investments this measure is a profitable alternative.

The second scenario of this measure implies increase of wind frequency because of climate changes. If because of climate changes winds are becoming more frequent and are fixed every year, the benefit gained from the windbreak zones will be much more and at the end of the period in conditions of the mean discount rate it will reach 15.7 million Gel. In case of any scenario the benefit gained by this measure is more than its expenditures.

8.6. Social Impact of Recommended Measures and Role in Implementation of Agriculture Development Strategy of Georgia

Carrying out of both measures (garden management with modern agro-technology and windbreak zones) the social effect will be positive and high, because most of the unkempt gardens are small personal gardens of the population. In the municipality of Zugdidi there are 15,806 hazelnut gardens, which is the one third of Samegrelo-Svaneti gardens and in this region – 46% of hazelnut gardens existed in Georgia. Carrying out this measure successfully depends on many factors. In case of the first measure (garden management with modern agro-technology) one of the impediments might be the increase of precipitations caused by climate changes and redistribution, when in the conditions of the prolonged rains agrotechnical measures can't be done. The second barrier might be that most part of population is unable to get information about these measures that is the reason of increasing their expenditures. It is also important that market must provide high quality preparations and other materials for agrotechnical measures.

The windbreak zone offered in the second measure is known for its positive effect in Agriculture practice, though because of their height and function it might have a negative effect on cultures of the neighbouring territories, which require much sun and light and this can be a barrier in the process of designing and building it. At this stage a social effect is not assessed. Earlier windbreak zones occupied a neutral (state) territory, but now actually in relation to hazelnut it will be on a private territory, though it might also be on the territory of the municipality and have more users. It needs consultations with farmers and municipalities that were not done within the scope of the project.

The first measure implying carrying out agrotechnical measures timely and foresees climate changes risks is in compliance with the agriculture strategy and will contribute in such directions as deepening and extension of farmers' knowledge. In the agriculture strategy building of windbreak zones responds to the rational use of soils. Both measures contribute to climate-smart agriculture.

Local information centers of the Ministry of Agriculture of Georgia are responsible for disseminating the information concerning agrotechnical measures. Within this process, various international projects and programs must be applied. The role of the private sector providing the market with necessary materials for agriculture measures is significant, as well as the role of Scientific Research Center of the Ministry of Agriculture, constantly monitoring the diseases and other risks related to climate.

Regarding planting the windbreaks- in case of industrial gardens, private sector would be responsible for it and for homestead lands/plots- municipalities can be involved in the process together with the inhabitants (co-financed). The role of the Ministry of Environment and Natural Resources Protection of Georgia is vital within this process of selecting the tree species for windbreaks (preserving biodiversity). However, firstly, legislative basis must be settled and the rights and responsibilities defined in regard with windbreaks. During the Soviet period, the planting of windbreaks was planned by the Ministry of Agriculture and managed/maintained by collective farms. The case of Dedoplistskharo clearly showed us that currently, as being non private, the protection of windbreaks can't be provided due to the absence of relevant legislative basis.

9. Impact of Climate Change on Pastures and Recommended Adaptation measures

9.1. Pastures in Georgia

Natural hay meadows and pastures take up 1911.2 thousand ha in Georgia, 143.0 thousand ha of which is hay meadows and 1768.2 thousand ha is pastures[35]. These lands are found in lowland, lower mountain, mid mountain, subalpine and alpine zones[36].

In terms of regions, the largest hay meadow and pasture areas in Georgia are in Kakheti and Samegrelo Zemo-Svaneti, however the agricultural lands in Mtskheta-Mtianeti are also largely hay meadows and pastures (figure 9.1). The subalpine and alpine zones in Adjara have an area of 37 759 ha, the majority of which is held by summer pastures.

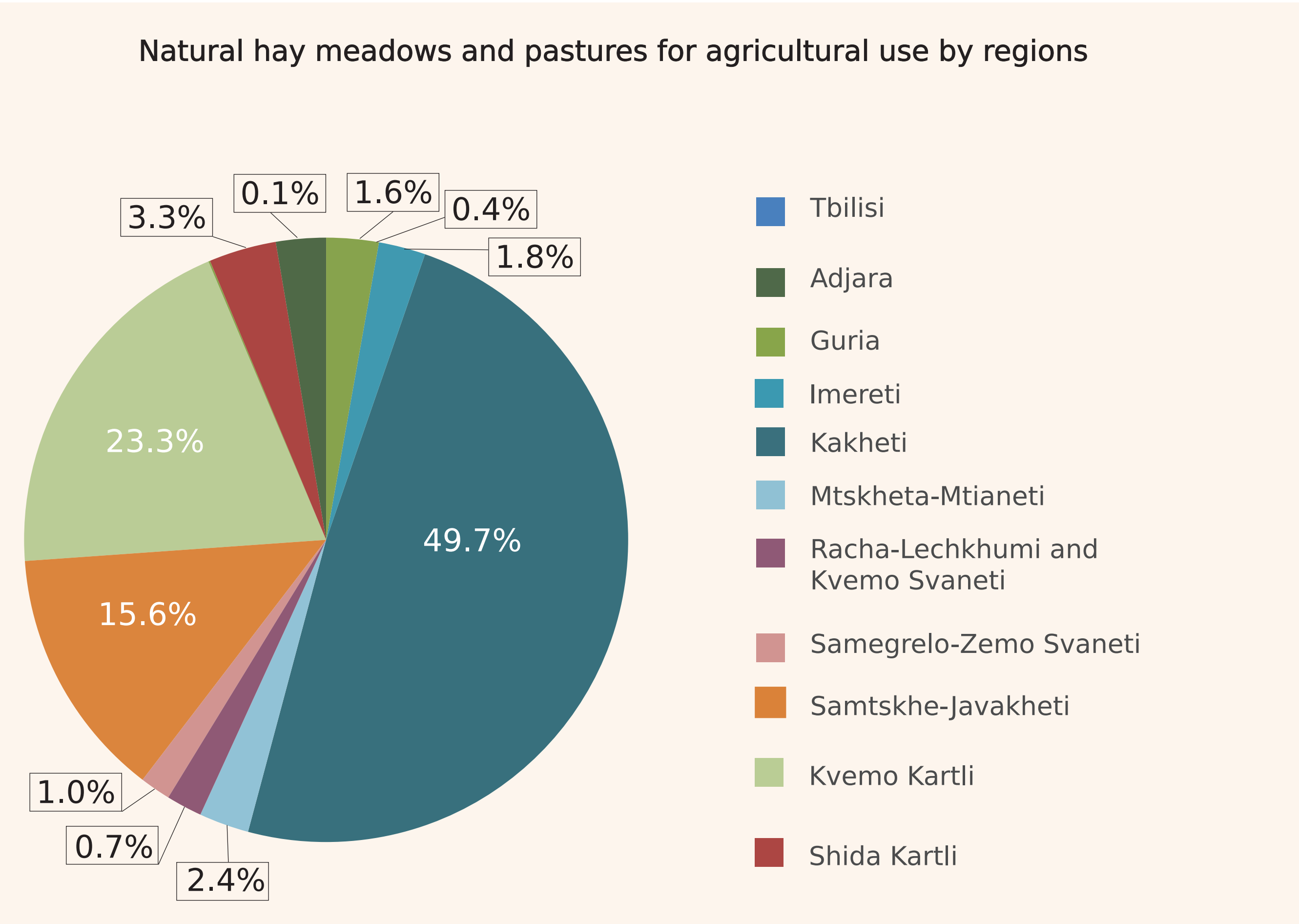


Figure 9.1. Natural hay meadows and pastures available to use for production (all categories of production, as of October 1, 2014, %)[37].

[35] http://www.geostat.ge/cms/site_images/_files/georgian/agriculture/Garemo_2015.pdf

[36] http://www.gaas.dsl.ge/pdf/recomendations_2016/რეკომენდაცია-სარჯველაძე-2016.pdf

[37] http://census.ge/ge/results/agro-census/meurneobebis-ganatsileba-sargeblobashi-arsebuli-mitsis-fartobis-mikhedvit

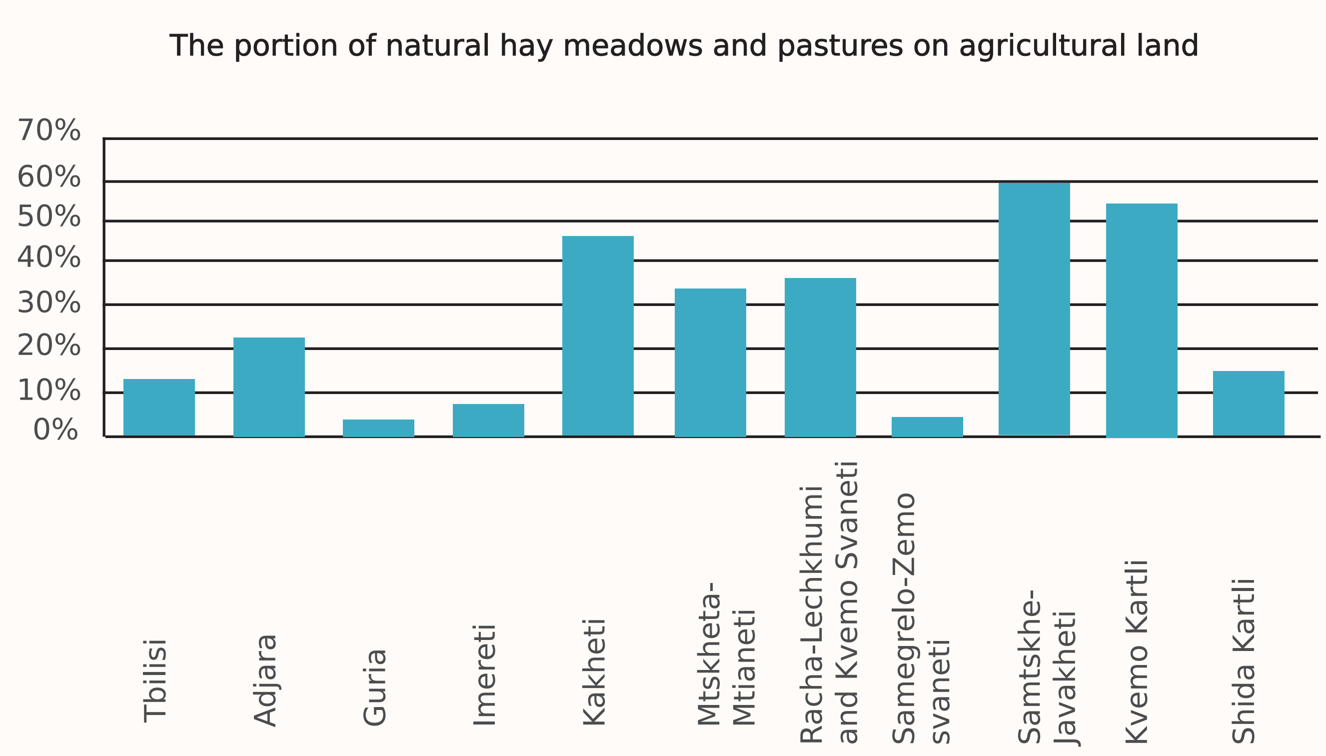


Figure 9.2. Ratio of hay meadows and pastures on agricultural lands by regions. (As of October 1, 2014, %) [38].

In the process of preparation of plans for agricultural adaptation to climate change in Georgia, an assessment of climate change impact of the productivity of pastures was done in Samegrelo-Zemo Svaneti, Mtskheta-Mtianeti and Kakheti regions as well as the Autonomous Republic of Adjara.

9.2. Impact of Ongoing Climate Change on Pastures Productivity

The majority of winter pastures and hay meadows in Kakheti are located in the surrounding areas of Tetritskaro, Signagi, Gurjaani and Sagarejo Municipalities. The largest area of these lands is in Dedoplistskaro (54.42 thousa contain sea salt percipitation and thus are susceptible to wind erosion, disintegration and washing out. The washed down layers accumulate on relatively even pastures which causes an increase in salinity on those areas.

In Dedoplistskaro Municipality, the average air temperature increased by 0.9^{0}C. The annual total precipitation in the years 1966-1990 and 1991-2015 decreased insignificantly, by 1%. The amount of precipitation increased by 6%. However, these precipitations are mainly in the form of powerful rains and their negative effects firstly occur on pastures in

[38] *http://census.ge/ge/results/agro-census/meurneobebis-ganatsileba-sargeblobashi-arsebuli-mitsis-fartobis-mikhedvit*

mountainous-hilly landscapes, from which the water flows down at great speeds, washing down the plant turf and topsoil. The change in climate over the past fifty years in Dedoplistskaro have caused decreased moisture in plant life, especially in April and July. The average seasonal value of the hydrothermal coefficient has decreased by 15%. Also worth noting, is the significant increase in powerful winds between the years of 1966-1990 and 1991-2015. The above mentioned changes in climate are contributing to the development of erosion processes, which is furthered by cutting down arid sparse forests and excessive grazing, as a result of which lowland pastures are experiencing and expansion of desert and half-desert plant life, xerophitization of pastures, dry bare rocks and salinization on slopes and hills.

The average amount of precipitation on pastures in arid and semi-arid zones (Eldari and Samuxi lowland and south-east part of the Taribana valley) is low at 300mm, the average annual air temperature is 12-140C. In such climate conditions, dry and bedding soils mainly house salsola ericoides (30-40% coverage), which is often intertwined with Artemisia. Grazing of salsola ericoides by sheep is low and does not exceed 30%. It should be noted that, the sheep graze on them only after the first frost, i.e. in December. On dry, salinized and rocky places there is a smaller amount of hawthorn (20-30% coverage), which the sheep graze on more extensively (40-50%).

The largest area on winter pastures is held by Artemisia fragrans and bluestems. These pastures are used all year round (from beginning of Autumn until the end of Summer). meadow steppes (Stipa pontica) take up relatively less area on the winter pastures. Due to their irrational use by humans, they are on the brink of extinction and the bluestems are taking their place bit by bit.

By the year 2100, the average annual air temperature in Dedoplistskaro is forecasted to increase by 3.3^{0}C, as well as a 14% decrease in the amount of annual precipitation. By the year 2050 the annual sum of precipitation in Dedoplistskaro will decrease by 4%. The temperature during active vegetative periods will increase by 50C, and precipitation will decrease by 90mm, contributing to further aridization of the climate.

The increase of temperature in the summer will not greatly affect the winter pastures as the vegetation period is already halted in July-August. However, there might be a transformation in the pastures, specifically in semi-deserts, where the most used grazing plants artemisia vulgaris, meadow grass, bromus, couch grass and others will be substituted by dryKhurkhumi-Chariyan, pasture and pastry pastures. These tendencies can already be seen today.

Real steppes and their components that are already on small areas will be in a dire situation, specifically such plant that are especially good for livestock grazing like feather grass, alfalfa. Pistacia mutica forests will be in danger in terms of expansion. Hay meadows and pastures on denuded-erosive and accumulative landscapes will be close to desertification. The largest artemisia vulgaris grazing areas in eastern Georgia will be under threat, as they start vegetation later (end of April, May) and dry out at 35-40^{0}C. Transitional pastures will also be under threat (500-1000 m from sea level), because they develop best in relatively humid conditions.

The winter pastures and hay meadows in Kazbegi are situated on a 20-30 degree incline. Around 80% of them are in subalpine and alpine zones, at heights of more than 3500 m from sea level. The total area of hay meadows and pastures in Kazbegi municipality are 387 ha, however the number of cattle is 2593, with an additional under 4 thousand sheep and goats. Thus, there is about 7 units of cattle and 10 of sheep and goats per each hectare.

The summer pastures are influenced by the negative effects of soil exhaustion, denudation, erosion, landslides, mudflows. In addition, they are also impacted by a relatively high continentality of climate, lack of snow cover, intensive tourism and most importantly irrational grazing.

In the summer, (end of July, August) there are recordings of hot and dry air coming from the middle east, in the form of foehns. This helps the invasion of dry xerophytic plants and their expansion, mainly on southern slopes. foehns also significantly speeds up the vegetation of plants.
In the upper and subalpine zones (1800-2400 m) of the forest, one can find steppes, dry, mid humid and swampy hay meadows and pastures. The alpine zone (2400-2500-3000 m) is mostly populated by thick turfed and sedge pastures.

Currently, the centuries old tradition of strict practice of substitutive grazing and hay cutting is not upheld. Since the 90s, there has been a significant decrease in the number of sheep, which resulted in a faster regeneration of grass on the pastures, as well as the expansion of forest plants (especially birch) on the fields. However, in addition to this, there has also been an increase in temperature (especially in the summer months) and drought, especially in the years 1998-1999. During the drought, there was a rapid transformation of plant cover, specifically in the subalpine zone, Daphne caucasica dried out, plants on the field started early flowering, but already started withering in the budding phase. The productivity of phytomass decreased significantly (by 2 times).

At the moment, the situation of pastures in Kazbegi is quite dire, the number of sheep is on the rise, the balance between grazing areas and hay meadows has been upset and most importantly, the number of tourists has increased. By last year's observations, the plant live in the direction of Sameba and Gergeti has been greatly degraded, however the grazing of sheep and horses has continued the same. The plain field near Sameba, which is a perfect grazing area is being used for transportation of tourists and parking. The projected increase in temperature and decrease in precipitation will result in the alpine pastures turning into steppes. The primary form of vegetation will be lost, these processes have already begun.

Wild grass nitrogenous-granular and nitrogenous-legume fields are frequent in the ravines, alluvial fans and generally at the bottom of mountains. These constitute the main portion of hay meadows for villages in the surrounding area. 20-30 years ago, these areas were strictly bordered, today however, there is cattle grazing in the majority of them. The consequence of this is that the grass mass on these hay meadows is now 80% less than the norm. the main threat is that instead of high nutritional value vegetation like: violet barley, calamagrostis, fescue meadows, timothy-grass, varieties of clover, alfalfa and others, there is an increase in useless plants such as: varieties of ranunculus, satile, rhinanthus and others.

The projected changes in climate by the end of the century in this region is almost the same as in Dedoplistskaro. Specifically, by the year 2100 an increase in air temperature is to be expected by 3.2 degrees and a decrease in precipitation by 14%, which will result in the xerophitization of plant live in the mountains upper and subalpine zones. Steppe vegetation is expected to take over in these zones, as well as shifting of the forest borders higher by 100-150 m[39]. The vegetation on highland steppes, if left untouched and if there is no erosion, will retain its nutritional value and even expand in area. Current eroded slopes will further degrade. The current ecological state of the meadows does not show positive perspective of improvement or even retention of current state as the climate changes in the future. In the interest of minimizing such impact, measures have to be put in place right now to rehabilitate eroded areas.

The changes in climate are also expected to impact Alpine zone pastures in a positive way. Specifically, in the form of mesophilic (preferring humidity) plants moving up by 100-150 m and being substituted by dry climate loving plants. This type of expansion in terms of pastures will not be negative.

[39] This is in terms of climate zones, but if we take into consideration current erosive processes and landslides, the reverse processes might take place, as it happened in Adjara, where the forest borders reseeded by 300 m due to soil erosion and landslides, which was helped by strong rains.

The pastures and hay meadows in Samegrelo are between the sea level and the alpine zone. The Winter pastures contain parts of Kolkhetian swamps (0-50 m from sea level), some of which are lower than sea level. Summer pastures are located in subalpine and alpine zones. The Kolkheti lowlands contain swampy sedge pastures, in which the dominant species are Baked-fetch sedge, Caucasian Rinhospora and others. The vegetation does not cover the entire territory, the bare parts are filled with water. The subalpine and alpine pastures of Samegrelo are mainly under karst (containing limestone) landscape conditions. The dominant plants there are: geranium, calamagrostis and others.

In Samegrelo, the high mountain pastures and hay meadows are in a difficult state. They are overloaded with cattle and goats, elementary plot-substitutive grazing regimes are not being kept, there is no deliberation on the capacity of the pastures. Overloading the pastures causes erosion, degradation of grass cover. It is imperative to take some of the load away from the pastures and to have a plot substitution system. It is important to use deep karst funnels (pouring cement in the bottom) formed on karst territories for providing water for livestock.

By the year 2100, on the territory of the Zugdidi municipality, an increase in air temperature is to be expected by 3^0, which will cause great erosion and extinction of mesophilic pastures. The Kolkheti lowland swamps will become more swampy, due to the increase of water flow from the melted ice caps. As for precipitation, before the year 2050 it will be on the increase, however by 2100 it will have decreased by 12% in comparison to the 2020-2050 period.

The pastures and hay meadows in Zemo Svaneti are located on harsh and fragmented landscapes. This territory is known for steep slopes and depth of erosion and denudation basis positioning, which in the case of high atmospheric precipitation can have significant impact on vegetation and soil. All of this causes the top layers of the vegetation to be washed down and prevents turf from forming. In the years 1966-1990 and 1991-2015, precipitation in Mestia increased by 9% and this process will continue until the year 2050, however the increase by this time will be about 2%, after which it will start decreasing, but at a comparatively lower rate, it will decrease by 6% until the year 2100 as compared to 2050.

Unlike the high mountainous pastures of Kazbegi, Svaneti has large areas of wild grass hygrophilous and mesophilous non-turf pastures, which are more vulnerable towards grazing. On these lands, the change in temperature will have a significant impact on the composition of plant live.

Unlike other regions, the Svaneti pastures are less overloaded, and so the vegetation is less disrupted. The coefficient of pasture land use here is quite low (40%), because it largely contains nutritiously useless vegetation.

Significant transformation is to be expected for the wild grass (Geranium ibericum, Anemone fasciculata) pastures due to climate change (increase in temperature by 0.3^0C and will increase by a further 1.2^0C by the year 2050, and 3.7^0C by the end of the century). They will be substituted by forest grass vegetation. In terms of granular plants, the most dominant are fields of calamagrostis, wild grass (Renard geranium, hedgenettle and others) and with participation from legumes (clover, vicia). The productivity of these plots varies from 18 to 30 C/ha. The use of this land for grazing is done only by cattle 50-60%. It is more used for hay at 80-90%.

The alpine zone better displays fields of Jimili and Colorful Fescue. The former of which is in high use and the latter no more than 30-40%. Because of this it’s better to use Colorful Fescue for hay, as its use in the form of hay is higher.

The pastures and hay meadows in Adjara hold 15% of its entire territory. They are in almost all of Adjara's soil and climate conditions, but are mainly situated in subalpine and alpine zones. There are significant changes in vegetation on the pastures. Due to overloading, Namikrefia pastures are trampled on, and the slopes are riddled with pathways.

The subalpine fields were traditionally used and are still often used by the inhabitants of nearby villages as summer pastures. In the last period, the increase in population and thus in livestock has greatly overloaded the fields, causing a decline in nutritious vegetation, namely granular and legumes. Subsequently the role of the vegetative cover in soil formation and development process decreases, the soils are already degraded, the turf is gradually collapsing, the structure is lost and powerful water erosive processes are taking place. The sum annual precipitation in the alpine zone of Adjara increased by 13%, the largest increase is during summer. Also, significantly increased are rains that last for 5 days.

The Adjarian pastures are characterized as having rehabilitative capabilities, however, there is already an increase in degraded pastures due to intensive grazing (3-4 units of cattle per ha) and lack of care. A significant part of the pastures are eroded and degraded, in places it is covered by rocks, stones and rough clastic, plots that have lost their soil cover are frequent here, on this territory, the productivity of dry edible mass is no higher than 6-7 centners per ha, whereas the average productivity per hectare on hay meadows is 12-13 centerns.

The current change in climate has already had some impact. As a result of ongoing processes, stronger and more frequent rains have been washing down the soil on the mountain slopes, which in combination with intense land use causes a decline in hay meadow/pasture productivity.

Adjarian high mountainous regions are expected to have an increase in air temperature of 1.4-1.5^{0}C by the year 2050, in the warm part of the year, which should support the increase in productivity of the hay meadows/pastures. The possible 1-8% decline in precipitation, will not have a significant effect on the pastures.

9.3. Assessment of Climate Change Impact on Grasslands (Hay Meadow/Pastures) Productivity and Irrigation Water Demand

The impact on hay meadows and pastures' productivity and irrigation water demand due to climate change was assessed in three Georgian regions (Kakheti, Kazbegi and Zemo Svaneti) using the Aquacrop(FAO) model in cooperation with experts' assessment[40]. Four different periods were simulated for each region using the model: two current 25 year (1966-1990; 1991-2015) and two projected periods of 30 years (2021-2050; 2070-2099).

The climate parameters of the vegetation periods for the modeling as well as the simulated productivity is shown in tables 9.1; 9.2 and 9.3.

Of course, when comparing the simulated results with real statistics, we have to consider that the model does not account for such important factors as

[40] http://www.fao.org/land-water/databases-and-software/aquacrop/en/ IPCC climate change, scenario A1B was used for simulating future climate. The climate parametres (atmospheric precipitation, maximal and minimal air temperature, standard evapotranspiration) were extrapolated from scaling down the global circulatory model (ECHAM4.1) to the region, using regional dynamic climate model (RegCM).

extreme events: increase in pests and diseases due to the rise in temperature and frequency of heat waves, floods, landslides, soil erosion. Most importantly, the model bases its results on the assumption of correct pasture management and comprehensive and timely implementation of agro technical measures. Thus, the model shows the potential results, rather than the real outcome, however in ideal circumstance the two might align.

Using the AquaCrop model for the purposes of assessment of climate change impact on hay meadows and pastures' productivity and irrigation water demand, two varieties of grass were chosen:

1. Alfalfa, as the best method of hay production, because it contains nutritional substances and large amounts of protein. Alfalfa can be use as green food, as well as hay. According to feeding guidelines, it is an important food source for cattle.

2. Grass of general good quality, to simulate the general types of pastures.

In the tables 9.1, 9.2 and 9.3 we can see the productivity of Alfalfa in all three regions, when the increased effects of CO_2 taken into account[41]. Aside from this, in relation to the significant degradation of pastures in Georgia, soil stress in various amounts was applied to different regions, in accordance to the amount of degradation in the given region (44% in Dedoplistskaro, 23% in Mestia and Kazbegi).

Alfalfa was used for the modeling of hay productivity, as the most beneficial and nutritious food source for livestock. The results of the modeling and the input data can be seen in tables 9.1, 9.2 and 9.3.

[41] *The increased concentration of CO2 will have a positive effect on the productivity of hay meadows and pastures, and the negative effects of the climate parameters (precipitation, evapotranspiration) will be compensated by conditions supporting of growth and development, e.g. a better water balance. This effect is however dependent on soil conditions and regional specifics.*

Table 9.1. Values (in dry material) of climate characteristics and productivity for the alfalfa vegetative period and changes through the years of 1966-1990 (1) and 1991-2015 (2), 2021-2050 (3) and 1991-2015 (2), 2070-2099 (4) and 1991-2015 (2) (Mestia)

Period / Parameter	Precipitation, mm	Evapotranspiration, mm	Sum of active temperatures C*day	CO_2, ppm	Soil fertility on optimal level			Low stress of soil fertility (23%)		
					produtivity t/ha (unirrigated)	productivity t/ha (irrigated) (RAW50)	productivity , t/ha (irrigated) (RAW70)	productivity , t/ha (unirrigated)	productivity , t/ha (irrigated) (RAW50)	productivity d, t/ha (irrigated) (RAW70
1966-1990(1)	313	354	1190	336	3.8	4.0	4.0	3.2	3.3	3.3
1991-2015(2)	312	362	1257	376	4.1	4.4	4.4	3.5	3.7	3.7
2021-2050 (3)	342	351	1352	442	4.6	5.0	4.9	3.9	4.1	4.1
2070_2099(4)	344	439	1570	540	4.5	5.5	5.4	3.9	4.6	4.5
Absolute change_21[42]	0	8	66	40	0.4	0.4	0.4	0.3	0.4	0.4
Absolute change _32	30	-10	96	65	0.5	0.6	0.5	0.4	0.5	0.4
Absolute change _42	31	77	313	163	0.4	1.1	1.0	0.4	0.9	0.9
Relative change_21	-0.1%	2%	6%	12%	10%	11%	11%	10%	11%	11%
Relative change _32	9%	-3%	8%	17%	11%	13%	12%	11%	12%	12%
Relative change _42	10%	21%	25%	43%	9%	24%	24%	11%	24%	23%

Table 9.2. Values (in dry material) of climate characteristics and yields for the alfalfa vegetative period and changes through the years of 1966-1990 (1) and 1991-2015 (2), 2021-2050 (3) and 1991-2015 (2), 2070-2099 (4) and 1991-2015 (2) (Stepantsminda)

Period / Parameter	Precipitation, mm	Evapotranspiration, mm	Sum of active temperatures C*day	CO_2, ppm	Soil fertility on optimal level			Low stress of soil fertility (23%)		
					productivity , t/ha (unirrigated)	productivity t/ha (irrigated) (RAW50)	productivity , t/ha (irrigated) (RAW70)	productivity , t/ha (unirrigated)	productivity , t/ha (irrigated) (RAW50)	productivity , t/ha (irrigated) (RAW70)
1966-1990(1)	416	406	1494	336	3.6	4.4	4.4	3.2	3.9	3.8
1991-2015(2)	355	431	1586	376	3.1	4.9	4.8	2.8	4.3	4.3
2021-2050 (3)	430	468	1700	442	3.4	5.5	5.4	3.0	4.8	4.8
2070_2099(4)	403	562	1992	540	1.9	6.0	5.9	1.7	5.3	5.2
Absolute change_21	-62	24	92	40	-0.5	0.5	0.5	-0.4	0.4	0.4
Absolute change _32	75	37	114	65	0.3	0.6	0.6	0.3	0.5	0.5
Absolute change _42	48	132	406	163	-1.2	1.1	1.1	-1.0	1.0	0.9
Relative change_21	-15%	6%	6%	12%	-14%	11%	10%	-13%	11%	11%
Relative change _32	21%	9%	7%	17%	10%	13%	12%	10%	13%	12%
Relative change _42	14%	31%	26%	43%	-39%	24%	22%	-37%	24%	22%

[42] *Denotes change between first and the second periods. Respectively for other periods as well.*

Table 9.3 Values (in dry material) of climate characteristics and productivity for the alfalfa vegetative period and changes through the years of 1966-1990 (1) and 1991-2015 (2), 2021-2050 (3) and 1991-2015 (2), 2070-2099 (4) and 1991-2015 (2) (Dedoplistskaro)

Period / Parameter	Precipitation, mm	Evapotranspiration, mm	Sum of active temperatures C*day	CO_2, ppm	Soil fertility on optimal level			Low stress of soil fertility (23%)		
					productivity, t/ha (unirrigated)	productivity, t/ha (irrigated) (RAW50)	productivity, t/ha (irrigated) (RAW70)	productivity, t/ha (unirrigated)	productivity, t/ha (irrigated) (RAW50)	productivity, t/ha (irrigated) (RAW70)
1966-1990(I)	259	311	1316	336	2.4	3.6	3.6	1.5	2.3	2.3
1991-2015(II)	245	315	1373	376	2.6	4.0	4.0	1.6	2.5	2.5
2021-2050 (III)	225	231	1492	442	3.5	4.5	4.5	2.1	2.8	2.8
2070_2099(IV)	155	197	1703	540	3.6	4.9	5.0	2.2	3.1	3.1
Absolute change_21	-14	4	57	40	0.2	0.4	0.4	0.1	0.2	0.2
Absolute change _32	-21	-84	119	65	0.9	0.5	0.5	0.5	0.3	0.3
Absolute change _42	-90	-118	330	163	1.0	1.0	1.0	0.6	0.6	0.6
Relative change_21	-5%	1%	4%	12%	9%	11%	11%	9%	11%	11%
Relative change _32	-8%	-27%	9%	17%	34%	13%	13%	29%	13%	13%
Relative change _42	-37%	-37%	24%	43%	36%	24%	24%	35%	24%	24%

From the tables 9.1-9.3, we can extrapolate that in both soil conditions, in unirrigated cases, in all three regions, Alfalfa has the highest productivity potential in Mestia currently (3.8 t/ha) as well as in the future (5.5 t/ha). The lowest potential is shown in Dedoplistskaro (2.4 t/ha currently and 3.6 t/ha by the end of the century). As for Stepantsminda, it is somewhere in the middle in terms of productivity potential, but it shows a declining trend, from 3.6 t/ha currently to 1.9 t/ha by the end of the century. Of course, all of this is assuming that all parameters aside from the ones input into the model stay the same. The data on productivity of pastures by regions is not available, but the average productivity of hay country wide is 2.4 t/ha, which is based on the current state of hay meadows (not fenced, with livestock grazing on them).

As for the demand on irrigation, table 9.4 shows the water demand for Alfalfa in the three regions in two possible scenarios of readily available water (RAW[43]).

[43] *Two scenarios of readily available water (RAW) in the root distribution zone, when the acceptable degree of drying out in the root zone is 50 and 30% (RAW50, RAW30).*

Table 9.4. Values (mm) of alfalfa irrigation water demand and changes through the years of 1966-1990 (1) and 1991-2015 (2), 2021-2050 (3) and 1991-2015 (2), 2070-2099 (4) and 1991-2015 (2) (on optimal level of soil fertility)

Period/Change	Samegrelo-Zemo Svaneti (Mestia)		Mtskheta-Mtianeti (Stepantsminda)		Kakheti (Dedoplistskaro)	
	RAW50	RAW70	RAW50	RAW70	RAW50	RAW30
1966-1990(1)	53	35	59	50	134	152
1991-2015(2)	65	47	105	93	134	153
2021-2050 (3)	46	32	82	73	76	94
2070_2099(4)	83	63	146	136	93	113
Absolute change_21	11	12	45	43	0	0
Absolute change _32	-19	-16	-22	-20	-58	-59
Absolute change _42	18	15	41	42	-41	-40
Relative change_21	21%	36%	77%	87%	-0.1%	0.3%
Relative change _32	-29%	-33%	-21%	-22%	-43%	-38%
Relative change _42	28%	32%	39%	45%	-30%	-26%

For calculating the general productivity for pastures, the model was fed information on grass of general good quality. The results and input data can be seen in tables 9.5, 9.6 and 9.7.

Table 9.5. Values (in dry material) of climate characteristics and productivity for the vegetative period of natural pasture grass and changes through the years of 1966-1990 (1) and 1991-2015 (2), 2021-2050 (3) and 1991-2015 (2), 2070-2099 (4) and 1991-2015 (2) (Mestia)

Period/Parameter	Precipitation, mm	Evapotranspiration, mm	Sum of active temperatures C*day	CO_2, ppm	Soil fertility on optimal level			Low stress of soil fertility (23%)		
					productivity , t/ha (unirrigated)	productivity , t/ha (irrigated) (RAW50)	productivity , t/ha (irrigated) (RAW70)	productivity , t/ha (unirrigated)	productivity , t/ha (irrigated) (RAW50)	productivity , t/ha (irrigated) (RAW70)
1966-1990(1)	375	430	806	336	4.2	4.6	4.6	3.4	3.7	3.7
1991-2015(2)	380	439	882	376	4.8	5.5	5.5	3.9	4.4	4.4
2021-2050 (3)	410	419	985	441	6.0	6.9	6.9	4.9	5.5	5.5
2070_2099(4)	407	513	1238	539	7.1	8.6	8.6	5.8	6.9	6.9
Absolute change_21	5	8	76	40	0.6	0.9	0.9	0.5	0.7	0.7
Absolute change _32	30	-19	103	65	1.2	1.4	1.4	1.0	1.1	1.1
Absolute change _42	27	74	355	163	2.4	3.1	3.1	2.0	2.5	2.5
Relative change_21	1%	2%	9%	12%	14%	19%	19%	15%	19%	19%
Relative change _32	8%	-4%	12%	17%	25%	25%	25%	26%	26%	25%
Relative change _42	7%	17%	40%	43%	50%	56%	56%	51%	57%	57%

Table 9.6. Values (in dry material) of climate characteristics and productivity for the vegetative period of natural pasture grass and changes through the years of 1966-1990 (1) and 1991-2015 (2), 2021-2050 (3) and 1991-2015 (2), 2070-2099 (4) and 1991-2015 (2) (Stepantsminda)

Period/Parameter	Precipitation, mm	Evapotranspiration, mm	Sum of active temperatures C*day	CO_2, ppm	Soil fertility on optimal level			Low stress of soil fertility (23%)		
					productivity , t/ha (unirrigated)	productivity , t/ha (irrigated) (RAW50)	productivity , t/ha (irrigated) (RAW70)	productivity , t/ha (unirrigated)	productivity , t/ha (irrigated) (RAW50)	productivity , t/ha (irrigated) (RAW70)
1966-1990(1)	397	380	592	336	3.1	3.3	3.3	2.4	2.6	2.6
1991-2015(2)	356	396	651	376	3.8	4.2	4.2	3.0	3.3	3.3
2021-2050 (3)	414	439	766	441	5.1	5.9	5.9	4.1	4.7	4.7
2070_2099(4)	396	533	990	539	5.3	7.8	7.8	4.2	6.2	6.2
Absolute change_21	-41	15	59	40	0.7	0.9	0.9	0.6	0.7	0.7
Absolute change _32	57	43	115	65	1.2	1.6	1.6	1.1	1.4	1.4
Absolute change _42	39	137	339	163	1.5	3.5	3.5	1.2	2.9	2.9
Relative change_21	-10%	4%	10%	12%	22%	28%	28%	24%	29%	29%
Relative change _32	16%	11%	18%	17%	33%	38%	38%	36%	41%	41%
Relative change _42	11%	35%	52%	43%	40%	83%	83%	40%	88%	88%

Table 9.7. Values (in dry material) of climate characteristics and yields for the vegetative period of natural pasture grass and changes through the years of 1966-1990 (1) and 1991-2015 (2), 2021-2050 (3) and 1991-2015 (2), 2070-2099 (4) and 1991-2015 (2) (Dedoplistskaro)

Period/Parameter	Precipitation, mm	Evapotranspiration, mm	Sum of active temperatures C*day	CO_2, ppm	Soil fertility on optimal level			Low stress of soil fertility (23%)		
					productivity , t/ha (unirrigated)	productivity , t/ha (irrigated) (RAW50)	productivity , t/ha (irrigated) (RAW70)	productivity , t/ha (unirrigated)	productivity , t/ha (irrigated) (RAW50)	productivity , t/ha (irrigated) (RAW70)
1966-1990(I)	315	448	1311	336	2.5	4.6	4.6	1.6	2.8	2.8
1991-2015(II)	293	453	1394	376	2.6	5.1	5.1	1.8	3.1	3.1
2021-2050 (III)	279	321	1525	441	4.6	6.1	6.1	2.9	3.7	3.7
2070_2099(IV)	212	280	1773	539	4.5	6.9	6.9	3.0	4.2	4.2
Absolute change_21	-21	5	83	40	0.1	0.5	0.5	0.1	0.3	0.3
Absolute change _32	-15	-132	131	65	2.1	0.9	0.9	1.1	0.6	0.6
Absolute change _42	-82	-173	379	163	1.9	1.7	1.7	1.2	1.1	1.1
Relative change_21	-7%	1%	6%	12%	2%	10%	10%	8%	10%	10%
Relative change _32	-5%	-29%	9%	17%	80%	18%	18%	63%	19%	19%
Relative change _42	-28%	-38%	27%	43%	74%	34%	34%	71%	34%	34%

From the tables 9.5-9.7, we can extrapolate that in both soil conditions, in unirrigated cases, in all three regions, the pastures have highest productivity potential in Mestia currently (4.8 t/ha) as well as in the future (7.1 t/ha). The lowest potential is shown in Dedoplistskaro (2.6 t/ha currently and 4.5 t/ha by the end of the century), which will experience slight further decrease after the year 2050. As for Stepantsminda, it is somewhere in the middle in terms of productivity potential. The data on productivity of pastures by regions is not available, but the average productivity of hay countrywide is 2.4 t/ha, which is based on the current state of hay meadows (overgrazing, improper management, soil erosion, etc.), however the expert's findings show that in mountainous pastures (Zemo Svaneti and Stepantsminda) the productivity of natural grass is 2.5-3.0 t/ha.

As for the demand on irrigation, table 9.8 shows the water demand for pastures in the three regions in two possible scenarios of readily available water (RAW[44]).

Table 9.8. Values (mm) of pastures' irrigation water demand and changes through the years of 1966-1990 (1) and 1991-2015 (2), 2021-2050 (3) and 1991-2015 (2), 2070-2099 (4) and 1991-2015 (2) (on optimal level of soil fertility)

Period/Change	Samegrelo-Zemo Svaneti (Mestia)		Mtskheta-Mtianeti (Stepantsminda)		Kakheti (Dedoplistskaro)	
	RAW50	RAW70	RAW50	RAW70	RAW50	RAW30
1966-1990(1)	83	68	45	32	206	221
1991-2015(2)	94	80	66	53	216	232
2021-2050 (3)	74	60	74	64	104	121
2070_2099(4)	114	96	153	137	115	131
Absolute change_21	11	12	21	21	10	11
Absolute change _32	-20	-19	9	12	-113	-111
Absolute change _42	20	16	87	84	-102	-100
Relative change_21	13%	17%	47%	65%	5%	5%
Relative change _32	-21%	-24%	13%	22%	-52%	-48%
Relative change _42	21%	20%	133%	160%	-47%	-43%

The analysis of the modeled results showed that:

- According to the chosen climate change scenario (A1B), in unirrigated conditions, the potential productivity of natural hay meadows and pastures is expected to increase over the entire projected period in all of the selected regions. The exception is the expected decline of productivity of alfalfa (-40%) in Mtskheta-Mtianeti by the end of the century. Maximal growth of alfalfa and natural pasture grass is to be expected in Kakheti (35-40%) and (75-80%), relatively. The changes are least significant in Zemo Svaneti and in case of alfalfa it is within 10%, the increase in the productivity of the pastures however is projected to be 50% in comparison to the current situation.

[44] *Two scenarios of readily available water (RAW) in the root distribution zone, when the acceptable degree of drying out in the root zone is 50 and 30% (RAW50, RAW30).*

- In case of irrigation, the productivity increases everywhere, in some cases however it will have a more significant impact, namely on alfalfa in Mtskheta-Mtianeti during the projected period and on natural pastures in Kakheti during the current period. In properly irrigated conditions it is possible to achieve a productivity of 7-9 t/ha for natural pastures and 5-6 t/ha for alfalfa in case of soil fertility stress relieve. For degraded land with irrigation the productivity of the pastures would be 4-7 t/ha and 3-5 t/ha for alfalfa.

- In Kazbegi according to the prognosis, the productivity of alfalfa and natural pastures will be relatively unstable, however Kakheti has the most optimistic prognosis, which intails the largest productivity in alfalfa and natural pastures compared to the current period. In Zemo Svaneti the projected outcome is most stable, in the proposed period the growth in productivity is most stable even without irrigation.

- In case of alfalfa, which belongs to the number of cultures that are sensitive towards the level of water in the soil, the effect of precipitation in relation to irrigation demand, in the current period is significant in the Kazbegi municipality. In the projected period, especially by the end of the century, the impact of change in precipitation in all three regions is overshadowed by decreasing trends in evapotranspiration. The same dependence on climate change was found in the case of natural pastures as well.

- The demand for irrigation for alfalfa and natural pasture grass in high mountainous Svaneti and Mtskheta-Mtianeti will by the middle of the century decrease on average by 20-30%. The exception in this period is the increase in water deficit in Kazbegi (10-30%). By the end of the century this deficit intensifies in both regions and for the natural pasture vegetation will reach 130-160% on non-degraded areas and 150-190% in degraded areas.

- The prognosis for hay meadows and pastures was the most optimistic in Kakheti, where 20-50% less water will be needed to achieve maximum productivity for alfalfa and other natural pasture vegetation, i.e. less water is expected to be needed for winter pastures.

- The comparison of simulated results to real world statistics (according to the unofficial statistics provided by available sources) showed that loss of productivity in hay meadows and pastures should not be solely based on climate change and should possibly take into account improper land use and inconsistent management, e.g. lack of fertilizer, mowing at improper time periods, unsystematic grazing and others.

9.4. Recommendations for Adaptation Measures in Pasture Management

Kakheti winter pastures

- The load of the pastures must be maximally decreased. The number of sheep grazing on absolute winter pastures must decrease from 2.5 to 2-1.5 per 1 Ha, on Autumn pastures no more than 4 sheep may be permitted to graze per 1 Ha. At least partial transition to feeding cribs must be supported.

- Irrigation of pastures, which have suitable soil conditions (where irrigation wouldn’t cause salt to surface from the ground, Botriochloeto-Artemisietum and Andropogon). Transfer of hay meadows and pastures to users.

- Reinstating plot substitution, so that grazing on the same plot every year is prohibited. One plot should be chosen in the winter pastures to be used only in extenuating circumstances, in times of very bad weather, as reserve stock for lambs and female sheep.

- Naturalization-strengthening of eroded areas (in Dedoplistskaro: Pantishara, Kotsakhuri Ridge, Parasi), because of this, drought-resistant timber plants like: Juniper, saree, sugarcane, as well as xerophyte grasses.

- Creation of artificial hay meadows by way of over-plowing the land, sowing should preferably be done in October, but only in case of precipitation. The plants chosen to create artificial pastures should be plants like esparcet, capueta, ryegrass and others that prefer dryer conditions

- Restoration of windbreaks.

Kazbegi Pastures

- Artificial pastures and hay meadows must be created on areas that have been transformed plains or slopes with small inclines (<10 degrees) in the form of sowing mixed wild grasses. 3-4 varieties of wild grasses may be planted on hay meadows. For this purpose, wild grains like violet barley, meadow fescue, meadow timothy, digitalis; from legumes: Caucasian alfalfa, yellow alfalfa, esparcet, clover; wild grass wild grasses: bistort, carum, milfoil can be used. All of these plants are local. For long term use pastures, multivariate (5-6 species) grass are recommended, such as: A mottled oatmeal, alpine timothy, quaking grass, koeleria, from legumes: clovers, vetches, lotus, wild grasses: Caucasian caraway, sheep's caraway, plantains.

- Prohibiting grazing on eroded slopes and putting regenerative measures into place.

- 10 plot substitutive system has to be put in place, in order to lengthen the frequency of grazing on each plot and give sufficient time for regeneration of vegetation to occur. In less degraded plots, 4-5 can be used with the same system. In each case, the plots need to be rested, i.e. stopping grazing for at least a year.

- Use of highly degraded pastures must be temporarily stopped. Not doing so will cause desertification of the pastures, the constitution of grass varieties will completely change – development-dominance of useless nutritional grass. Feeding crib (feeding the hay in the cattle-shed) use is necessary.

- Use of pastures in the Spring is unacceptable.

- Hay cutting must be done at optimal periods: during ripening of grain seeds, during the fruit bearing period of legumes and wild grasses. Cutting must start in second half of July (instead of second half of August).

- It is necessary to plant wild, sometimes cultivated nutritious grass

- Adding fertilizer is one of the effective means for improving the hay meadows and pastures

Samegrelo-Zemo Svaneti pastures

- It is necessary to use hay racks, which entail increasing hay reserves and maximal use of hay meadows. Irrigation was widely used on these lands in months of drought (end of July, August). The irrigation canals are still apparent today. Hay meadows must be expanded, irrigation must be introduced to comparatively dryer valleys.

- Hay meadows that are low in productivity, which are difficult to take care of as well as to harvest must be used as pastures.

- Artificial hay meadows must be built.

Adjara pastures

- Main attention must be paid to optimal loading of pastures, keeping to grazing deadlines, resting degraded pastures for some time, sowing soil protective and water catching plants. Separate plots must be used to grow potatoes and single year cultures of vegetables, in order to have vitamin rich plants. These measures are no doubt perspective and will support soil protection and improvement of production in mountain-field soils.

- In the interest of mountain-field soil protection and improvement, wild medicinal plants must be planted on open sub-alpine fields, especially of those plants that are low in number

9.5. Cost-Benefit Analysis of Adaptation Measures in Pasture Management

Two measures were chosen in the sector of pastures. Both measures are connected to pasture rehabilitation, however, one of them is a government programme[45] and coveres 29 municipalities, and the second one is aimed at the region with toughest climate conditions, Dedoplistskaro, where largest pasture areas are located and have a high coefficient of overgrazing. The first measure – a government program that will form a cooperative between 29 municipalities with co-financing and renting out hay meadows and pastures. The budget of the program is 6 million GEL and cooperatives that are interested in taking part must fulfill certain requirements of livestock numbers and size of the cooperative. The cost-benefit analysis covers the standard 11 year period 2018-2028.

Main categories of benefits of this measure are: improved hay productivity and improved milking productivity, the main costs are: Government program budget, producing hay bales, taking care of pastures and hay meadows and the cost of additional milking cows. Over 11 years, 69.5 million GEL have been spent, the profits however at an average discount rate is 120,000 GEL, which in high discount (9.98%) conditions generate loss, which by the end of the period amounts to 167,000 GEL

[45] *http://acda.gov.ge/index.php/geo/news/show/61/202*

According to the second scenario, climate change will cause a decline in pasture and hay meadow productivity by 5% each year after 2021 (possibility). In this case, productiveness is lower at 1.25 t/ha (as opposed to 1.4 t/ha in the main scenario). The benefits in this scenario are higher than in the main scenario, however at the high discount rate, this scenario would also productivity loss.

In case of the second measure, which concerns the rehabilitation of pastures in Dedoplistskaro and entails improvement of surface covers – clearing it of stones, weeds, cut down Kolbokhi and enriching the soil with mineral fertilizers, the cost over the entire period is 450 million GEL. Minimal loss in this case is 170 million. The main benefits of this measure are: higher productivity of hay, improved milking productivity and the saved cost of carbon; the costs are: producing hay bales, rehabilitation of hay meadows and pastures and their subsequent care. The discussed measure demands large costs and is economically unprofitable.
According to scenario two, climate change will cause a decrease in the productivity of hay meadows and pastures by 5% (possibility) every year starting from 2021 and the loss here is larger than in scenario two.

9.6. Social Impact of Recommended Measures and Role in Implementation Agriculture Development Strategy of Georgia

Both of these measures have a very large social and environmental effect. Especially, environmental effect.

The social benefit at this stage would be quite high, because a certain part of the pastures is on the balance of the Ministry of Economics and Sustainable Development and is in public use. The program also discusses the possibility of supporting dairy processing enterprises, which is not discussed here, however when discussing hot water supply, in the cases where solar energy is used, we will have to deal with decreasing greenhouse gas emissions, as milk production needs large amounts of hot water.

The rehabilitation of pastures will have a special social effect in the Dedoplistskaro municipality, because these pastures are used not only by local population and farms, they are also used as winter pastures for livestock from other municipalities.

The first measure directly answers agricultural strategic question of supporting cooperation development in agriculture, but both measures have a component concerning rational soil use.

At this stage, the Ministry of Agriculture (LEPL Agricultural Cooperatives Development Agency) as well as livestock farms are involved in the implementation process of the state program. Engagement and responsibility of the local municipality is crucial in the process of rehabilitating Dedoplistskharo rangelands, as well as the role of the Ministry of Economy and Sustainable Development in defining the types of ownership of rangelands, the role of the Ministry of Agriculture in offering farmers development programs and the role of the Ministry of Environment and Natural Resources Protection to safeguard the sustainability of the rangelands considered as the parts of biodiversity.

10. Impact of Climate Change on Livestock Farming and Adaptation Measures

10.1. Overview of Development State of Livestock Farming

Georgia is distinguished with diversity of its local breeds of domestic animals and birds. From the local breeds of animals can be noted the following ones: the Tush and the Megrelian horse; the Georgian mountain cow (Khevsurian, Pshavian and Ossetic kinds), the Megrelian Red, the Caucasian chestnut horse, Georgian buffalo; the Tush and Imeretian sheep, the Megrelian goat, the Kakhetian and the Svan pig; the black, the straw-colored gray hen, the Megrelian and the bare-necked hen, the straw-colored turkey, the Javakhetian goose, the Georgian sheep-dog and others.

In the eighties of the last century the livestock population in Georgia greatly increased reaching its peak, but after the nineties it started declining sharply. By 2010 the number of cattle was decreased by 36.6% compared to 1984, among them the milch-cow by 14.6%; sheep and goat by 66.6%.

Table 10.1 Number of agricultural animals in Georgia (thousand heads, poultry)

Animal	1984	2010	Compared to 1984 (%)	2016	Compared to 2010 (%)
Cattle	1652,6	1049,4	–36,5	878,4	–6,14
Milch-cow	657,9	561,7	–14,6		
pig	1133,4	110,1	–90,3	115,4	+4,6
Sheep and goat	1955,7	653,9	–66,6	821,5	+20,4
poultry	24000	6521,5	–72,8		

Table 10.2 Production of livestock products in Georgia (thousand ton)

Animal	1984	2010	Decreased (%)	2016
Milk	663,0 Million L	587,7 Million L	–11,4	540,1 Million L
Meat	157,6 Thousand Ton	56,4 Thousand Ton	–64,2	66,1 Thousand Ton
Wool	6,1 Thousand Ton	1,7 Thousand Ton	–72,1	2 Thousand Ton

According to statistical data the productivity of livestock in Georgia is low. Low milking is caused by very many interconnected reasons:
- Feeding base is disordered, in households the proper attention is not paid to a number of livestock population, composition and quality of food;
- The qualification of breeding farming is low;
- Insufficient supply of calves and heifers with food;
- Barrenness of milch-cows;
- Non-observance of milking hygiene.

10.2. Impact of Ongoing and Forecasted Climate Change on Livestock Farming Sector

The change of climate might impact on animals in many different ways:
- Its direct impact on the organism;
- Its impact on animals' nutrients, which are contained in their food and water;
- Its impact on the growth-development of animals' nourishment plants, their productivity (number);
- Its impact on the chemical composition of nourishment plants, on accumulation of toxic substances in them.
- On the disease causing (insects, rodents) population;
- On preservation of disease causing population in surroundings (air, soil, water).
- The climate change can awake such disease causing insects or rodents, which are forgotten for a long time or activate those, which are spread at present.
- Extremely warm winter can support spreading of exotic diseases transmitters (insects) from hot countries of south to north.
- Warm weather in winter might support spreading of number of diseases from valleys to mountains and etc.

These factors can impact individually or in a certain combination.

High-productive cultural breed of animals are more sensitive to climate and weather changes, than low-productive local indigenous species.

Unfavorable and long climate change has a considerable impact on permanent nonspecific factors of resistance of the organism, such as:

- the protective ability of skin and mucous membranes;
- the protective ability of normal microflora;
- phagocytosis and barrier function of a lymphatic system;
- humoral factors (lysozyme, complement, normal antibodies and others);
- Physiological factors (temperature, changing processes, and metabolism).

The skin must be clean with proper wetness, the protection of which is impossible under the impact of thermal waves. The skin wholeness must not be disturbed. Lysozyme, the mucous membrane ferment, which is characterized with bacteriocidal action, is active in a weak alkali reaction area. At low temperature its action is getting weak. Its action is also weakening or terminated at the temperature over 40^0C. In unfavorable climatic conditions the microflora action of the digestive system is diminishing.

The basic factor after nourishment, which has a great impact on animal's health and productivity, is the ambient temperature. The low temperature – coldness favors the decrease of leukocytes in blood and phagocytic activity and humid air and high temperature hinder giving heat from the organism that causes overheating. Humid and high temperature is a favorable environment for reproduction of microbes. Keeping animals densely in hot dirty dwelling places without ventilation is causing accumulation of harmful gases, at the same time the air humidity is increasing that is favorable for reproduction of microbes and propagation of respiratory infections.

When climate is unfavorable and animals are kept in unsanitary conditions, protective forces of the organism are slackening and at the same time microbes are gathered in big quantities, which afterwards become a reason of propagation of different diseases. Products (in the first place - milk) produced in such conditions are bacteriologically much polluted and become harmful for humans.

Cold weather favors colds and freezing of animals. Cloudy weather (in winter and spring) is sharply lessening the active action of ultraviolet rays of the sun upon the animal's organism.

By the impact of climatic factors, the growth-development of nourishing plants might be activated or slackened, the biochemical processes in them might be changed and toxic substances can be accumulated, the quality of food and water might be increased or lowered, reproductive activity of animals might be slowed or intensified, reproduction and propagation of agents of infectious and invasive diseases might be suppressed or on the contrary intensified. By the impact of climate factors grass growing on the dry soil fail to absorb a certain part of mineral substrates and consequently there will be the deficiency of these substrates in the animal's organism.

The gradual change of weather does not affect negatively on the animal because the animal's organism is adapting gradually, animals become hardier. Their skin thermoregulation, the tonus of muscles and humoral apparatus, metabolism and the organism function are activated.

The impact of climatic factors on a high-water level of rivers should also be taken into consideration, when rivers often change riverbeds grasping thousand hectares of soil every year, including even territories of populated areas. In such a case old burial grounds of anthrax might be washed off and stripped off, as it happened in Mtskheta-Mtianeti, where several cases of anthrax in animals and people were fixed. It was stated that the focus of infection was the soil washed off by the heavy rains in that year. As it was found out years ago on that territory there were cases of the death of animals from anthrax.

In Adzharia as a result of warming frequent and abundant atmospheric precipitations are causing washing off the soil on the mountain slopes and in conditions of intensive exploitation of the grass cover the productivity of grasslands is decreased very sharply, for example, if in 1990 on 1 ha grassland there was 20-25 centner hay, at present it is in the range of 10-12 centner, and on pastures even less 7 centner/ha.

The increase of the ambient temperature often reveals a lot of hard problems, among which is animal watering.

As a result of observations on cattle watering in hot days of summer in Kakheti and Kvemo Kartli it was found that with the growth of temperature (30–38^{0}C) a supply of animals with water in June- September decreases every day. In ponds originated from rainwater (which is often a single source of watering) water is gradually decreasing or is generally dried out. In the remained ponds, which are mostly very far from pastures, the water is warm, muddy (because of animals standing there), besides it is polluted with fecal and urine. Animals do not like polluted water, but as their main nourishing grass is gradually dried out and withered because of drought, the animals are compelled to drink the polluted water remained in the ponds, as they become very thirsty after grazing.

The dwelling places of animals on such a territory were not fully provided with water and the animals were kept in very low veterinary-sanitary conditions. The milk produced in such conditions was much polluted mechanically and bacterially.

As a result of high temperature there is very frequently water deficiency; because of this cattle don't gain the necessary amount of water, the water is hot, polluted and does not quench their thirst. In the animal's organism lots of pathological processes take place, such as indigestion (in the first place atonia of anterior gastric branches) and infectious and invasive diseases. At the same time the amount and quality of products (milk, meat) are falling down very fast.

In recent years the duration of high temperature in summer has been fixed in Samegrelo that causes constant droughts and decrease of nourishing grass on pastures. In such conditions feeding of cattle is very hard and decline of productivity is observed very early. In the region cattle diseases with blood parasites are increasing. Piroplasmosis in cattle was observed frequently in early spring (which had not been observed before). It is caused by early activation of disease transmitter ticks in conditions of high temperature. The early manifestation of piroplasmosis started in mountainous regions and villages of Samegrelo.

10.3. Recommendations on Adaptation Measures in Livestock-farming Sector

The primary precondition of re-establishment and development of livestock farming is improvement of natural agricultural lands and rising of yielding.

The correspondence of opportunities of high quality products production with the cattle population will enable farmers to produce by 30-40% more livestock products using the same amount of nutrients.
In cow farming for improving breeding first of all positive properties of local breeds should be maximally shown and developed, than a method of artificial insemination and a sperm of the cultural breeds (the Valley Red, the Swedish, the Jersey) zoned by districts, should be used.

In order to grow high-productive and healthy milch cows it is recommended to separate young cows from the herd.

For improving a general physiological condition of cattle and especially for maximal manifestation of a female animal in season it is very important to take it out, especially in winter. A certain part of tied up animals in winter is left unmanifested, the cycle is lost and the duration of a service period is artificially increased.

On further increasing the sheep population there should be taken into consideration the number and quality of winter and summer pastures. Along with sheep-breeding a great attention must be paid to the development of a Georgian traditional field – goat-breeding, especially in Samegrelo, preferably breeding of milch goats, such as the Megrelian breed of milch goat and Zaanenuri.

10.4. Cost -Benefit Analysis of Livestock Farming Adaptation Measures

For the livestock farming sector at this stage there was only one measure, concerning watering of cattle on pastures in the period of droughts. With increasing the droughty days the request for drinking water is also increased and it is necessary to supply the animals on the pasture with drinking water, so that the water deficiency will not have a negative influence on milking.
This measure means provision of watering of animals by means of tanks in an organized manner on considering Sagarejo, Dedoplistskaro, Signagi and Gurjaani pastures. There were discussed two scenarios: considering the existing droughts and increased droughts in the future.
The analysis comprises standard 11 years (2018-2028). The admissions for estimation of the measure and other details are represented in Attachment 1.10. The profit discussed in this measure is avoidance of milk loss, which is favored by this measure, but expenditure involves the price of water tanks and their transportation expenses. The expenditure during the whole process is 15 million GEL, but today's value at the end of 11 years is 12.6 million GEL at 7.37% discount and even at a less discount.   So, this measure is not economically profitable and it should be replaced by an alternative one requiring less expenditure.

If the number of droughty days increased from 112 (the existed) to 115 because of the climate change, this measure will be more unprofitable, as the necessary quantity of tanks will be more than in the previous case.

So in case of both scenario the expenditure in this measure will exceed its profit and this approach is economically unprofitable, though this measure has a high social effect, as these pastures are common, which is mostly used by animals of small farmers and village population for grazing.

10.5. Social Impact of Recommended Measures and Role in implementation of Agriculture Development Strategy of Georgia

In the agriculture development strategy this trend is not emphasized in priorities, but an optimal decision will be necessary to be found on the background of increase of droughts frequency and duration. The measure will contribute in the development process of climate-reasonable agriculture.

It must be noted that this measure has a high social effect, because here is meant common pastures used mostly by animals of small farmers and village population for grazing. The measure is meant for watering of 34 000 milk cows, milking of which will be increased by 30% per day.

The profit in this measure was only estimated considering decline of milk loss. In the first place it will be necessary to estimate this measure considering the weight of cow, as a source of income.

Until the type of ownership of rangelands is not fully determined, this measure should be undertaken with the guidance of the Ministry of Agriculture and local municipalities, within the frames of personal as well as national programs.

Conclusions and Recommendations for the Next Steps 11.

In the process of preparing the national plan of adaptation to climate changes for the agricultural sector there were discussed the following previously chosen trends:

- Producing of citrus (tangerine) in Adzharia
- Producing of hazelnut in municipality of Zugdidi
- Producing of wheat in Kakheti (Dedoplistskaro, Signagi)
- Producing of maize in municipality of Zugdidi (Samegrelo)
- Producing of potatoes in Akhaltsikhe (Samtskhe-Javakheti), Dusheti (Mtskheta-Mtianeti) and Khulo (in Adzharia)
- Pastures in Dedoplistskaro (Kakheti), Kazbegi (Kakheti), Kazbegi (Mtskheta-Mtianeti) and Mestia (Samegrelo-Zemo Svaneti)
- Livestock farming (Samegrelo, Kakheti)

For choosing adaptation measures for these trends first of all were estimated current and expected changes of those climate parameters, which are necessary to estimate positive or negative impact of climate changes on this or that culture or trend. There were stated current and expected climate changes for each agricultural plant in comfortable agroclimatic zones. The changes in agroclimatic zones represented in the document are only based on climatic parameters (sum of active temperatures and atmospheric precipitations in the vegetation period, also frost) necessary for development of the culture, but at this stage there are not foreseen issues, such as how much favorable are the types of soil for the culture in its comfortable agroclimatic zone, how much land of agricultural category is in this zone, how many infrastructures are there and etc. In order to define exactly what areas in which regions can be usable for the discussed cultures more detailed study is necessary to be carried out, within the scope of which for each priority culture there must be stated productivity potential of each region, shortage of water and etc., there must be stated the economic profit and social effect of each agricultural plant.

For assessing the impact of climate changes on cropping capacity and consumptive water use of annual cultures Aqua Crop (FAO) model was applied. A real problem in this process was that there was not the local statistics or accessibility to it, which could have enabled the experts to verify the results obtained by the model and state real reasons of increasing or decreasing cropping capacity. Such information is necessary for correct interpretation of the results obtained by the model. At the next stage it will be necessary to check in place the different events and reasons causing them, represented in this document.

to assess the adaptation ability of the plant in the area where it is. For example, if we know that an agricultural plant is sensitive to droughts and it needs to be watered, it is necessary define accessibility to water and its economical and environmental effect. At this stage it has not been completely studied yet how the runoff will be changed in those rivers, which historically were used for irrigation or whether the irrigation water will be accessible to those territories where it was not necessary before. At this stage this issue was not considered in the project, but at the following stages it must be envisaged by all means.

In the measures prioritizing process it was hard to decide whether the culture was priority for the country or only for a certain region. Since agriculture sector has a very local character and one and the same plant gives different results in different regions and has different priorities for different regions, in carrying out paragraphs 3.4.1 of the agriculture strategy (working out of plans of agriculture development and investments in priority fields for regions and support to carry out them) and paragraphs 3.4.2 (working out of sectoral programs for agriculture development of Georgia and support in realization of them) it is necessary to envisage the adaptation ability of the region to climate changes and adaptation measures to climate changes must be integrated in them.

In preparing Georgian national report on climate changes applying the method of multi-criteria analysis 14 municipalities were estimated in Kakheti and Adzharia. By this method it can be defined intensity of the climate change process on the territory of the municipality or the region, then how much sensitive is the field (in this case agriculture) to the current climate changes and finally to what extent is the adaptation ability in place (at the municipality or region level). The final one is the most important component in the process of decreasing risks of climate changes, as for planning adaptation measures properly and effectively we must know exactly where the weak points are and where adaptation measures must be taken in the first place.

Such approach at this stage failed to be carried out, as it required more time than the time assigned for the project; defining adaptation ability also required detailed local statistics and involvement of local authorities and experts. In the process of preparing the adaptation plan a fragmentary approach was mostly used, during which certain priority cultures and sector trends were emphasized, the influence of climate changes on these cultures was assessed that was sine qua non, but is not enough.

Just for this reason a social effect of climatic changes and adaptation measures was not assessed perfectly, barriers to the feasibility of adaptation measures were not defined.

As for achievements and novelties of this stage there must be emphasized that apart from the agroclimatic zones the trend of which was assessed for each culture and direction, in the agriculture sector for the first time in Georgia was assessed considering climate changes and a social factor in some measures. Though it should be noted, that in the assessment of the expenditure-profit there were so many admissions, which are increasing errors in results. For avoiding this it is necessary to involve local farmers and authorities.

Throughout the adaptation measures discussed within the report, the various technologies are recommended. The part of these technologies are well-known, but rather not applied, as far as it makes the final products more expensive. The majority of small farmers have limited amount of startup capital and some don't have the relevant knowledge and/or information. The part of technologies are also modern (insurance package, using "mini-tillers" in wheat production, the hybrids of maize of Georgian and foreign origin,).Analyzing prices of used technologies have shown that usage of improved and modern technologies for adaptation to climate change costs 82 % more than basic situation which is shown in the table 1.

Table 11.1 Comparison of the cost of technology required for adaptation to climate change with basic / traditional technologies

Name of technology / measureand crop, Cost-benefit result Cost-benefit result	The cost of basic technology	The cost of recommended technology	Description of the technology
wheat			
irrigation	0	400 l/ha	Nowadays wheat is not irrigated in Dedoplistskaro. During the period of Soviet Union it was irrigated by rainfed and irrigation
Modern agrotechnical measures [46]	1,000 l/ha	1,496 l/ha	The measure includes: determination of optimal depth of sowing , fertilization of soil , soil ramming after the sowing, Snow retention in plots, crop rotation, Improved varieties
"mini-till" [47]	1,000l/ha	1,466 l/ha	This measure means the wheat harvesting in the lowest land cultivation condition. This action costs less than 30l/ha in compare to the usual ploughing. All other measures are same
"no-till" [48]	1,000l/ha	-	Mechanization that sows like this costs 100,000 dollars

[46] This measure is suitable for unirrigated circumstances and if irrigated- 400 l/ha will be added to the basic as well as adaptive options. Agrotechnical measures include: irrigation, soil fertilization, crop rotation and selection of suitable varieties considering the irrigation conditions

[47] This is one of the modern agrotechnical measures, but in the table it is presented separately, as far as in Dedoplistskaro it is used by almost 70% of farmers and cultivation of 1 ha land using this method is estimated to be about 38% less expensive.

[48] This is the modern technology of wheat sowing, which is not used in Georgia and is not included in the recommended agrotechnical activities. This method of sowing requires highly expensive and sophisticated technology (about $ 100,000)

maize			
Introduction / dissemination of high-yielding varieties of maize (hybrids)	1,230 l/ha	2,043 l/ha (Georgian hybrid) 2,523l/ha (Foreign hybrid) (105% expensive)	In the basic situation, the portion of white corn is used in the West as a livestock feeder and Georgian and foreign hybrids, which are used only as a livestock feed
Improved agrotechnic measures profitable	1230 l/ha	1641 l/ha	The measure includes comparing two technologies for bringing white food maize: the most common technology in farming farms and improved technology implemented at Abasha's experimental station in Agrarian University of Georgia
tangerine			
distribution of early species of tangerine in adjaria (unshiu)	16,870 l/ha	22,870 l/ha	This early varieties of tangerine allow to prevent hail, It means that 60% of the harvest, which was lost in the usual breed due to hail, will not be lost if the early varieties are planted
Promote agro insurance Profitable (for small farmers) It is unprofitable (for large farmers and as a whole, because the majority of taxpayers are a large farmer)	0	300 l/ha (700 l/ha 70% State co-financing)	The agro insurance program insures small farmers. A small farmer is considered the one who insures less than 5 hectares of land. The state offers 70% co-financing of the insurance tariff to this category of farmers. Full insurance tariff in case of tangerine is 1000 l / ha, from which small farmers pay 300 Gel and the rest 70% is paid by the state
Hazelnut			
Maintenance of hazelnuts with improved agrotechnic measures profitable	2,260 l/ha (fruiting trees) 2,000 l/ha (non-fruiting trees , new garden)	6,000 l/ha (fruiting trees) 5,291 l/ha (non-fruiting trees , new garden)	The measure includes: soil processing in autumn, bringing mineral fertilization, trimming,fertilization by nitrogen, fight against harmful diseases
Planting of windbreak	0	1,146 l/ha[49]	The measure means providing hazelnuts garden with windbreaks

[49] *This is the cost of planting 10 m wide and 100 m long windbreak, that is considered to protect 1 ha plot from a single side*

Rangelands			
Rehabilitation of pastures within the state program profitable(in case of low and medium discount) unprofitable (in case of high discount)	0	500 l/ha (maintenance, no lease)	The state program implies letting of pastures under the condition of their rehabilitation. Also transfer of technical equipment to 29 municipalities
pastures rehabilitation in Dedoplistskaro unprofitable	0	500l/ha	Rehabilitation includes surface improvement of pastures-cleaning from stones, from the weeds, and fertilization of the area with mineral fertilizers
potatoes			
Protect potato crops from pests in Dusheti mountainous areas profitable	3,000 l/ha	10,000 l/ha	Agrotechnic measures of potato should be done in order to avoid possible diseases related to expected climate change
Arrange potato storage bases in Dusheti unprofitable (if the total number of crops is less than 2 tons and the price is 0.7 lari)	0	1,250 Gel (Improvements and not building new ones)	the action means that the potato producers should arrange special bases for potatoes and to store only the healthy one
Fight against excessive presipitation in Akhaltsikhe profitable	0	0	Introduction of the method used in Western Georgia in Samtskhe-Javakheti. The method involves arrangement of water channels and catchments in potato plots
Comparison of the value of profitable measures resulting from cost-benefit	26,590 l/ha	48,342 l/ha	increasing prices 21,752 l/ha (82%)

Here it should be noted, that the complete study and evaluation of the modern technologies, which are necessary to reduce the risks caused by climate change and adapt the sector to the new environmental conditions, has not been implemented and must be discussed within further stages with the involvement of international experts.

Prioritization of adaptation measures was done basing on the following criteria: export potential of the trend, the economic effect of the measure, the social effect of the measure, the environment protection effect, the technical-economic feasibility and barriers, contribution in carrying out priorities of the agriculture strategy. The stakeholders involved in the prioritization of measures assigned the first priority to the adaptation measures recommended for the hazelnut industry, especially to undertake agrotechnical measures timely and perfectly; the next measures are connected with citrus production and supporting the development of insurance service in the agriculture sector, which is very important for the country; support of propagation of high yielding maize in the development of livestock farming and rehabilitation of pastures takes the third place; very important was intensifying the role of agrotechnical measures in wheat production, but watering of wheat was causing some doubt, which apart from its expensiveness is harmful for a certain type of soil in Dedoplistskaro and this measure can only be taken where the soil affords it, moreover until 2050 precipitations in Dedoplistskaro are expected less, but increasing anyway; less priority are adaptation measures offered in potatoes production and watering animals on pastures in conditions of long-term droughts. In case of potatoes a real problem was not stated and consequently the measure is doubtful.

Within the scope of the project in 3a) and 3b) paragraphs of the terms of reference It was required close collaboration between the Ministry of Environment and Natural Resources and the Ministry of Agriculture for eradication of existed defects and maximal consideration of climate changes in plans of agriculture development. The first steps have been made, the Ministry of Agriculture is already expressing more initiatives in this direction, but it is not enough, it is necessary to carry out more joint programs and working meetings.

Annex 1.4 Wheat

Adaptation measure: Irrigation of Dedoplistskaro farmlands

Description of measure

At present, unirrigated agriculture is prevalent throughout Dedoplistskaro area. It has been established through climatic modelling that autumn wheat in Dedoplistskaro lacking water and irrigation water demand in black-earth soils is 100-150mm. This shortage will be somewhat reduced in the nearest future (2021-2050), but will increase again later (2070-99) to go back to the current level. Concurrently with this, the sum of active temperatures and CO2 concentration will steadily increase and this will have positive impact on the productivity of winter wheat. The activity may seem to be contrary to the changes expected by 2050, but the reduction of water shortage does not mean the elimination of shortage altogether.

Over the past ten years autumn wheat productivity across the Dedoplistskaro municipality ranges in a quite low levels, from 2 to 3 tons mainly due to water shortage. If sufficient moisture is ensured for autumn wheat, its productivity will increase 2-3 times and will reach 6-8 t/ha. Therefore, main recommendation is to ensure irrigation of Dedoplistskaro agricultural farmlands.
State irrigation system installation costs are not included in the analysis, since the analysis focuses on farmers' benefits and costs.

The analysis covers 11 years, 2018-2087. The analysis focuses on Dedoplistskaro and Sighnagi only.

Assumptions

- productivity with no irrigation is 2.5 t/ha and is constant throughout years
- in case of irrigation productivity is 5.5 t/ha and is constant throughout years
- wheat price increases annually by 5.4%[1]
- additional costs due to irrigation (water fee and other irrigation related costs) are GEL 400/ha and do not change over years
- original size of areas under wheat crops is 43,100 ha and it is reduced annually by 0.7%[2]
- 87% of wheat area is not irrigated
- average price of unirrigated land is GEL 1,625/ha and does not change over years
- irrigated water price is GEL 3,750/ha and it does not change over years
- It is implied that in Year 1 10% of unirrigated lands will be irrigated and this indicator increased gradually to reach 25% by the last year of the analysis
- Discount rate is 7.37% [3]

Outcomes

Key benefit categories are:
- Value of additional productivity derived as a result of irrigation. Irrigation increases productivity from 2.5t/ha to 5.5 t/ha

[1] *This growth rate is based on the observation of the wheat flour price dynamics during 199-2015*

[2] *This rate has been calculated based on the trend in areas under wheat crops during 2006-2013*

[3] *Average annual income for a 10-year government bond*

- The difference in the irrigated and unirrigated land prices. Unirrigated land is on average 2.3 times cheaper than land equipped with irrigation system.

Key costs categories are:

- additional costs related to irrigation, comprised of water fee and other expenses related to the irrigation process

Table 1.4.1. Key indicators

Indicator	Value
NPV of Net Benefits	GEL 153,053,231 (NPV>0)
Irrigated land area by 2027 (ha)	8,744 (25% of total area)

Since Net present value of benefits is positive, monetized benefit of the above-mentioned activity is higher than its costs.

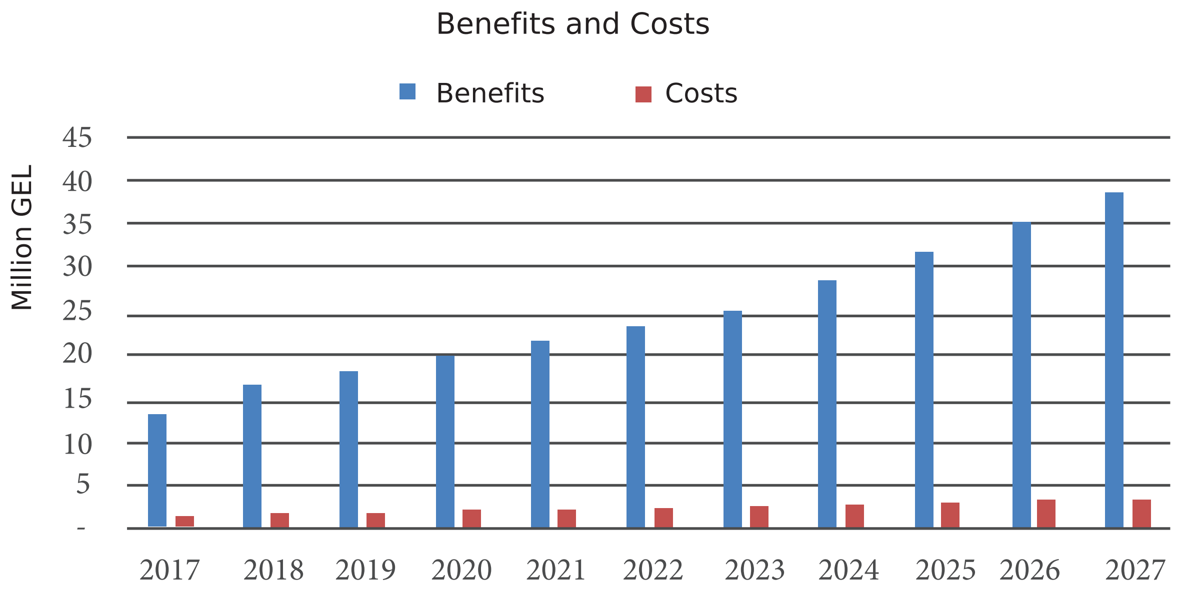


Figure 1.4.1. Benefit and costs by years

Irrigation has positive impact on productivity and the price of land and given the existing rates, large income derived by farmers from this activity is considerably higher than costs.

Conclusion

The activity reviewed above is profitable from the cost-benefit perspective, since its monetized benefit is higher than monetized costs.

Sensitivity analysis

Scenario 1. Low and high discount rate

Net present value of benefit given low discount rate ((R=4,76%) is GEL 179,227,287 (NPV>0), while in case of high discount rate (R=9.98%) - GEL 131,960,513 (NPV>0).
In case of both discount rates, NPV of benefits is positive.

Scenario 2. More frequent droughts

Given more frequent droughts due to the climate change, the productivity of wheat in unirrigated areas falls by 5% (decline). In 2018, productivity in unirrigated lands is 2.5t/ha and following annual 5% reduction, by 2028 this indicator is 1.3 t/ha.

Table 1.4.2. Key indicators

Indicator	Value
NPV of Net Benefits	GEL 171,451,486(NPV>0)
Irrigated land area by 2027 (ha)	8,744 (25% of total area)

In this case, the benefit from an activity is higher as compared to the main scenario.

Adaptation measure: Improved agrotechnical activities

Description of the measure

Solid agro technical activities have positive impact on wheat productivity capacity. The analysis reviews the effect of agro technical activities for two cases: wheat farming in unirrigated conditions and wheat farming in irrigated conditions. In the 1st case, the results from application of basic and improved agro technical measures in unirrigated conditions are compared, while in the 2nd case the results from application of basic and improved agro technical measures in irrigated conditions are compared.

Agro technical activities in unirrigated conditions includes: Semi raised cultivation of land, following the optimal period for sowing, determining optimal depth of sowing, soil fertilization, firm the soil after sowing, retaining snow in land plots, rotation, no-till and improved varieties.
Agrotechnical measures for farming wheat in irrigated conditions include: irrigation, soil fertilization, rotation and selecting relevant varieties for irrigated conditions.

Assumptions

- In unirrigated conditions, 2.5 t/ha (this indicator is constant over years) is obtained using basic technologies, while in case of the use of modern agricultural equipment productivity is 4 t/ha (this indicator is also constant over years)
- In irrigated conditions through the use of basic technologies productivity is 5.5 t/ha (this indicator is constant over years), while in case of modern agricultural equipment use the productivity is 7t/ha (this indicator is also constant over years)
- Wheat price increases annually by 5.4%[4]
- In unirrigated conditions, costs for basic agrotechnical activities is GEL 1,000/ha, while in case of using modern agricultural equipment – GEL 1,496/ha (these indicators are constant over years)
- in irrigated conditions costs for basic agrotechnical activities is GEL 1,400/ha , while if modern agricultural equipment is used – GEL 1,866/ha (these indicators are constant over years)
- wheat area baseline value in Dedoplistskaro and Sighnagi is 43,100 ha and it is reduced by 0.7% annually[6]
- In irrigated conditions, during the first 4 years of analysis, modern agrotechnical methods are used on 2% of crops, over the following 4 years this indicator is 5%, while over the final 3 years – 10%. The identical indicators are applicable to the introduction of modern agro technical methods in unirrigated conditions. [7]
- Discount rate is 7.37%[8]

Outcomes

Table1.4.3. Key impact indicators

Indicator	Value	
	Unirrigated	Irrigated
NPV of Net Benefits	GEL 7,047,497(NPV>0)	GEL 8,749,387(NPV>0)
Wheat area covered by modern agro technical activities by 2027	4034 ha	4034 ha

Since NPV of benefits is positive in both cases, the use of modern agro technical methods has positive effect both in unirrigated and irrigated conditions. The indicator is higher when modern agro technical activities are used in irrigated conditions.

[5] *GEL 400 associated with irrigation has been added to the costs involved in the application of basic technologies in case of irrigation, which totals GEL 1,400/ha*

[6] *Based on statistical information about the dynamics of areas under wheat crops*

[7] *The same areas have been taken for comparing the results for unirrigated and irrigated situations*

[8] *Average annual income for 10-year government bonds*

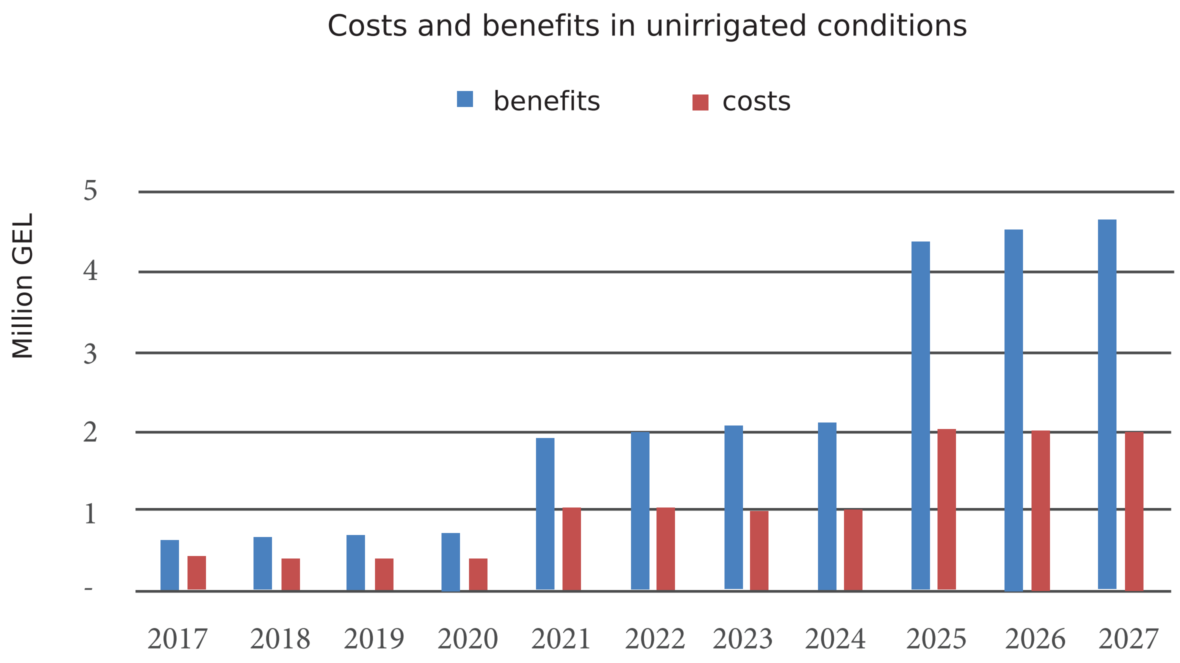


Figure1.4.2.Benefits and costs by years,unirrigated conditions

in every year, benefits are higher than costs and the ratio depends on the share of cultivated areas.

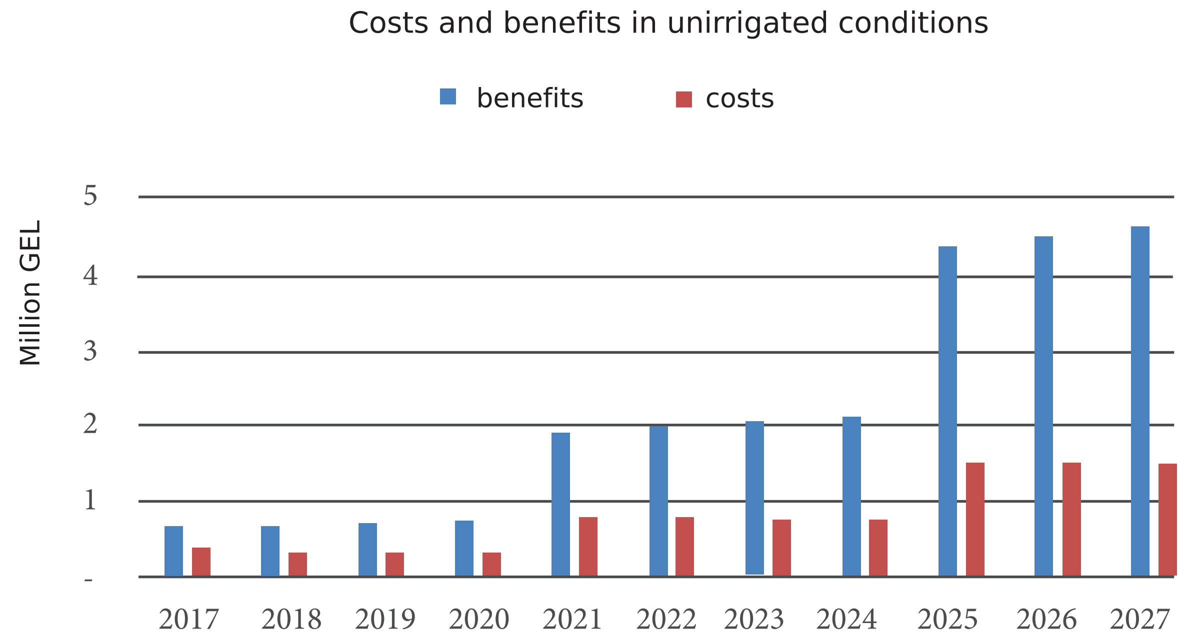


Diagram 1.4.3. Benefits and costs by years, irrigated conditions

The dynamics in irrigated conditions is the same as in unirrigated conditions, since the areas are the same.

Conclusion

The activity reviewed above is beneficial from cost-benefit perspective, since its monetized benefit is higher than its monetized costs. Moreover, if a farmer uses modern agro technical activities, then it is more profitable to farm wheat in irrigated conditions, since these two measures taken together derive higher effect.

Sensitivity analysis

Scenario 1. Low and high discount rate

Table1.4.4Key indicators

Indicator	Value	
NPV of Net Benefits, in case of low discount rate (R=4,76%)	Unirrigated	Irrigated
	GEL 8,564,038(NPV>0)	GEL 5,852,283(NPV>0)
NPV of Net Benefits, in case of low discount rate (R=4,76%)	GEL 10,609,184 (NPV>0)	GEL 7,281,248(NPV>0)

NPV of benefits in case of low and high discount rate is positive, which indicates that the activity is profitable.

Scenario 2. Reduced productivity capacity given the increase of the days of drought

If drought increases due to the climate change and farmers do not introduce modern agro technical activities, productivity capacity will decrease.
It means that in case of the use of basic methods, in unirrigated conditions productivity capacity reduction will be 5% a year, and in irrigated conditions – by 2.5%.

Table 1.4.5. Key indicators

Indicator	Value	
NPV of Net Benefits	Unirrigated	Irrigated
	GEL 14,615,461 (NPV>0)	GEL 17,074,147 (NPV>0)
Areas under wheat crops where modern agricultural activities are introduced by 2027	4034 ha	4034 ha

In case of the increase of droughts, benefit from the activity is almost doubled which is an indication that modern agrotechnical activities are even more important given the climate change.

Annex 1.5 Maize

Adaptation measure: Introduction/dissemination of high productivity maize varieties (hybrids)

Description of the measure

The activity aims at selecting best varieties of high productivity hybrids for local conditions, through the testing. The analysis applies to the Zugdidi municipality only. White maize is considered, which is used in the west for food as well as feed for livestock as well as Georgian and foreign hybrids used for feed only. It is implied that along with the increase of drought days, certain farmers will move from regular Georgian maize variety to Georgian hybrid, while other farmers move to the foreign one.
The analysis covers 11 years and applies to the following period: 2018-2028.

Assumptions

- Area under maize crops is 4,877 ha and is reduced by 6% annually[9].
- According to the expert, the most prevalent technology for farming white food grade maize results in 3.5 t/ha productivity
- According to the expert, the productivity of Georgian hybrids, according to the Agricultural Research Center, LEPL, is 7 t/ha
- The productivity of foreign hybrids, in case of farming according to Cartlisi, Ltd, is 10t/ha
- The costs for farming white food grade maize using the most prevalent technology at present is GEL 1,230/ha
- The cost for farming a new Georgian hybrid variety is GEL 2,043/ha
- The costs for farming a foreign hybrid is GEL 2,523/ha
- The cost for maize for feed is GEL 450/t and it increases by 5% per annum [10]
- The area under maize for feed is 29% of total sown area . [11]
- It is implied that at present, Georgian hybrid is sown on 2% of area under maize for feed. During 2020-2021 this indicator increases to 2.5%, during 2022-2023 increases to 3%, and during 2024-2025-to 3.5%, while during 2026-2027 this indicator reaches 4%.
- It is implied that at present, foreign hybrid is sown on 1% of area under the maize for feed. During 2020-2022, this indicator increases to 1.5%, during 2023-2025—to 2%, in 2026 -- to 2.5%, while in 2027 this indicator reaches 3%. Relatively low growth rate is due to, as has been mentioned above, that maize is less sensitive to high temperature, compared to many other field crops.
- Discount rate is 7.37% [12]

Outcomes

Key benefit category:

- Additional productivity value. In case of the use of Georgian hybrid, productivity increases from 3.5 t/ha to 7 t/ha, while in case of foreign hybrid, productivity increases from 7t/ha to 10t/ha.

[9] *Percentage change has been calculated based on the trends during 2013-2017. Over this period, the reduction of areas has been observed and the minimum reduction was 6%*

[10] *Growth rate has been determined based on prices statistical data*

[11] *This share has been derived based on food balances, where it can be seen that on average 29% of produced maize is used for feed2014-2016*

[12] *Rate of income for ten-year government bond*

Key costs category:

- The difference between costs involved in hybrid variety production and regular variety production. In case of Georgian hybrid, costs increase from GEL 1,230/ha to GEL 2,043/ha, while in case of a foreign hybrid – from GEL 1,230/ha to GEL 2,523/ha [13]

Table 1.5.1. Activity impact key indicators

Indicator	Value
NPVof Net Benefits	GEL 545,976(NPV>0)
Total area under maize crops by 2027	2,627 ha
Area under Georgian hybrid by 2027 (ha)	30 ha(1.2 % of total area)
Area under foreign hybrid by 2027 (ha)	23 ha(0.9% of total area)

Since NPV of benefits is positive, monetized benefit of the above activity is higher than its costs.

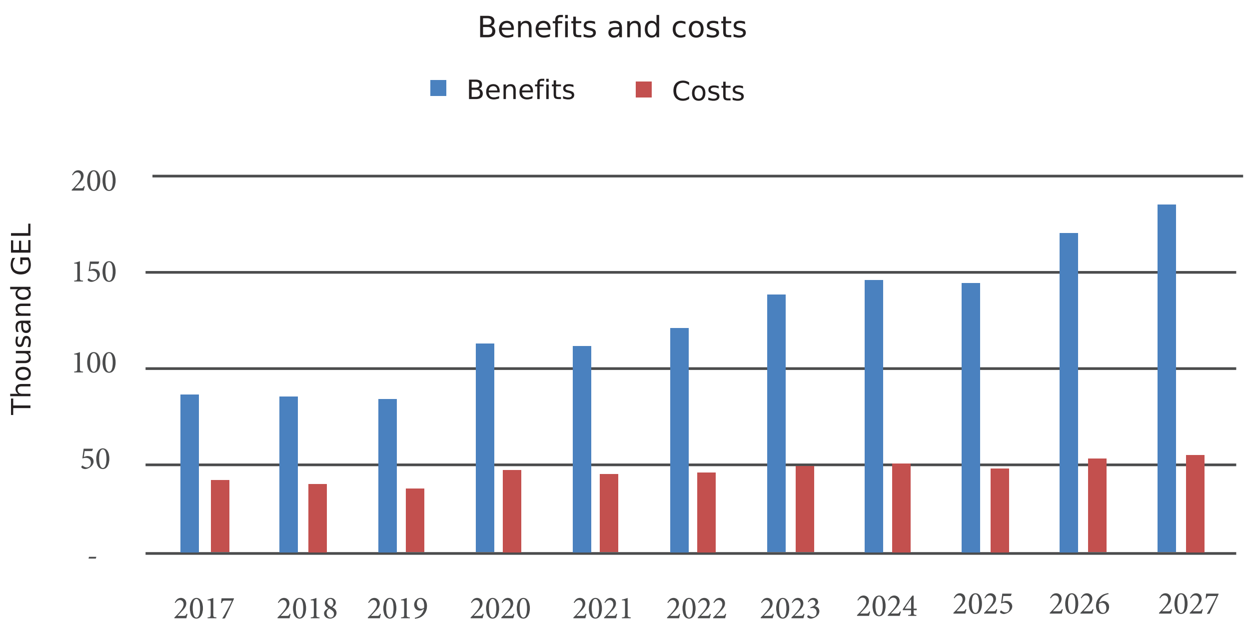


Figure 1.5.1. Benefit and costs, by years

In each year, benefits are higher than costs because in case of moving to a Georgian hybrid, productivity increases from 3.5 t/ha to 7 t/ha (100% growth), while costs increase by just 66%. In case of the shift to a foreign hybrid, productivity will increase by 186%, while costs – by 105%.

[13] *Due to the scarcity of data, a case when a Georgian farmer shifts from Georgian hybrid to a foreign hybrid is not considered*

Conclusion

The activity reviewed above is profitable from cost-benefit perspective since its monetized benefit is higher than monetized costs.

Sensitivity analysis

Scenario 1. Low and high discount rate

NPV of benefit in case of low discount rate(R=4.76%)is GEL641,211(NPV>0), while it is GEL 469,368 in case of high discount rate(NPV>0) [14].

In case of low, as well as high discount rate, net profit is positive, which means that this activity is a profitable alternative in terms of investment.

Scenario 2. Reduction of productivity in case of using basic technologies

If temperature increases due to the climate change, this will result in the reduction of the productivity of maize (regular variety, not a hybrid) from 3.5 t/ha to 1.1 t/ha[15].

Table 1.5.2. Key indicators for the effect of the activity

Indicator	Value
NPV of Net Benefits	GEL 777,579(NPV>0)
Non-hybrid variety maize productivity(t/ha) by 2027	1.1 t/ha

In case of both scenarios, benefit derived as a result of this activity is higher than its costs.

Adaptation measure: Improved agrotechnical activities

Description of the measure

In maize agro technology, autumn ploughing is a key method for retaining moisture in soil. Usually, in West Georgia soil designed for maize should be ploughed in autumn, at the end of November and the beginning of December. Tilled soil collects moisture during the winter, its lumps are broken down with the low temperature effect and in spring, prior to sowing, just soil cultivation (surface

[14] *Discount rates are derived by adding standard deviation +-1.96 to average value (here and everywhere in the document)*

[15] *Based on statistical data, 1,1 t/ha is the lowest indicator observed in the Samegrelo region during 2006-2013.*

cultivation) is necessary. Exception is the fields located in coastal area lowlands, where, due to highly abundant and strong rains, soil is formed and such soil requires repeated tilling in early spring. And soil tilled in spring dries quickly (due to high temperature), which has negative effect on sprouting and sprout development. Therefore, in rainy lowlands, ploughing is desirable later, in late February or March – in such case, soil will not be dried prior to sowing and tilling will not be necessary. Therefore, it is extremely important to follow optimal timeframes for ploughing, which is not done at present.

This activity envisages the comparison of two technologies for producing white maize for food: comparing two alternatives: the technology that is prevalent in farms and the improved technology implemented at the Georgia Agrarian University Abasha testing field.

The analysis covers the Zugdidi municipality area.

The analysis covers 11 years and applies to the following period: 2018-2028.

Assumptions

- Area under maize crops is 4,877 ha and is reduced by 6% annually [16] .
- The most prevalent technology for producing white maize for food productivity 3.5 t/ha
- Improved technology for producing white maize for food productivity 5t/ha
- According to the presently most prevalent technology, producing white maize for food costs GEL 1,230/ha, while producing using the improved technology – GEL 1,641/ha
- The price of maize for food is GEL 500/t and it increases by 5% annually [17]
- At present, 10% of total area under crops is cultivated under the improved technology, in 2019-2021 - 15%, 2022-2025 - 20%, while in 2026-2027 this indicator reaches 30%.
- Discount rate is 7.37%

Outcomes

Key benefit indicators are:
- Proceeds from extra productivity as a result of technology improvement. Productivity is 3.5 t/ha following the maize production technology prevalent in basic and farmlands, while over 5t/ha can be produced if improved technology is used. The value of difference is additional benefit derived by a farmer.

Key cost categories are:
- Difference between the cost of basic and improved agro technical activities. Improved activities derive higher productivity, yet they are more expensive.

Table1.5.3. Key indicators

Indicator	Value
NPV of Net Benefits	GEL 2,479,548(NPV>0)
Area under maize crops cultivated using the improved technology by 2027	788 ha (90% of total area under crops)

Since NPV of benefits is positive, monetized benefit of the above activity is higher than its costs.

[16] *Based on trend observed in statistical data for 2006 – 2015*

[17] *Based on trend observed in statistical data for 2006 – 2015*

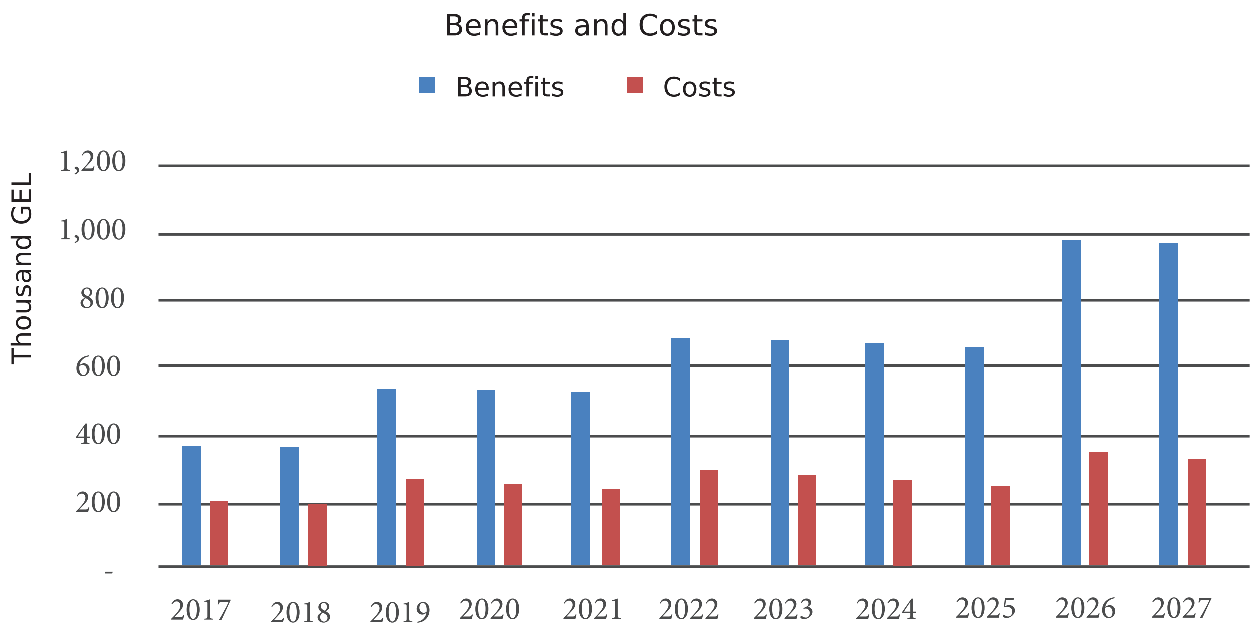


Figure 1.5.2. Benefits and costs by years

Each year, benefit is higher than costs because in case of the shift to improved agricultural equipment, productivity increases from 3.5 t/ha to 5 t/ha (43% increase), while costs increase at a lower rate (33%).

Sensitivity analysis

Scenario 1. Low and high discount rate

NPV of Net Benefits at the low discount rate (R=4,76%) is GEL 2,923,348 (NPV>0), while in case of high discount rate (R=9.98%) – it is GEL 2,123,323(NPV>0).
In case of low, as well as high discount rate, net profit is positive, which means that this activity is profitable for investment.

Scenario 2. Increase of costs in case of use of basic agro technologies

If temperature increases due to the climate change, basic agro technical activities for deriving the same productivity will become more expensive. It is implied that costs will increase by 5% every year.

Table 1.5.4. Key indicators for the effect of the activity

Indicator	Value
NPV of Net Benefits	GEL 3,803,497(NPV>0)
Area under maize crops cultivated using the improved technology by 2027	788 ha (90% of total sown area)

In case of both scenarios, benefits derived as a result of this activity is higher than costs involved.

Appendix 1.6 Potato

Adaptation measure: Protection of potato crops from pests in Dusheti mountainous areas

Description of the measure

Farmers of mountainous villages of the Dusheti municipality should carefully observe and implement the agrotechnical measures of potato care for the growing potato diseases caused by the climate change. Farmers should timely, at the time of detection, to control the disease and pests using recommended doses of plant protection products.
In Dusheti, most farmers are already using plant protection products because the number of diseases in the valley is relatively large. In the mountains, the number of diseases is less and the need for plant protection is less as well in today's times. However, in the future, climate change is likely to increase the number of diseases in the mountains, for which it is recommended to implement more comprehensive agro technological measures that will be reflected in up growth of expenditures.

The analysis covers 11 years and applies to the following period: 2018-2028.
The potato sown areas represent the areas sown in the mountains.

Allowances

- The potato sown area in the mountains is 359 hectares and is expanding by 3% annually [18]
- Cost of baseline agro technological measures is 3000 GEL per hectare, and as it is estimated that the diseases are to be more intense, which will increase expenditures for plant protection, cost of basic measures is increased by 300 GEL annually. In the conditions of frequent diseases, more costs will be required to get the same crop.
- The cost of improved agro-technologies is 10000 GEL per hectare and it is continuous for years.
- The amount of harvest per hectare with agrotechnological measures of 22.5 tons and it is unchanged for years.
- The number of harvesting per hectare basal agro technological measures constitutes 40% of 22.5 t and corresponds to 9 tonnes; This indicator is continuous for years.
- Improved agro technological measures are used in 1st and 2nd year of 10% of potato sowed areas (359 ha). But then the speed of introducing new technologies increases because more and more farmers are using pests to fight diseases. Thus, in the 3rd, 4th and 5th years, 15%, 20% and 25% of the most common areas have been introduced with more comprehensive agro technological measures. In the rest of the years, this indicator increases by 10% annually to 2027 and reaches 85% in 2027.
- The market price of one ton of potatoes is 700 Gel/ t and is growing at 9.3% annually according to the statistics agency[19].
- The discount rate is 7.37% [20]

Results

Main Category:

- Cost of increased productivity. The basic technology is adopted by 9 t / ha, and improved technology makes it possible to increase the number of crops to 22.5 t / ha. Depending on the cost of potato, this increment is estimated at the cost of harvest

18 The growth rate is determined based on the annual data of widespread of potato spaces in Dusheti.

19 It implies that since 1991 the rate of growth has increased, the same pace will be maintained for the next 10 years.

20 Average Annual Income on State Bonds for 10 Years

Main Category of expenditures:
- Difference between the values of improved and basic agro technological measures

Table 1.6.1. The main indicators of the impact of the arrangement

Indicator	Value
Present-day Net value of net interest (NPV of Net Benefits)	11 248 139 GEL (NPV> 0)
The crops processed by advanced agro technological measures for 2027 (ha)	398 (85% of the total area)

Forasmuch as the value of the present net of the benefit is positive, the monetary benefit of this arrangement exceeds its expenses.

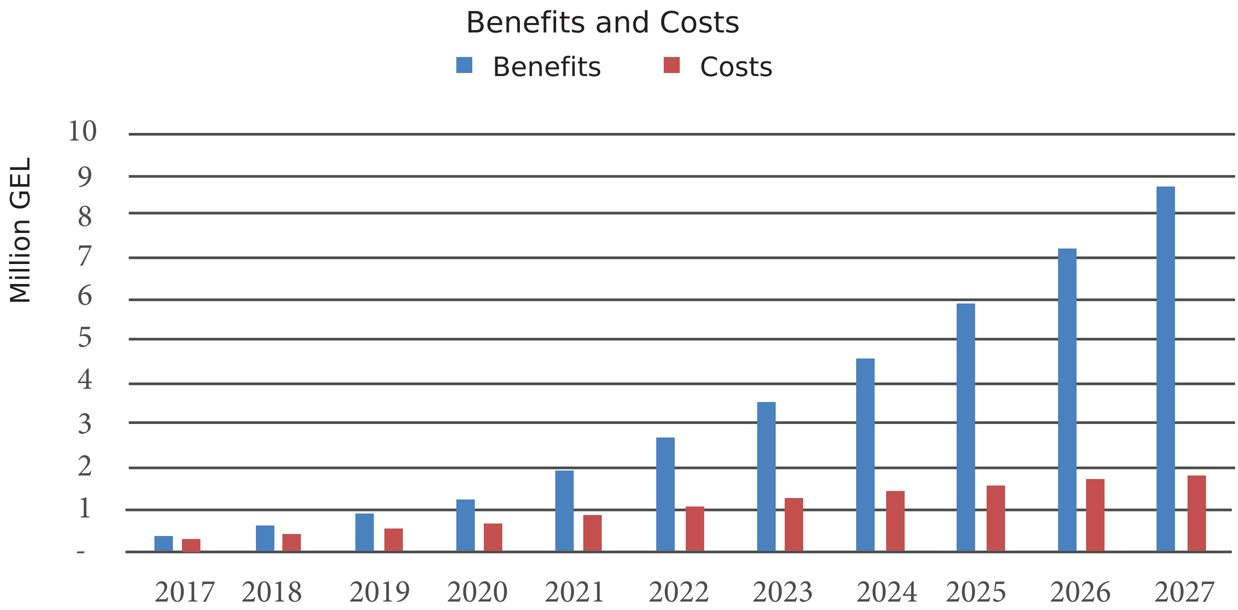


Table 1.6.1 Benefits and expenses according to years

Every year the benefit exceeds the expenditure because the crop is grown by 150%, and the difference in expenditure decreases with the year. Initially, the difference in the expenditure of the company is 233%, since the complete agro technological measures cost 10000 GEL / ha, while in the mountain 3000 l / ha is spent on basic technology, but in later years the cost of basic technology increases and by 2027 it reaches 6000 and hence the difference decreases from 10000 to 67%
Furthermore, the cost of potato and the sowed areas are growing, which also increases the benefits for years.

Conclusion

The discussed measure is profitable in terms of cost-benefit, as its monetary benefits exceed the monetary expenditure.

Sensitivity analysis

Scenario 1. Low and high discount rate

The present-day net value of the net interest in terms of low discount rate[21] is 13,898,673 GEL (NPV> 0), while in the highest discount rate is - 9,177,514 GEL (NPV> 0).

In case of both, low and high discount rate, net income is positive, which means that this arrangement is a beneficial alternative to invest money in.

Scenario 2. Crop reduction in case of use of basic technologies

If climate change increases the frequency of the disease, it is possible that the harvest obtained by baseline technology will decrease over the years. This scenario implies that the part of the farmers who apply basic technology worth 3000 GEL and do not increase its expenses will not be able to maintain 9 tonnes of crops over the years and it will be reduced to 8 tons and 7 tons by 2027.

Table 1.6.2 Main indicators of the impact of the arrangement

Indicator	Value
Present-day Net value of net interest (NPV of Net Benefits)	10 469 015 GEL (NPV>0)
Potato productivity (t / ha) by baseline technologies for 2027	7
The crops processed by advanced agro technological measures for 2027 (ha)	398 (85% of the total area)

In both scenarios, the benefit received by this arrangements exceeds its expenses.

Adaptation measure: Arrangement of potato storage bases in Dusheti

Description of the measure

In Dusheti municipality, about 6% of potato productivity is wasted during the Winter time to those farmers who do not have special storage cellars. The cause of the problem is not precisely established, but at this point there are two possible reasons: increased frost days, which cause freezing of potatoes if the yield is not properly stored, and a serious increase in precipitation in May-June, what not only damages harvesting but also reduces the hibernating ability of potatoes. Observation and research in this direction should be continued, but at this stage, in the framework of the Adaptation Program, there is offered the arrangement that considers that the potato producers should organize special cellars for storaging potatoes, and store only unblemished potatoes.

The analysis covers 11 years and applies to the following period: 2018-20287.

[21] *Discount rates are received by adding + -1.96 standard deviation on average value*

Allowances

- The original potato sowed area is 523 hectares and is expanding at 3% [22] annually
- The average productivity of potato is 15 t / ha[23]
- Loss caused by frosts is 6% of the crop
- An average cost of one-time arrangement of the basement is 1,250 GEL, which means improving the existing cellar and not building a new one
- In the basement as an average can be stored 450 kilograms of potatoes
- At the initial stage, 10% of all crops will be stored in new cellars and this indicator will increase by 5% every year
- The market price of one ton of potatoes is 700 GEL / t, and is growing at 9.3% annually according to the statistics agency[24]
- The discount rate is 7.37% [25]

Results

The main categories of benefit are:

- The value of the productivity saved from frost

The main categories of expenditure are:

- Cost of arrangement of basements

Table 1.6.3. The main indicators of the impact of the arrangement

Indicator	Value
Present-day Net value of net interest (NPV of Net Benefits)	-8 677 735GEL (NPV<0)
The amount of the productivity to be impacted by frost (T) for 2027	614 (6% of the whole productivity)
The number of safely stored crops (tons) By 2027	368 (60% of the amount of the productivity to be impacted by frost)

Forasmuch as the value of the present net of the benefit is negative, the monetary benefit of this arrangement is less than its expenses.

[22] *The growth rates are determined based on the annual data extensive spaces of potato in Dusheti*

[23] *This is the data of 2015 for Dusheti municipality*

[24] *It implies that since 1991 there has been an increase in the rate of growth, the same pace will remain in the next 10 years*

[25] *Average Annual Income of 10-year State Bonds*

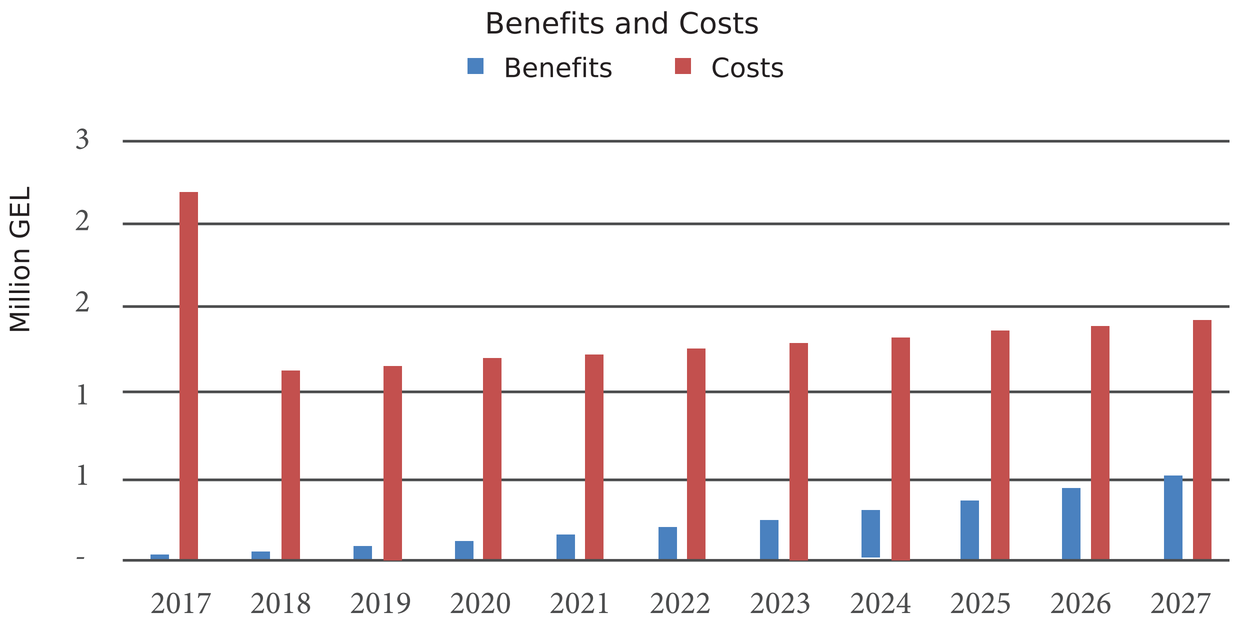


Diagram 1.6.2. Benefits and expenses according to years

The highest expenditures are fixed in 2018, as the largest number of rehabilitated basements is observed this year. The number of improved cellars is increasing at a relatively low rate every year, and costs are lower than the first year.

In addition, it is important to note that due to a 6% loss caused by the low price on potato, the farmer may not be motivated to spend 1250 GEL on the basement improvement. If the price of 1 kg potato is 0.70 GEL, the farmer should have at least 1.8 tonnes of wasted potatoes so that he made the 1250 GEL investment in the basement improvement.

Sensitivity analysis

Scenario 1. Low and high discount rate

The present-day net value of the net interest in terms of low discount[26] (R=4, 76%) rate is -9 772 148 GEL (NPV<0), while in the highest discount rate (R=9.98%) is -7 773 640 GEL (NPV<0).

In both cases, the present-day net value of the benefit is negative and indicates the unprofitableness of the arrangement if scale of the production will not increase.

Scenario 2. Increased losses on the background of increased frost days / rainfall

In the first two years, 6% of the total harvest is wasted due to the absence of the cellars, from 2020 to 2022 this indicator increases to 10%, and from 2023 to 2028 this indicator reaches 15%. It means that through the climate change the number of frosty days will increase and consequently will increase the losses.

---

[26] *Discount rates are received by adding ± 1.96 standard deviations on average value*

Table 1.6.4. Basic Indicators of the arrangement Effect

Indicator	Value
Present-day net value of net interest (NPV of Net Benefits)	- 6 902 798 Gel (NPV<0)
The amount of the productivity to be impacted by frost (T) for 2027	1536 (6% of whole productivity)
The number of safely stored crops (tons) By 2027	921 (60% of the amount of the productivity to be impacted by frost)

The present-day net value of benefits in both scenarios is negative.

Adaptation meare: Adaptation measure against excessive precipitation in Akhaltsikhe

Description of the measure

In Meskheti (Akhaltsikhe and other municipalities), in the last five years, through the climate change, the number of precipitation has increased by 10% in May-June. This increase is observed in Dusheti municipality and Khulo. In the future, during the annual precipitation and vegetation period, the amount of precipitation decreases, but the growth trend is kept by the intensity of rain, which will continue to temporarily flood the potato margins, which in its part will negatively effect on the quantity and quality of the produced products. In order to adapt to this process, it is necessary to introduce the methods applied in the municipalities of Western Georgia in Samtskhe-Javakheti, which implies arrangement of catchments and water tanks in potato plots. On the above-mentioned plots flows the recent precipitation, which will be flowed out from the field by means of the water vapor. The water vapors are to be arranged during the spring plowing of the plots, and its price is built in the price of plowing. It should be noted that both processes are done simultaneously. Excess precipitation is observed basically in Vale and nearby areas.
The analysis covers 11 years and applies to the following period: 2018-2028.

Allowances

- The sowed area in Akhalkalaki municipality is 2,105 hectares and it expands by 5%[27] annually
- The total harvest of potatoes is 35,555 tons and it increases by 19%[28] annually
- Troubleshoot areas are mainly located in the Vale area and 18% of all crops grow in this area

[27] *Growth rates were based on statistical data from previous years*

[28] *Growth rates are based on statistical data*

- 70% of the crop is lost in the first three years in flooded areas, and 80% from 2020 to 2023, and from 2024 to 2027, this indicator reaches 90%
- The market price of one ton of potatoes is 700 GEL/t and is growing at 9.3% annually according to the statistics agency[29]
- The discount rate is 7.37%[30]

Results

The main categories of benefit are:
- The value of the productivity saved from flood

The main categories of expenditure are:
- Cost of arrangement of water catchments, which equals to zero, as it is built in the cost of the harvest and does not require additional expenses

Table 1.6.5. Basic Indicators

Indicator	Value
Present-day net value of net interest (NPV of Net Benefits)	63 022 521GEL (NPV>0)
Amount of the productivity saved from flood (ha)	13,093 (13% of total amount)

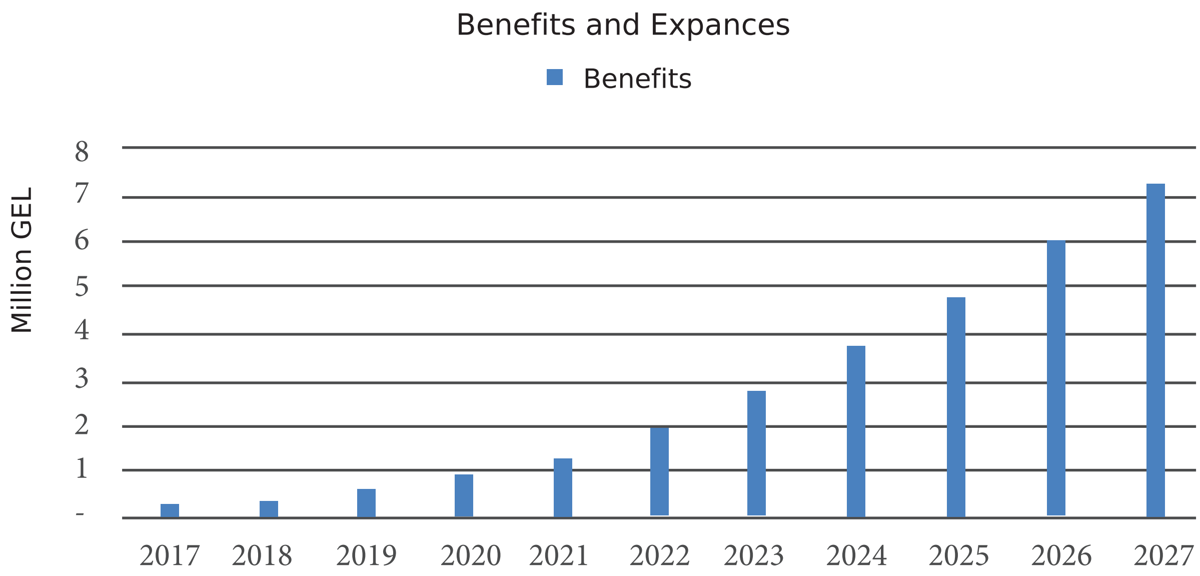


Table 1.6.3 Benefits and expenses according to years

[29] *It implies that since 1991 the rate of growth has increased, the same pace will remain in the next 10 years.*

[30] *Average Annual Income for 10-year State Bonds*

Sensitivity analysis

Scenario 1. Low and high discount rate

The present-day net value of the net interest in terms of low discount rate is 74 906 528GEL(NPV<0), while in the highest discount rate is 53 523 736 GEL (NPV<0).

In both cases, the present-day net value of benefits is positive, what indicates the profitability of the arrangement.

Scenario 2. Increased losses due to intense rains

It is implied that the intense rains will cause the expanse of flooded areas. 70% of the harvest will be destroyed in the first three years, 80% during 2020 to 2023, and from 2024 to 2028 this indicator reaches 90%.

Table 1.6.6 Basic Indicators of the arrangement Effect

Indicator	Value
Present-day net value of net interest (NPV of Net Benefits)	74 796 424GEL (NPV>0)
The amount of the productivity to be impacted by flood (T) for 2027	18705 (18% of whole productivity)
The amount of crops saved from flood for 2027 (T)	16834 (90% of the productivity to be impacted by flood)

The present-day net value of the benefit of both scenarios is positive.

Annex 1.7 Analysis of the cost-benefit of adaptive arrangements of producing tangerines.

Adaptation measure: Spreading Tiakhara-Unshiu, the early variety of Tangerines in Adjara

The analysis covers 11 years and applies to the following period: 2018-2028.

Allowances

- Tangerine plantations in Adjara hold 5,206 ha and this indicator remains unchanged over the years
- Hail-hazardous zone consists of 2000 hectares of plantations

- Amortized trees provide 5000 kg / ha, while the new varieties of tangerine in third year of yielding gives about 1500 kg / ha,then 6500 kg / ha, then 12,000 kg / ha, then 20000 kg / ha, then 30000 kg /ha, then - 40000 kg /ha and in high yielding - 50000 kg / ha.
- Over the last 7 years, new varieties had been grown to 50 hectares [31], each year in 7 hectares. During the next 4 years, this indicator is doubled and 14 hectares are grown in 8th, 9th, 10th and 11th years.
- Hail occurs every second year, and consequently, 60% of the harvest in the risk zone is lost
- The cost of cultivation of the old varieties is 16,870 Gel/ ha, and the cost of cultivation of new ones is- 22,870 Gel/ ha. The difference in cultivation costs is caused by the difference in the price of seedlings. New varieties of Tangerines seedling cost 8 Gel and older - 2 Gel.
- Care expenditure is the same in both cases and gradually increasing over the years [32]
- Tangerine price is 0.6 Gel/ kg and it is unchanged for years
- Forasmuch as most plantations are too old, it means that new varieties should be planted in the old place. Therefore, when the new plantation is being built and is not included in the fertility, during those years the reduced productivity from the old root plants is the alternate expenditure of the farmer
- The discount rate is 7.37% [33]

Results

Main Category of expenditure:

- The cost of the productivity saved from hail. Forasmuch as the early varieties allow to prevent hail, it means that the 60% of the harvest, which was lost in the usual varieties due to hail, will no longer be lost if the premature species are planted. Benefits are made only in the years when the hail is observed

Main Category of expenditure:

- Difference between the expenditure of building new and old plantations
- Alternate expenditure, which means the loss of income from the root of the old varieties, when old trees are replaced by new ones, but new ones are not yielding yet

Table 1.7.1. The main indicators of the impact of the arrangement

Indicator	Value
Present-day Net value of net interest (NPV of Net Benefits)	334,645GEL (NPV>0)
Total area of early yielding Tangerine varieties by 2027 (Ha)	107(2% of total area, 5% of risk zone area)
The amount of productivity from early yielding varieties in 2027 (t)	1,914

[31] According to experts, breeding new varieties of tangerine in Adjara started 7 years ago and is still cultivated on about 50 ha. It implies that for the next 7 years the same trend will be maintained. And when the farmers see the advantages of the early varieties, the new variety will be more actively cultivated.

[32] According to expert's assessment

[33] 16 Average Annual Income of 10 Years State Bond

Forasmuch as the value of the present net of the benefit is positive, the monetary benefit of this arrangement exceeds its expenses.

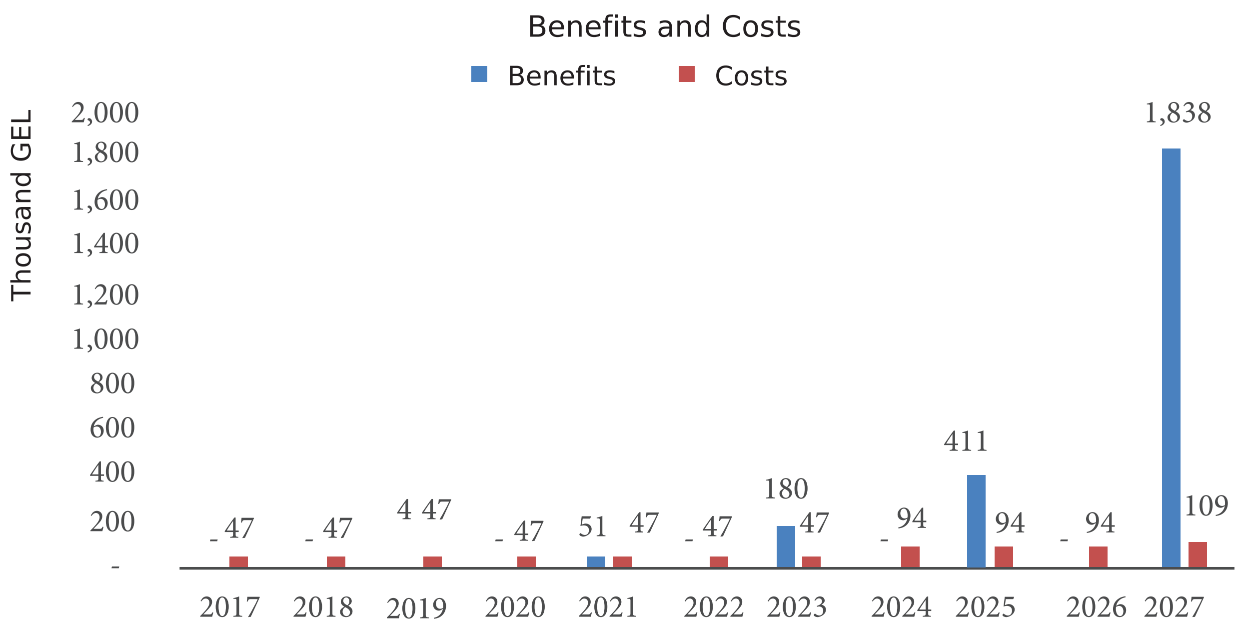


Table 1.7.1. Benefits and expenses according to years

During the first 2 years when new gardens are not yielding yet, the farmer has only expenses and no benefits, and then every year the productivity increases annually, as the productivity increases after fertilization.

conclusion

The discussed arrangement is considered as profitable in terms of cost-benefit, as its monetary benefits exceed the monetary expenditure.

Sensitivity analysis

Scenario 1. Low and high discount rate

The present-day net value of the net interest in terms of low discount rate is 519,000 GEL(NPV<0), while in the highest discount rate is 201 thousand GEL (NPV<0).

In case of both, low and high discount rate, net income is positive, what means that this arrangement is a beneficial alternative to invest money in.

Scenario 2. Hail Frequency

If through climate change hail is fixed every year, then the benefit of the arrangement will be even higher.

Table 1.7.2. Main indicators of the impact of the arrangement

Indicator	Value
Present-day Net value of net interest (NPV of Net Benefits)	845,000 GEL (NPV>0)
Total area of early yielding Tangerine varieties by 2027 (Ha)	107(2% of total area, 5% of risk zone area)
The amount of productivity from early yielding varieties in 2027 (t)	1,914

In both scenarios, the benefit received by this arrangement exceeds its expenses.

Adaptation measure: Promoting agricultural insurance

The Activity is focused on supporting the development of citrus agro-insurance. The analysis covers the region of Adjara and envisages agro-insurance program put into force by the Agricultural Projects Management Agency (APMA)[34], beneficiaries of which are small farmers - who insure less than 5 hectares of land parcel. The government offers this category of farmers 70% co-financing of insurance rate in case of tangerines. Full insurance rate in case of tangerines is 1000 GEL / ha; small farmers will have to pay 300 GEL and the rest 70% is paid by the government, while the Large farmers pay a full amount.

The analysis covers the region of Adjara envisages agro-insurance program put into force by the Agricultural Projects Management Agency (APMA)[35], beneficiaries of which are small farmers - who insure less than 5 hectares (in case of wheat less than 15 hectares) of land parcel. The government offers this category of farmers 70% co-financing of insurance rate in case of tangerines. Full insurance rate in case of tangerines is 1000 GEL / ha; small farmers will have to pay 300 GEL and the rest 70% is paid by the government, while the Large farmers pay a full amount.
Analysis covers 11 years: from 2018 to 2028.

Assumptions

- The total area of tangerine plantations in Ajara makes up 5,206 ha, and is unchanged for years.
- In 2017, the insured land area amounted 5.7% of the total land, the second year - 6.3%, then 6.9% and in 2027 - 13.9%, in the next year it was 6.3%, the third year 6.9%, and in 2027 - 13.9%[36].
- Since small and large farmers have different insurance conditions, areas insured by small farmers and their dynamics are separated from areas insured by large farmers and their dynamics. Distribution of insured areas between small and large farmers is based on a certain proportion[37]

34 *http://apma.ge/projects/read/agroinsurance/4:parent*

35 *http://apma.ge/projects/read/agroinsurance/4:parent*

36 *The growth rate is taken from the research conducted by the ISET "Assessment of Agro Insurance Regulation Impact", 2015*

37 *Proportion is taken from the research conducted by the ISET "Assessment of Agro Insurance Regulation Impact", 2015*

- The insurance tariff is 10% of the expected crop value on one ha (in average 10,000 GEL in Adjara), which is equal to 1000 GEL/ha [38]
- Small farmers pay 30% of insurance premium, while the large farmers pay 100%. These figures remain constant over the years.
- Loss Ratio (The proportion of the amount of compensation of losses paid by insurance company to the insurance premiums is 55% and is constant for both categories of farmers).
- discount rate is 7.37% [39]

Outcomes

The main categories of benefit are:

- The farmers' compensation by the insurance company, depending on the insured area, the insurance tariff and Loss Ratio. 55% Loss Ratio implies that 55% of the premiums received by insurance company is spent on average on compensation.

The main categories of expenditure are:

- The premium paid by the farmers to insurance company. The amount of premium depends on the insurance tariff, the state co-financing and the land area. Small farmers incur lower expenses as 70% is funded by the government.

Table 1.7.3. The main indicators of the impact of the Activity

Indicator	Value
Net present value (NPV of Net Benefits)	-545 486GEL (NPV<0)
Total insured area by 2027 (ha)	726 (13.9% of Total Area)
An area insured by small farmers by 2027 (ha)	302 (5.8% of Total Area)
An area insured by large farmers by 2027 (ha)	423 (8.1% of Total Area)

Since the net present value of Net Benefit is negative, the monetized benefit of the Activity is lower than its expenses, which can be explained by the fact, that co-financing is only for small farmers. Majority of the insurance premium payers are a large farmers, who pay 100% of the premium, while the rest of the farmers pay 30% and the insurance company issues 55% of the premiums. Average weighted premium paid by farmers is higher than the Loss Ration of Insurance Company (55%).

37 Proportion is taken from the research conducted by the ISET "Assessment of Agro Insurance Regulation Impact", 2015

38 Insurer uses the term 'normative price' (insurance limit), which is case of tangerines equals 10000 GEL / ha, and in case of 10% insurance tariffs, the farmer's fee is 1000 GEL / ha.

39 average annual productivity from 10-year government bond

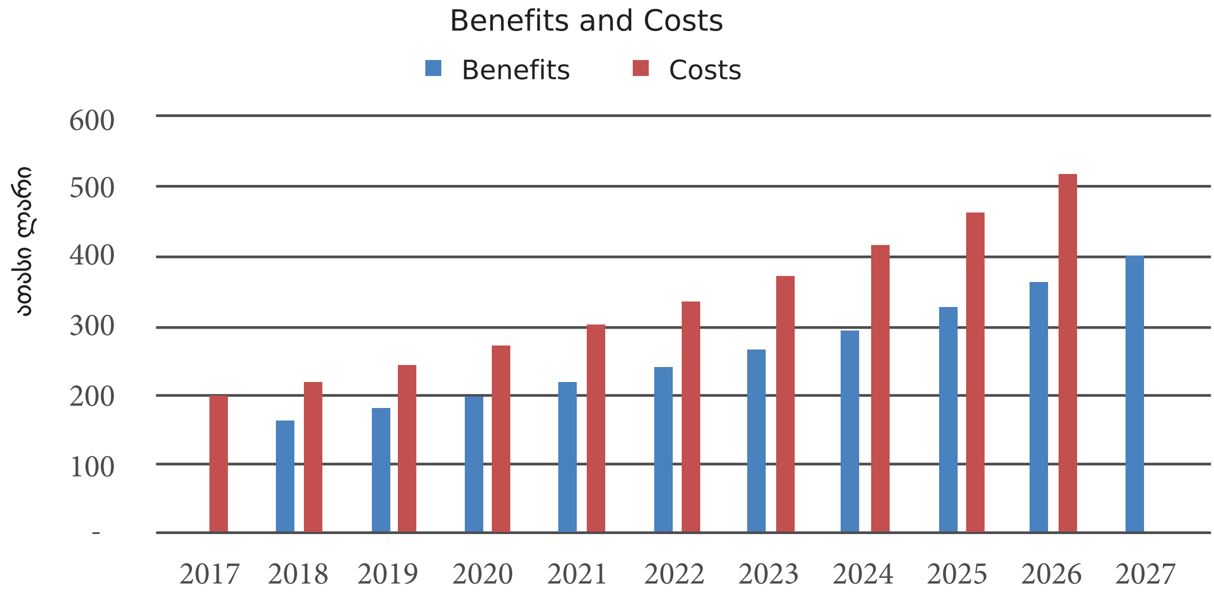


Figure 1.7.2. Cost and Benefit by years

In the case of large farmers, cost is higher than the benefit, while for small farmers, who pay less, the benefit exceeds the cost.

Sensitivity analysis

Scenario 1. Low and high discount rates

NPV of Net Benefit for low discount rate is -587 302GEL (NPV<0), while for high discount rate -506 927GEL (NPV<0).

In both cases, NPV of Net Benefit Is negative and indicates that the event is costly for large farmers.

Scenario 2. Increase in Loss Ratio

If the frequency of hails rises, compensations to be paid by insurer might also increase raising the Loss Ratio from 55% to 75%.

Table 1.7.4. The main indicators of the impact of the Activity

Indicator	Value
Net present value (NPV of Net Benefits)	38 244 GEL (NPV>0)
Total insured area by 2027 (ha)	726 (13.9% of Total Area)
An area insured by small farmers by 2027 (ha)	302 (5.8% of Total Area)
An area insured by large farmers by 2027 (ha)	423 (8.1% of Total Area)

The scenario shoes that if the Loss Ratio increases from 50% to 75%, then the benefit for all groups (for small and large farmers) exceeds the cost.

Annex 1.8 Cost-benefit analysis of hazelnut production adaptation measures

Adaptation measure: Management of hazelnut orchards through improved agrotechnical measures

Description of the measure

Implementation of agrotechnical measures in neglected hazelnut orchards, agrotechnical measures include: soil autumn processing, mineral fertilization, trimming, removal of trimmed waste, nitrogen fertilization, inter row cultivation of soil, application of chemicals against harmful diseases, and harvesting.
Analysis covers 11 years and applies to the following period: 2018-2028

Admissions

- Without modern agrotechnical measures, average productivity per tree is 1 kg, per total orchard -700-800 kg. Neglected orchards are meant here
- With modern agrotechnical measures, average productivity per tree is 4-5 kg
- The number of trees per hectare is on average 750
- Number of fertile trees is 20,347,200, remaining constant over the years
- Number of unfertile trees is 2,998,700 for 2017 and 2018
- The admission is made that in 2019 above mentioned unfertile orchards will also obtain fertility and in 2019 will provide 25% of potentially possible (4,5kg), next year – 35%, later – 60% and finally- 100%
- Management of fertile trees through basic (unimproved) methods costs 2,260 GEL/ha
- Management of unfertile trees through basic (unimproved) methods costs 2,000 GEL/ha
- Management of unfertile trees through improved agrotechnical measures costs 5,291 GEL/ha
- Management of fertile trees through improved agrotechnical measures costs 6,000 GEL and this number remains unchanged over the years
- Market price for shelled hazelnuts is 21.5 GEL /kg, remaining constant over the years[40]
- Market price for hazelnuts with shells is 4.5 GEL /kg, remaining constant over the years[41]
- At the initial stage, improved agrotechnical measures are used in 5% of hazelnut orchards, then this number increases on yearly basis (2nd year - 7%, 3rd year - 10%, 4th year - 14%, 5th year - 19%, 6th year - 25%, 7th year - 32% and so on) and by the last year of the analysis reaches 70%. The admission is made that by 2027, in 70% of orchards modern agrotechnical measures will be introduced and their productivity per tree will increase from 1kg to 4.5kg.
- The discount rate is 7.37%[42]

Results

Main benefit categories:

- Increased harvest value resulting from improved agrotechnical measures. In the properly managed orchards, the productivity amounts to 4-5 kg, while in neglected orchards the same indicator equals to 1 kg

Main costs categories:

- Difference in the costs for neglected and well-groomed orchards. Proper orchard management entails higher costs. Costs differ depending on whether the trees are fertile or not. The fertile orchard management costs amount to 6000 GEL/ha, while unfertile orchard management costs are 13% less (5,291 GEL/ha)

---

40 *Price forecasting for the next years is complicated due to high variation in price*

41 *Price forecasting for the next years is complicated due to high variation in price*

42 *Average annual income per 10-year state bond*

Table 1.8.1. Key Indicators

Indicators	Value
NPV of Net Benefits	401,790,266 (NPV>0)
by 2027, total area of hazelnut orchards cultivated with the new technology (ha)	21,790 (70% of total area)
Number of trees in well-groomed orchards	16,342,130 (70% of total number of trees)

Since NPV of Net Benefit is positive, the monetized benefit of this measure exceeds its costs

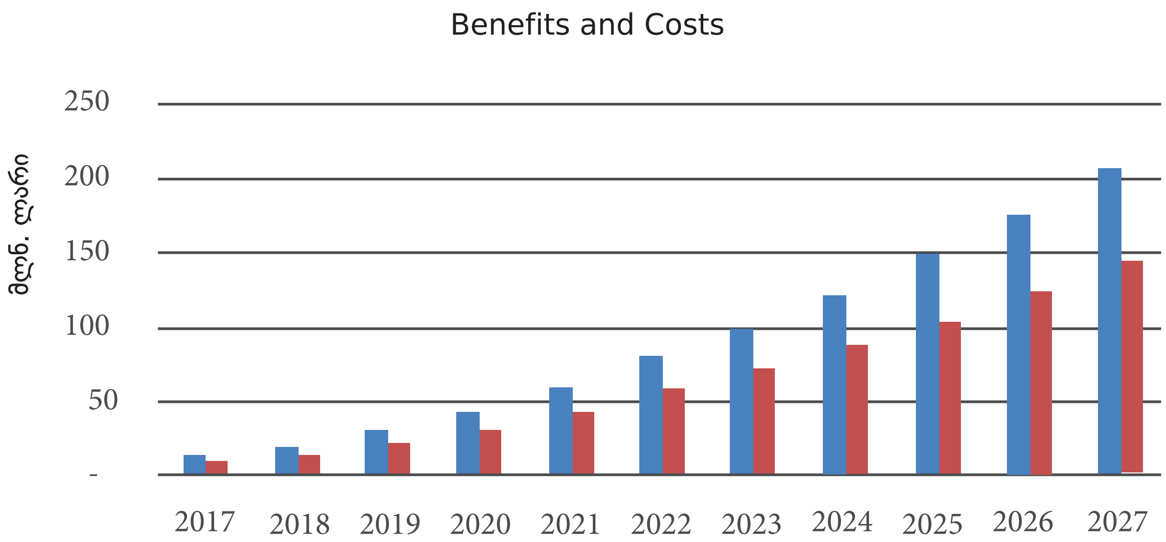


Figure 1.8.1. Benefit and Costs by Years

The benefit exceeds the costs every year. As a result of expansion of improved agrotechnical measures area, both benefit and costs are higher in the last years of analysis.

Sensitivity analysis

Scenario 1. Low and high discount rates

At law discount rate, NPV of Net Benefits is 485,951,528 GEL (NPV> 0), while at high discount rate it amounts to 335,156,995 GEL (NPV> 0).

At both low and high discount rates, net income is positive, which means that this measure is a beneficial alternative in terms of monetary investment.

Scenario 2. Reduction of harvest in neglected orchards

If climate change causes increase in prevalence of diseases, it is possible that harvest obtained from neglected orchards will be reduced over the years. This scenario implies that the part of the farmers who spend minimal money on their orchard management and fail to increase their expenses will not be able to get 1 kg per tree and this indicator may be reduced by 50% (admission). It is understood that during first 5 years of analysis the productivity is 1 kg and within the next 5 years - 0.5 kg per tree.

Table 1.8.2. Key Indicators of Measure Impact

Indicator	Value
(NPV of Net Benefits)	464,592,564GEL (NPV>0)
by 2027, total area of land cultivated with the new technology (ha)	21,790 9 (70% of total area)
Number of trees in well-groomed orchards (items)	16,342,130 (70% of total number of trees)

In both scenarios, the benefit obtained through this measure exceeds the corresponding costs.

Adaptation measure: Planting of windbreak strips

The measure implies provision of hazelnut orchards with windbreaks.
The assessment applies only to the hazelnut orchards located in Samegrelo.
The analysis covers 11 years and applies to the following period: 2018-2028

Admissions

- In 2018, In Zugdidi Municipality production of hazelnut is 15,300 t and remains unchanged for years
- 50% of the annual harvest is in the strong winds risk zone
- In case of strong winds, if the orchard is not protected by the windbreak strip, 80% of harvest at risk is lost
- The garden productivity is 1,65 t / ha
- Strong winds are observed every 3rd year
- Price of hazelnuts with shells is 4.5 GEL / kg, remaining constant over the years[43]
- Cost of windbreak planting is 11,460 GEL / ha [44]
- 12.2% of 4000 ha windshields existing in the 80s account for Samegrelo, amounting to 487 hectares, which is the target area for 2027 [45]
- At the 1st year of the analysis, 5% of the target area is planted, another 5% will be planted in the second, equaling in total to 10%. Every subsequent year, the planted area is growing by 10%, reaching 487 hectares by 2027
- The discount rate is 7.37% [46]

---

[43] *Price forecasting for the next years is complicated due to high variation in price*

[44] *Windbreak strip length is 100 m, maximum width – 10 m; The cost of 1000 m² windbreak strip planting is 1,146 GEL*

[45] *The portion of Samegrelo-zemo Svaneti in agricultural corps*

[46] *Average annual income per 10-year state bond*

Results

Main benefit categories:

- Cost of the harvest that will not be lost if the windbreak strip is planted

Main costs categories:

- Cost of windbreak strip planting

Table 1.8.3. Key Indicators

Indicator	Value
NPV of Net Benefits	1,606,468 GEL(NPV>0)
The amount of harvest at the risk of strong winds, by 2027 (t)	6,845 45% of total harvest))
Windbreak striparea by 2027 (ha)	487

At both low and high discount rates, net income is positive, which means that this measure is a beneficial alternative in terms of monetary investment.

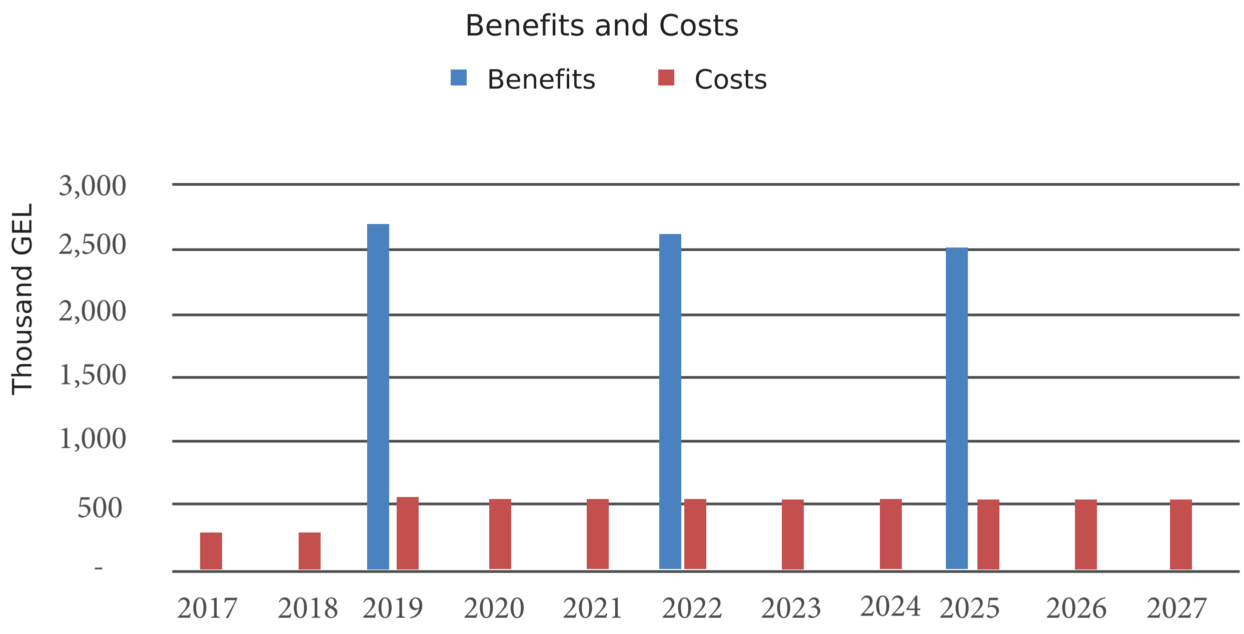


Figure 1.8.2. Benefits and Costs by Years

As it is understood that strong winds (23 m/sec) are observed in Zugdidi municipality every 3rd year, the benefits are observed every 3rd year accordingly. Benefits tend to decrease because the area of windbreaks increases every year, leaving less area of orchards in the risk zone.

Expenditure is almost constant because the growth rate of windbreaks remains same, accounting for 10% each year, except for first two years of analysis.

Sensitivity analysis

Scenario 1. Low and high discount rates

At law discount rate, NPV of Net Benefits is 17,875,818GEL (NPV>0), while at high discount rate it amounts to 13,983,095GEL (NPV>0).

At both low and high discount rates, net income is positive, which means that this measure is a beneficial alternative in terms of monetary investment.

Scenario 2. Frequent Winds

If due to the climate change, the winds become more frequent and are observed every year, the benefit received from the windbreaks will be higher.

Table 1.8.4. Key Indicators of Measure Impact

Indicator	Value
NPV of Net Benefits	15,741,438GEL(NPV>0)
The amount of harvest at the risk of strong winds, by 2027 (t)	6,845 (45% of total harvest)
Windbreak striparea by 2027 (ha)	487

In both scenarios, the benefit obtained through this measure exceeds the corresponding costs.

Annex 1.9 Pasture adaptation measures cost-benefit analysis

Adaptation measure: Rehabilitation of pastures within the framework of state program

Since 2016, the State Program on Rational Use of the State-owned Grasslands[47] , is carried out in high mountain regions. Cost-benefit analysis of above mentioned Program was made for 2018-2028. The program implies transfer of equipment to 29 municipal cooperatives with co-financing as well as leasing of grasslands. The program budget is 6 million GEL and cooperatives willing to participate in it must meet the requirements of cattle quantity and size of cooperative.

The analysis does not cover the Dedoplistskaro municipality and therefore is based on data from 28 municipalities.
The analysis covers 11 years and applies to the following period: 2018-2028.

[47] *http://acda.gov.ge/index.php/geo/news/show/61/202*

Admissions

- Each cooperative participating in the program has 200 milking cows and leases 200 ha of grasslands
- Depending on the requirements of the program, the cooperative increases the number of livestock by 10% every year for 8 years
- With the increase in the number of cattle, number of leased grasslands proportionally increases, because due to the requirements of the program, 1 milking cow is allowed per 1 ha of grassland (on average)
- Based on program rules, only one cooperative is selected from each municipality
- According to experts, in case of proper use of grasslands, their productivity increases by 2.75 tons / ha on average, which corresponds to 138 tons of Lucerne bales (each weighs 20 kg)
- Price and cost of bale are 3.5 GEL and 1 GEL respectively, and remain unchanged for years
- Average annual milk productivity per 1 cow is 1213 liters
- Caw productivity increases by 30% as a result of access to improved pastures
- Rehabilitated lands are used for one year as haylands and for another year – as grazing lands
- Based on program requirements, leasing cost of grassland for the first two years is 1 Gel/ha and later - 15 GEL/ha
- Annual cost of grassland management is 500 GEL
- The cost of milking cow is 850 GEL / per cow, remaining unchanged for years
- The discount rate is 7.37%[48]

Results

Main benefit categories:
- Increased hay productivity
- Increased milk productivity

Main costs categories:
- Program budget
- Production of bales
- Grassland management
- Cost of additionally purchased milking cows

Table 1.9.1. Key Indicators of Measure Impact

Indicator	Value
NPV of Net Benefits	120,331 GEL(NPV>0)
The number of milking cows engaged in the program by 2027	12,004 (5,4% of total amount)
Rehabilitated grassland area by 2027 (ha)	12,004 (9,5% of total amount)

48 *The average annual income of 10 years State bond*

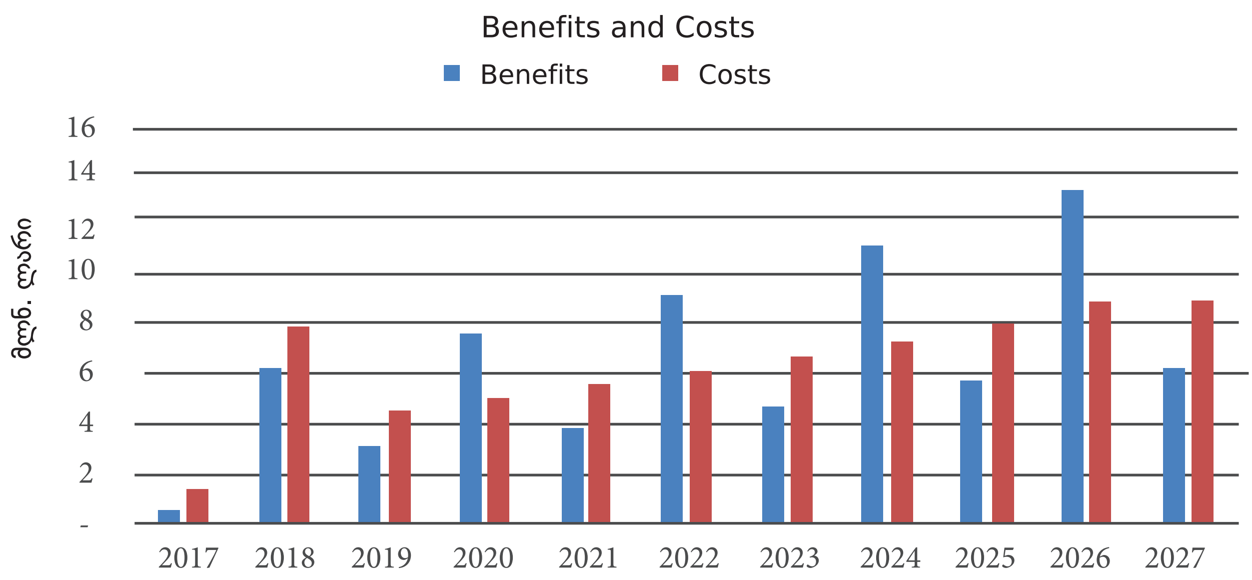


Figure 1.9.1 Benefits and by years

Conclusion

The discussed measure is profitable in terms of cost-benefit, as its monetary benefits exceed the monetary costs.

Sensitivity analysis

Scenario 1. Low and high discount rates

The area of grasslands and number of milking cows are unchanged. At law discount rate, NPV of Net Benefits is 479,713GEL (NPV> 0), while at high discount rate it amounts to 167,015 GEL (NPV< 0).

At low discount rate net income is positive and at high discount rate – negative.

Scenario 2. Reduction of grassland productivity

Due to climate change, grassland productivity decreases by 5% every year since 2021 (admission).

Table 1.9.2. Key Indicators

Indicator	Value
NPV of Net Benefits	292,268 GEL(NPV>0)
Average productivity of grasslands (t / ha) before rehabilitation by 2027	1.25

In this case productivity is lower and amounts to 1.25 t/ha (1.4 t/ha in the main scenario). The benefit in this scenario is higher than in the basic scenario.

Adaptation measure: Rehabilitation of grasslands in Dedoplistskaro

Rehabilitation includes superficial improvement of pastures – removal of stones and weeds, and soil fertilization with mineral fertilizers.
The analysis covers 11 years and applies to the following period: 2018-2028. The analysis applies to the number of milking cows in Dedoplistskaro.

Admissions

- Rehabilitation of the Dedoplistskaro heylands is carried out overhe first 5 years, equally per each year (by 1/5)
- Rehabilitated lands are used for one year as haylands and for another year – as grazing lands
- According to experts, in case of proper use of grasslands, their productivity increases by 2.75 tons / ha on average, which corresponds to 138 tons of Lucerne bales (each weighs 20 kg)
- Price and cost of bale are 3.5 GEL and 1 GEL respectively, and remain unchanged for years
- Average annual milk productivity per 1 cow is 965 liters
- Caw productivity increases by 30% as a result of access to improved pastures
- Milk price is 0.70 GEL/liter, remaining unchanged over the years
- The cost of milking cow is 850 GEL / per cow, remaining unchanged for years
- Annual cost of grassland management is 500 GEL
- After rehabilitation, the amount of additionally absorbed carbon is 0.5 t/ha; the price is 11.95 GEL/t
- The discount rate is 7.37%

Results

Main benefit categories:
- Increased hay productivity
- Increased milk productivity
- Saved cost of Carbon

Main costs categories:
- Production of bales
- Rehabilitation and further management of the grasslands

Table 1.9.3. Key Indicators

Indicator	Value
NPV of Net Benefits	- 190,136,120GEL(NPV<0)
The number of milking cows engaged in the program by 2027	6,916 (100% of total amount)
Rehabilitated grassland area by 2027 (ha)	63,868 (100% of total amount)

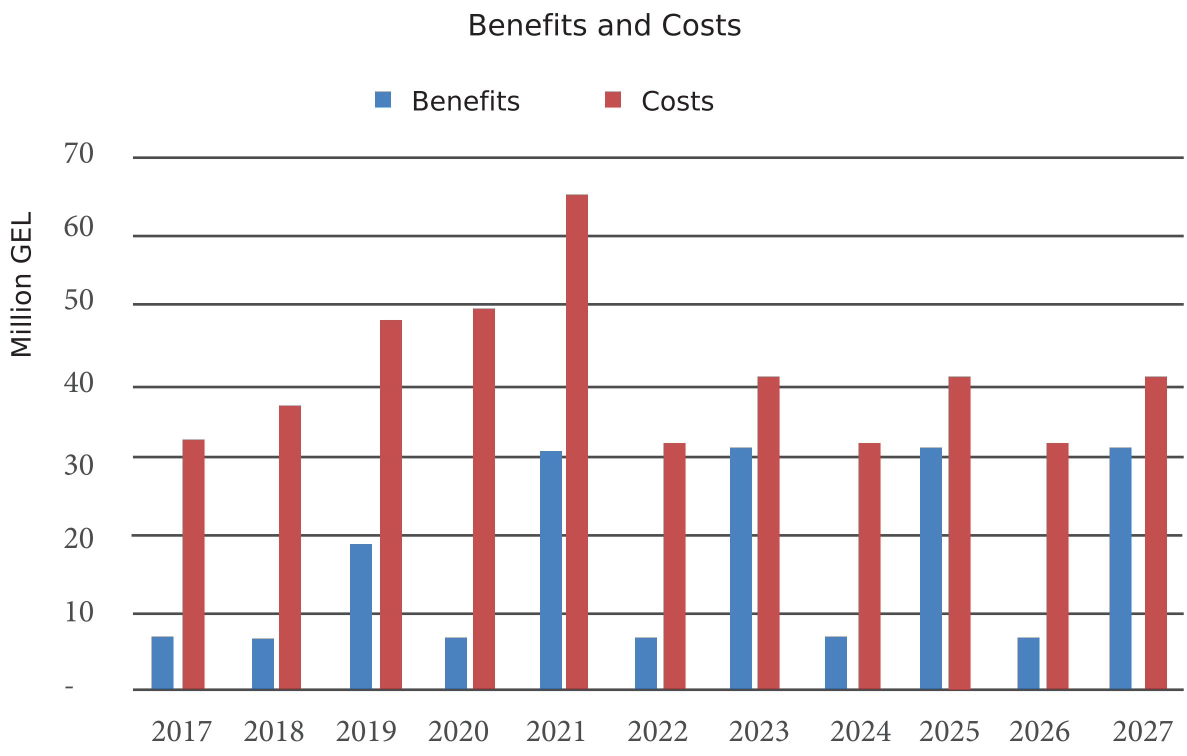


Figure 1.9.1 Benefits and costs by years

Conclusion

The discussed measure is unprofitable in terms of cost-benefit, since its monetary benefits are less than monetary costs, mainly due to large quantities of rehabilitated areas at the initial stage of analysis and relatively small quantities of cattle.
In order to ensure profitability of measure, it is necessary to gradually increase the number of cattle and reduce the pace of rehabilitation.

Sensitivity analysis

Scenario 1. Low and high discount rates

At law discount rate, NPV of Net Benefits is 209,924,688 GEL (NPV<0), while at high discount rate it amounts to 168,360,327 GEL (NPV<0).

The area of grasslands and number of milking cows are unchanged.
At low and high discount rates, net income is negative.

Scenario 2. Reduction of grassland productivity

Due to climate change, grassland productivity decreases by 5% every year since 2021 (admission).

Table 1.9.4 Key Indicators

Indicator	Value
NPV of Net Benefits	- 187,334,387 GEL(NPV<0)
Average productivity of grasslands (t / ha) before rehabilitation by 2027	1.25

In this case productivity is lower and amounts to 1.25 t/ha (1.4 t/ha - in the main scenario). The benefit in this scenario is even lower compared to the basic scenario.

Attachment 1.10 Analysis of Expenditures-profitability of Adaptation Measures of Livestock Farming

Adaptation measure: Livestock Watering

The measure implies provision of livestock watering in an organized manner by means of water tanks in the villages of Sagarejo, Dedoplistskaro, Signagi and Gurjaani.
With increasing droughty days the demand on water is expected to be growing and it is necessary to supply the livestock on pastures with drinking water, so that lack of water will not affect negatively on milk yielding.
The analysis covers 11 years for the period: 2018-2028

Admissions

- The number of milch cows in the corresponding municipalities totally is 34 043[49] and is not changed during years.
- The average daily milking in Kakheti region is 3.2 liter/day from 1 cow and every year it increases by 2.4% [50]
- In the conditions of shortage of water milking is decreasing by 22.5%. If under the normal conditions milking is 3.2 liter per day, in case of the lack of water it is 2.5 liter/day.
- The initial price of milk is 0.6 Gel/l and every year it increases by 9.7% [51]
- 1 cow needs 75-liter water per day, but in the analysis this number is halved, because it is meant that there are other means of watering too (river, borehole, gorge and etc.) and accordingly the amount of water to be supplied by tanks is halved
- Expenditure on transportation of 1 water tank is 50 Gel and is not changed during years1
- 1 tank contains on average 5.5-ton water and this indicator is not changed during years
- The price of 1 tank is 850 Gel and is not changed during years
- The number of droughty days is 112 per year [52]

[49] *Results of 2016*

[50] *It is meant that in the following years there will be maintained the same trend which was fixed in statistics data about milking for the period of 2006-2013.*

[51] *It is meant that in the following years there will be maintained the same trend which was fixed in 1999-2015 in statistics data about prices*

[52] *The average indicator for 109 days of Signagi and 115 days of Dedoplistskaro*

- It is meant that in the first year 40% of the necessary quantity of tanks will be acquired, in the second year 35% of the remained tanks, next – 25%, 20%, 15%, 10% and during the last 5 years 5% of the remained quantity of the proper year. The number of the acquired tanks is decreasing along with years, as it is meant that watering of pastures will be carried out gradually by different ways within the scope of state program.
- Discount rate is 7.37% [53]

Results

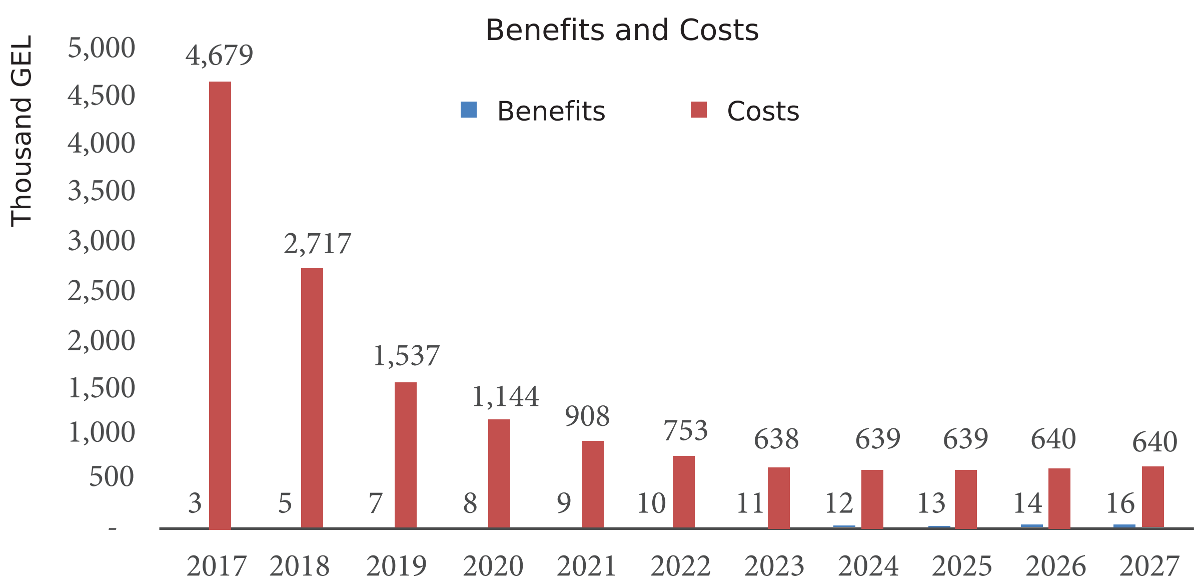
The main category of benefit:
- Avoiding of milk loss. The benefit is the cost of the milk, avoiding of losing of which is favored with watering by means of tanks

Main categories of expenditures:
- Cost of tanks
- Expenditures on transportation of the tanks

Table 1.10.1 Main indicators of the measure effect

Indicator	Value
NPV (Net present value) of Net Benefits	- 11 580 565GEL (NPV<0)
The required number of tanks	12,998
Total number of the acquired tanks	11 198 (86% of the whole quantity)

As the net present value of net benefits is negative, expenditure on the noted measure is more than its monetized benefit that might indicate that watering by means of tanks is an expensive measure and it must be substituted by a less expensive alternative.



Picture 1.10.1. Benefit and expenditures by years

53 *The average real annual benefit on a 10-year state obligation*

Every year the expenditure is more than the benefit and the difference between them is high especially initially, when comparatively big number of tanks is acquired. In spite of the fact that by the big number of tanks watering of more cattle will be possible, the cost of a tank is still higher compared with the cost of milk counted in the benefit.

Conclusion

The discussed measure is unprofitable from the point of view of expenditure-benefit and it must be either substituted by other alternative or must be modified.

Analysis of sensitiveness

Scenario 1. Low and high discount rate

The net present value of net benefit in the conditions of the low discount rate is -12 549 049Gel (NPV<0), but in the conditions of the high discount rate - - 10 742 139Gel (NPV<0).

As in the conditions of low, as well as of high discount rate the net income is negative, this measure from the point of investments is not a good alternative.

Scenario 2 Growth of the number of droughty days

If because of climate changes the number of droughty days increased from 112 to 115, the measure will have even less benefit because the necessary number of tanks will be more than in the previous cases.

Table 1.10.2 Main indicators of the measure effect

Indicator	Value
NPV (Net present value) of Net Benefits	- 11 885 456Gel (NPV<0)
The required number of tanks	13,346
Total number of the acquired tanks	11 498 (86% of the whole quantity)

In cases of both scenarios the expenditure on this measure exceeds its benefit.

Online versions of the main documents: “Climate Change National Adaptation Plan for Georgia’s Agriculture Sector” and the annex “Road Map and Gaps and Needs analysis, for preparing the National Adaptation Plan of Agriculture in Georgia” are uploaded to the website of LEPL Environmental Information and Education Centre - eiec.gov.ge