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Agroclimatic zoning of western regions of georgia

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A B S T R A C T

Assessment and efficient use of agroclimatic resources is important for agroclimatic zoning in agriculture, as the growth and development of the agricultural crops and harvest mostly depend on the rational spatial distribution of the crops. When developing new areas, agrarian workers and farmers must consider the demands of crops for agroclimatic conditions what will improve their productivity. This will significantly increase their economic incomes and will contribute to the better provision of the population with the agricultural produce. Aiming at identifying the agroclimatic zones in the western regions of Georgia, based on the data of a 60-year-long meteorological observation, the agroclimatic resources of 6 regions (Samegrelo-Zemo Svaneti, Guria, Imereti, Racha-Lechkhumi-Zemo Svaneti, Apkhazeti) were evaluated. The thermal regime during the vegetation period of agricultural crops was evaluated by means of the sum of active temperatures (>10°C), which changes by ±300-400°C annually and more. The parameters of atmospheric precipitations (in warm and cold periods), frosts (the first and the last one), periods without frost were determined according to vertical zoning in the agroclimatic zones identified within the region. In order to avoid the negative impact of frosts, it is recommended to use physical and biological methods against it. The perspective agricultural crops and soil types in the identified agroclimatic zones were described. Based on the agroclimatic zones identified in each region, the agricultural crops will be distributed in a rational manner and the prospects of their growth and development and high yield will be thoroughly identified.

Keywords: Agroclimatic zone, Active temperature, Atmospheric precipitation, Agroclimatic characteristics, Crops, Agroclimatic zone.

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Introduction

Provision of the population with agricultural products is one of the most important issues for the country. Therefore, profitable economy can be reached by employing the local agroclimatic resources (duration of sunshine, temperature, atmospheric precipitations, soil and air humidity, etc.) to the extent possible. These resources have an impact on harvest and economic income as a result. For Georgia, which is a land-poor country, the evaluation and efficient use of climatic and agroclimatic resources is of an utmost importance, and for the development of different branches of agriculture in the first place.

The agroclimatic resources must be evaluated on the basis of the climate properties (warmth, light, atmospheric precipitations, etc.) associated with the harvest formation. In case of irrational use of the given agroclimatic resources, favorable growth or development of the agricultural crops or gaining guaranteed rich harvest will be impossible. The above-mentioned climatic parameters help select the relevant crops, expediently plan land cultivation, carry out various kinds of farming operations, etc. The average values of the following agroclimatic parameters are very important: temperature, precipitations, frosts, etc. They can be used to evaluate the agroclimatic resources of different regions in West Georgia [1-3] what allows the efficient use of agroclimatic properties, favorable growth and development of agricultural crops and their rational spatial distribution.

The regions differ with their agroclimatic properties. Therefore, it is necessary to differentiate between the agroclimatic zones of cereals, vine, tea, citrus, fruit, oil-bearing and ether-oil bearing, technical and other crops. Efficient use of the agroclimatic parameters of each zone will contribute to the efficient growth and development of crops and rich harvest forming the basis for profitable farming in an economic respect.

Study area

The territory of West Georgia, which, under the combined action of the Black Sea, solar radiation, high mountains of West Caucasioni and transformation of air masses, as well as orographic and complex mountainous relief, has several types of climate, in particular, humid subtropical climate up to 500-600 m above sea level, reaching Zemo Imereti where the humidity is a bit less. Moderate climate dominates 700 to 1300 m above sea level, and the cold continental climate dominates at 1400-2200 m above sea level. Above the latter altitude, there dominates very cold climate of eternal snow and glaciers. The agricultural conditions of the first three zones are favorable to grow relevant agricultural crops. There are 6 regions (Samegrelo-Zemo Svaneti, Guria, Imereti, Racha-Lechkhumi-Zemo Svaneti, Apkhazeti) with diversified agroclimatic resources in the study area.

Data and methodology

The work used: the database of the meteorological observations of the Institute of Hydrometeorology of Georgian Technical University; long-term observations data on the territories of the weather stations of 6 regions in West Georgia (Department of Hydrometeorology of the National Environmental Agency of Georgia); agroclimatic bulletins of the National Environmental Agency of Georgia (2008-2018); the agroclimatic resources of the region were evaluated by using the climatic and agroclimatic reference books: solar radiation, radiation balance and duration of sunshine (1968); air and soil temperatures (1967); atmospheric precipitations (1970); winds (1968), agroclimatic reference book of Georgia (1961); reference book of the agroclimatic resources of Georgia (1978); applied scientific climatic reference book of Georgia (2004) and other relevant literary sources.

Besides, the classical study methods commonly used in agro-meteorology were used. The data of agro-meteorological observations were treated by using the method of mathematical statistics.

Results and discussion

Samegrelo-Zemo Svaneti region has a relief made up of plains, hills, mountains and high mountains (2000 m and more above sea level). The plain relief of Samegrelo (up to 100-150 m above sea level) is widely spread towards the Black Sea and created favorable geographical-economic conditions for social-economic development [4]. It extends north and north-eastwards with vertical zoning, reaches up the southern slope of main Caucasioni watershed ridge and covers the territory of Zemo Svaneti, above the altitude of 2000 m [5]. The given region is bordered by the Caucasioni mountain from the north, by Imereti region from the east, by Guria region from the south and by Apkhazeti region and the Black Sea from the west. Due to the influence of the Black Sea on the region, the plains and hilly (up to 500-600 m above sea level) relief of Samegrelo are located within the humid subtropical climate, while the average- and high-mountain locations of Zemo Svaneti are located within the moderate and continental climate characterized by moderately cold and cold climate, snowy winter and short summer, respectively [6]. The specific weight of the region in the production of annual and perennial plants is high. The following crops grow well on the plains and hills: tea, citruses, technical oil-bearing and essential-oil-bearing crops, vine (different varieties), kiwi (actinidia), nut, cherry laurel, fruit, etc. The following crops grow quite well in the mountainous and high-mountainous areas: cereals, vegetable, continental fruit, and there are vast areas of hay meadows and pastures (Table 1).

Table 1. *Agroclimatic zones characteristics of Samegrelo-Zemo Svaneti region*

Agroclimatic zones of Samegrelo-Zemo Svaneti region	Sum of active temperatures (>10°C)	Atmospheric precipitations (mm)		Frosts		Duration of periods without frost (day)
		Cold period	Warm period	First frost	Last frost	
I – zone	4400	630-850	800-1160	2.XII-7.XII	15.III-20.III	252-260
II – zone	4200-3700	860-990	1160-1220	23.XI-6.XII	21.III-29.III	236-257
III – zone	3700-2900	660-990	620-1220	1.XI-24.XI	30.III-11.IV	235-196
IV – zone	2800-2000	400-420	600-620	9.X-31.X	12.IV-25.IV	195-156
V – zone	1900-1100	870-1130	610-1130	16.IX-8.X	26.IV-8.V	155-116
VI – zone	1100-1000	390-490	650-790	7.IX-15.IX	7.V-22.V	115-75

The I agroclimatic zone covers the territory along the Black Sea coast, up to 200 m above sea level where Abasha, Zugdidi, Martvili, Senaki, partly Tsalenjikha, Khobi and Chkhorotsku municipalities are located. In the given area, along the Black Sea coast, there is a narrow strip of red-soil and podzolized soils. A bit far from this point, there are marsh-peats, and subtropical gleysols are found south, east and west of Khobi. Alluvial soils are spread around Abasha, Senaki and Khobi and partially, north-west of Chkhorotsku. North and east of Chkhorotsku, there are yellow soils spread and there are red podzolized soils spread around Zugdidi. Towards Mestia, there are brown acid and brown podzolized soils, and there are mountain-meadow turf soils north of Mestia [7, 8].

The factors in the given zone allow successful growing of cereals, vegetable-and-watermelons, citruses, some vine varieties (Tsolikauri, Ojaleshi, Tsitska), subtropical fruits, technical crops (tung, cherry laurel), kiwi (actinidia), nut, etc. Full ripening of oranges and grapefruit up to 200 m above sea level is limited due to the little necessary temperature sum in the vegetation period. In this zone, the production of citruses, besides warmth, depends on minimum winter temperatures, with the average indices of absolute air minimal temperature of -5°C to -6°C. These temperatures are not critical for citruses. However, they are more or less dangerous for lemon (unless it is protected against frosts). In the given region, the areas with citruses may be expanded over the elevated slopes and hills, excepting plains and basins.

The II zone covers the territory north of the I zone, as well as Zugdidi, Chkhorotsku, Tsalenjikha and Martvili municipalities. It is located at 200-500 m above sea level. There are following soil types in the given zone: alluvial (south of Tsalenjikha), podzol (west of it), as well as red podzolized soils. The agroclimatic conditions in the given zone are favorable to grow only mandarin and lemon (provided the latter is protected against frosts), where the average absolute temperatures do not exceed -7°C, -8°C. The distribution area of the said crops in this zone incorporates the territories of piedmonts, up to 200-250 m above sea level and 300 m above sea level at some locations. The conditions in the given region are favorable to successfully grow: tea, vine, fruits, subtropical fruits, cereals, vegetable, etc.

The III zone covers the area adjacent to the north of the II zone, including Khaishi and Lebarde. It is located at 500-1000 m above sea level. The following soil types are spread there: rendzic leptosols, brown and brown acid soils. The given zone is favorable to grow cereals, vine (late variety, up to 800 m above sea level), fruits, nut, walnut, vegetable, tea (up to 600-650 m above sea level). Other perspective varieties are vine (early and late varieties) at 800-900 m above sea level.

The IV zone covers the area adjoining the III zone from the north, including Mestia municipality, at 1000-1500 m above sea level. The sum of active temperatures in this zone is relatively less. Therefore, the possibility to grow thermophytes in this zone is somewhat limited. Therefore, only early vine varieties can be grown at 1200-1300 m above sea level (on the southern slopes), as well as cereals (wheat, barley, oats, rye, early corn varieties), vegetable, potato, nut, fruits and berries.

The V zone covers the area adjoining the IV zone from the north, at 1500-2000 m above sea level. The following soils types are spread within this zone: mountain-meadow turf, brown acid and brown podzolized. In this zone, the following crops can be grown successfully: spring wheat, barley, oats, potato, vegetable and berries (black currant, currant chokeberry, sea-buckthorn), as well as juicy root crops for cattle. Besides, hay meadows and pastures can be developed successfully.

The VI zone covers a relatively small area adjoining the V zone from the north, which is very high, is located within the Alpine zone, at 2000-2500 m above sea level. The following soil types are spread in this zone: mountain-meadow turf and brown podzolized soils. The climate in the given zone is totally Alpine. Therefore, the crops needing less sums of active temperatures (1000-1100°C) can be grown there: early potato, oats, barley and vegetable crops, as well as berries (blackcurrant, sea-buckthorn), root crops for cattle-breeding, and hay meadows and pastures can also be developed. The sum of said temperatures will be accumulated at 2100-2200 m altitudes above sea level.

Guria region covers partially hilly and high-mountainous relief and quite vast plain relief inclined towards the Black Sea, up to 100 m above sea level. The hilly locations are found up to approximately 400 m above sea level, the mountainous locations are found up to 1000 m above sea level, average-mountain relief is up to 1400 m above sea level and high-mountainous relief is at 2000 m above sea level. The given region is bordered by Ajara region from the south, partially by Samtskhe-Javakheti region from the south-east, by Imereti region from the north-east, Samegrelo-Zemo Svaneti region from the north and by the Black Sea from the west. The specific weight of Guria region in the development of agriculture of Georgia is very high, the following crops are produced in the region: cereals, tea, citruses, vine, subtropical, technical-oil-bearing and other crops. The agricultural crops are grown and produced in the region in terms of humid subtropical zone. Therefore, the leading branches in the region are: tea-growing and citrus-growing. Other important branches are: corn-growing, subtropical technical crops production, fruit-growing, etc. (Table 2).

Table 2. *Agroclimatic zones characteristics of Guria region*

Agroclimatic zones of Guria region	Sum of active temperatures (>10°C)	Atmospheric precipitations (mm)		Frosts		Duration of periods without frost (day)
		Cold period	Warm period	First frost	Last frost	
I – zone	4000	800-850	1000-1370	16.XII-25.XII	10.III-18.III	274-290
II – zone	3000-4000	850-900	1000-1200	11.XII-24.XII	11.III-21.III	265-288
III – zone	2000-3000	800	900	8.XI-26.XI	2.IV-18.IV	220-238
IV – zone	2000-1000	700	750-800	7.XI-20.XI	18.IV-27.V	202-113
V – zone	1000	650-700	700	20.IX-11.X	28.V-5.VI	96-113

The I zone covers the territory of Lanckhuti region, including the Black Sea coastal area and partially, the territory of Ozurgeti municipality. It is located at 10-200 m above sea level. The following soil types are spread in this zone: gleysols in the north, alluvial acid and marsh-peat soils in northwest, and red-soil and gleysols on the Sea coastal zone [7, 8]. The following crops can be grown successfully in the given zone: tea, citruses (mandarin, lemon), tung, kiwi (actinidia), feijoa, nut, vine (Tsolikauri, Chkhaveri, Izabela and some local varieties). As for the orange and grapefruit, full ripeness of their fruits, due to the little sum of active temperatures, is possible only 3 or 4 times in every ten years. The zone is also favorable to grow cereals, fruits and vegetable-and-watermelons.

The II zone covers the middle part of the region where the territories of Ozurgeti and Chokhatauri municipalities are located. The given zone is located at 200-300 m above sea level. The following types of soils are spread in the region: slightly alluvial and yellow podzolized north of Ozurgeti municipality, yellow soils and red soils east of Chokhatauri municipality and gleysols in the direction of the Sea coastal area. The given zone has quite favorable agroclimatic conditions in the west, on the piedmonts of Ozurgeti and Chokhatauri municipalities, at 200-300 m above sea level. Citruses (mandarin, lemon) can be grown successfully in the given zone, and vine, fruits, nut, cereals and other crops can be grown at higher altitudes. Tea can be produced at 500-600 m above sea level.

It should be noted that in the I and II zones, unless due protection is provided, lemon is expected to freeze for 3 or 4 times, orange and grapefruit - for 2 or 3 times in every ten years and mandarin - once in every 15 or more years.

The III zone spreads east and south-east of the II zone. It is located at 600-1000 m above sea level. The following soil types are spread in the east of the zone: yellow brown, red soils, brown acid soils and gleysols. The following varieties can be grown in the given zone: vine (average and early varieties), fruits, nut, berries, cereals, legumes and vegetable crops, as well as root crops for cattle-breeding and hay meadows and pastures can also be developed.

The IV spreads east and south-east of the III zone, from 1000 to 2000 m above sea level. The following types of soils are spread in the given zone: brown acid, yellow brown, red-soil and red podzolized soils. The sum of temperatures in the given zone does not support the ripening of perennial thermophyte fruits but the given zone is favorable for berries, cereals (grain corn at 1000-1200 m above sea level), wheat, barley, oats, legumes and vegetable. The given zone is also favorable to grow juicy forage root crop for cattle-breeding and to develop for hay meadows and pastures.

The V zone is relatively smaller and spreads south-east and south of the IV zone, at 2000-2200 m above sea level. The following types of soils are spread in the zone: brown podzolized, red-soil, red podzolized and brown yellow soils. The following crops can be grown in the given zone: berries (black currant, chokeberry, willow-leaved sea-buckthorn, etc.) and vegetable crops (fenugreek, fennel, cumin, garlic, onion, parsley, celery, radish, cauliflower and early cabbage, carrot, etc.), as well as forage root crops for cattle-breeding; besides, hay meadows and pastures can be developed.

Imereti is located in the center of Georgia, at 20-1500 m above sea level and higher. Following its relief conditions, it was named as Kvemo (Lower) Imereti and Zemo (Upper) Imereti. A part of Kvemo Imereti has a plain and low piedmont relief, while Zemo Imereti has a hilly relief spreading over quite large areas. In an agricultural respect, the territory of Zemo Imereti at 400-600 m, has a more complex relief. Therefore, grain-growing, vegetable growing, fruit-growing, vine-growing, etc. are better developed over the plains. Most of the area at 600-800 m is presented as dissected gorges. The said crops can be grown only over small number of land plots. The territory above 1000 m above sea level, due to the great inclination, is mostly presented by forests and hay meadows and pastures [9]. Imereti region is bordered by Mtskheta-Mtianeti region from the east, by Samtskhe-Javakheti region form the south, by Racha-Lechkhumi-Kvemo Svaneti region from the north and by Samegrelo-Zemo Svaneti region from the west. Agroclimatic resources of Imereti are favorable to grow many kinds of crops, particularly, cereals, vegetable, vine, fruits, etc. The specific weight of corn is high among the cereals and vegetables are also grown intensely. Another successful branch in the region is vine-growing. In addition, the region offers favorable conditions to develop such branches as cattle-breeding, poultry-raising, bee-raising and sericulture (Table 3).

Table 3. *Agroclimatic zones characteristics of Imereti region*

Agroclimatic zones of Imereti region	Sum of active temperatures (>10°C)	Atmospheric precipitations (mm)		Frosts		Duration of periods without frost (day)
		Cold period	Warm period	First frost	Last frost	
I – zone	>4000	640-830	600-1000	12.XI-30.XI	12.III-2.III	251-274
II – zone	3000-4000	450-950	450-1190	20.XI-29.XI	24.III-1.IV	194-249
III – zone	>2000	600-750	640-850	31.X-18.XI	2.IV-18.IV	185-231
IV – zone	>1000	600-700	900-950	17.X-27.X	23.IV-1.V	176-188
V – zone	<1000	800	1000	13.X	5.V	158

The I zone covers the plain (lowland) of Kvemo Imereti) and hilly locations of Zemo Imereti at 20-300 m above sea level. There are different soil types spread in the zone, e.g. west of the zone, around Samtredia and Khoni municipalities, there are alluvial calcareous soils, there are subtropical podzols south of Khoni, red-soils in the north and yellow soils in the north-east. South and west of Tskaltubo, there are subtropical podzols; there are yellow soils in the north and rendzic leptosols in the east; there are yellow-soils around Vani, and alluvial satiated soils in the north; there are yellow and limestone-calcareous soils around Bagdati and there are subtropical podzols in the north of it; north of Zestaponi, there are alluvial-calcareous soils, and there are rendzic leptosols in the south-west and east of it. East of the given zone, around Kharagauli, there are rendzic leptosols, and there are brown yellow-soils little eastwards [7, 8]. The agroclimatic resources in the given zone are favorable to grow many different kinds of agricultural crops, in particular, cereals, vine, tea, mandarin, lemon (provided the it is protected against the freeze), kiwi (actinidia), feijoa, subtropical persimmon, essential oil-bearing crops, nut, tung, continental fruits, vegetable-and-watermelons, etc. In some years, guaranteed harvest is possible to gain only if the soil is duly moisturized, mostly in the regions where the atmospheric precipitations are 700 mm or less.

The II zone borders the first zone from the north, east and south. It is located at 300-500 m above sea level. In the northern and southern parts of the given zone, there are yellow soils, and there are rendzic leptosols in the east. South of Tkibuli, there are yellow-brown soils spread. The same soil type is spread east of Kharagauli; immediately east of the given zone, east of Sachkhere, there are yellow-brown soils, and there are of rendzic leptosols spread in the south of the zone. It is possible to grow cereals, vine (early and late variety) fruits, vegetable and other crops in this zone. In some years when the atmospheric precipitations are 700 mm and less, it is recommended to increase moisture in the soil to gain the guaranteed harvest.

The III zone covers the area adjoining the II zone from the north-east, east and south, at 500-1000 m above sea level. Red soils are spread in the north-west of the given zone; there are intensely washed-down soils north and east of Tkibuli; there are limestone-calcareous soils east of Sachkhere and yellow brown soils east of Kharagauli. It is possible to successfully grow cereals, vegetable, vine (early variety) and fruit in the zone.

The IV zone covers the territories adjoining the III zone from the north-east and south, at 1000-1200 m above sea level. The following soil types are spread in this zone: limestone-calcareous soils in north-east and yellow-soils in the south of the zone. The following agricultural crops can be grown within the given zone: cereals, potato, vegetable, some early fruits and berries, and it is possible to develop hay meadows and pastures for cattle-breeding.

The V zone spreads in the extreme north-western and extreme southern parts of the region, at 1200 m and higher. The soil types in this zone are the same as in the IV zone. The following crops are perspec-

tive to develop in the zone: vegetable, berries and juicy root crops for cattle-breeding, and besides, hay meadows and pastures can be intensely developed.

Racha-Lechkhumi-Kvemo Svaneti region has a complex hilly-mountainous relief (plains, mountains, mountain slopes, gorges). The region is located on the southern slopes of West Caucasioni where Caucasioni watershed ridges and glaciers surrounding the area provide the conditions unfavorable for the sustainable development of agriculture in the region. The area of the plain relief in the region below 500 m above sea level is very small (2,2% of the total area). Village Tvishi is located at the lowest hypsometric altitude (400 m) and Mtiskalta is located at the highest hypsometric altitude (1840 m) [10]. Racha-Lechkhumi-Kvemo Svaneti region is bordered by Caucasioni Mountain from the north, partially by Shida Kartli region from the east, by Imereti region from the south and by Samegrelo-Zemo Svaneti region from the west and partially, from the north. The said region occupies the area up to 800-1000 m above sea level, in the moderate climate zone, while above this altitude, it is located in the continental climate zone (severe climate zone). Following relatively severe climatic conditions and complex relief, the plots of agricultural lands are few in number limiting an intense development of versatile branch of agriculture. Despite this, the dominating agricultural crops in the region, depending on relevant conditions are: vine, fruits, cereals and legumes. The soil and climatic conditions favorable to grow vine are mostly observed in the lowland and over the mountain slopes up to the altitude of 400-800 m. It is also promising to grow stone fruits, nuts and berries (Table 4).

The I zone covers the area of the region, in particular, western part of Oni region, central areas of Ambrolauri and Tsageri municipalities and southern part of Lentekhi municipality. The given zone is located at 400-800 m above sea level. Raw Humus Calcareous soils, rendzic leptosols and humus-acid soils are spread around Ambrolauri municipality. Soils of similar types are spread in Oni, Tsageri and Lentekhi municipalities [7, 8]. The agroclimatic conditions in the given zone, as compared to other zones, are most favorable to develop and grow many different agricultural crops. (Winter and spring) wheat, corn, barley, vine, fruit, kiwi (actinidia), vegetable and watermelons can be grown successfully in this zone. In the given zone, in the environs of Tsageri region, in village Tvishi (400-500 m above sea level), it is possible to grow dry subtropical crops (fig, pomegranate and subtropical persimmon). In some years, during intense winter frosts (-18°C, -19°C), the probability of preventing them from damage is low (%). The said crops freeze to the root collar once in every ten years, while 3-year-old plantings freeze by 3 or 4 times, 2-year-old plantings - by 5 times and 1-year-old plantings freeze by 7 times in every ten years. Clearly, growing them is associated with certain risks. However, these crops are perspective and it will be useful, if during the frosts (-15°C, -16°C or more), the relevant measures to protect them against the frosts are taken.

The II zone spreads over the territory adjoining the I zone from the east, north and west and it

Table 4. *Agroclimatic zones characteristics of Racha-Lechkhumi - Kvemo Svaneti region*

Agroclimatic zones of Racha-Lechkhumi - Kvemo Svaneti region	Sum of active temperatures (>10°C)	Atmospheric precipitations (mm)		Frosts		Duration of periods without frost (day)
		Cold period	Warm period	First frost	Last frost	
I – zone	3000-3600	420-550	630-750	31.X-13.XI	3-5.IV	199-222
II – zone	2000-3000	550-800	800-1300	9.X-29.X	17.IV-5.V	155-193
III – zone	2000-1000	500-550	700-800	23.IX-8.X	6.V-20.V	124-153
IV – zone	1000-600	550	800	15.IX-22.IX	21.V-27.V	110-123

also covers a small area in the south. It is located at 800-1400 m above sea level. The following types of soils are spread in the region: rendzic leptosols, mountain-meadow peat and brown acid soils. Cereals (winter and spring wheat), corn, vine (early), fruit, vegetable and other crops can be grown successfully in this zone.

The III zone covers the area adjoining the II zone from the east, north and west, at 1400-1800 m above sea level. The following types of soils are spread in the region: brown-podzolized, mountain-forest-meadow and mountain-meadow peat soils. Cereals (winter and spring wheat, barley and oats), potato, vegetable, berries and root crops for cattle can be grown successfully in this zone, and pastures and hayfields can be developed.

The IV zone covers the area adjoining the III zone from the north and partially from the east. It is located at 1800-2000 m or higher above sea level. There are mountain-meadow turf soils in the given zone. Some perspective vegetables and berries approved for growing in the high mountains giving rich harvest (fenugreek, coriander, fennel, anise, parsley, celery, potato, black currant, etc.) can be grown in the given zone. Besides, the zone offers favorable conditions to intensely grow juicy root crops for cattle-breeding and expand hay meadows and pastures.

In a geomorphological respect, **Ajara region** has quite a complex relief: lowlands, hills, deep gorges, and average and high mountains. The Black Sea coastal lowland is located at about 100 m above sea level, the hilly relief is found at 500 m above sea level. Average-mountainous relief is found at 1000 m above sea level, and high-mountainous relief is located at 2000 m or higher. The lowlands in the given areas occupy 13.6%, hills occupy 9.3%, and mountains and piedmonts occupy 77.1%. The region is bordered by Turkey from the south, by Samtskhe-Javakheti region from the east, by Guria region from the north and by the Black Sea from the west. Ajara region is located in the humid subtropical zone of West Georgia with its upper border reaching 500-600 m above sea level. Higher that altitude, the climate is relatively more moderate and continental. Therefore, various agricultural branches are developed in the given region: tea-growing, citrus-growing, corn-growing, and tobacco-growing tung growing, etc. as cultural crops. The agroclimatic conditions of the region support the development of the branch of subtropical and continental fruit-growing as well. In addition, the region offers favorable conditions for vine-growing (different varieties), potato-growing, vegetable-growing, etc. (Table 5).

Table 5. *Agroclimatic zones characteristics of Ajara region*

Agroclimatic zones Ajara region	Sum of active temperatures (>10°C)	Atmospheric precipitations (mm)		Frosts		Duration of periods without frost (day)
		Cold period	Warm period	First frost	Last frost	
I – zone	>4000	1150-1290	1360-1500	2.XII-7.I	4.III-15.III	246-304
II – zone	3000-4000	850-1100	800-1330	6.XII-1.I	13.III-26.III	255-273
III – zone	2000-3000	700-750	750-800	11.XI-1.XII	30.III-15.IV	202-247
IV – zone	2000-1000	700	800	14.X-7.XI	18.IV-8.V	158-202
VI – zone	<1000	650	700	20.IX-9.X	12.V-28.V	158-113

The I zone covers the low part of the Black Sea coastal zone, including the territories of Kobuleti and Khelvachauri, at 100-200 m above sea level. There are soils typical to the humid subtropics spread within the given zone: subtropical gleysols west of Khelvachauri and alluvial soils on the Sea coastal lowland [7, 8]. The given zone offers favorable conditions to grow tea, citruses (mandarin, lemon, orange, grapefruit), tung, kiwi (actinidia), feijoa, nut and vine (Tsolikauri, Izabela and some local varieties). Full ripening of orange and grapefruit is possible only 5 or 6 times in every 10 years. The zone offers favorable agroclimatic conditions to grow cereals, legumes, subtropical persimmon, fruits and other crops [11].

The II is relatively vast and covers the territories of Kobuleti, Kedi and partially Shuakhevi regions. The zone is located at 200-400 m above sea level. The following soil types are spread in the region: brown yellow-soils are spread in all parts of Kedi region and mountain-meadow turf and brown acid soils are spread in the east. The given zone has humid subtropical conditions offering favorable conditions to grow the crops specified for the I zone. Orange, grapefruit or mandarin late varieties cannot yield desirable commercial results due to the little sum of active temperatures in the zone. Lemon in the I and II given zones may freeze twice or 3 times, while mandarin may freeze once in every 20 years unless provided by relevant protection.

The III zone is located in the central part of the region, at 500-1000 m above sea level and covers the territories of Shuakhevi and Khulo regions. From all sides of Shuakhevi municipality, there is brown yellow-soil spread, while brown acid soils are spread in the north and south. It is promising to grow the following crops in the given zone: cereals, legumes, vegetable, vine (average and early varieties), fruits, nut, berries, etc. The given zone is also favorable to grow root crops for cattle-breeding and for developing hay meadows and pastures.

The IV zone spreads north, east and south of the region, over small areas. It is located at 1000-1500 m above sea level. There are brown yellow-soils and brown acid soils in the region [7, 8]. It is possible to grow wheat, barley, oats, grain corn (1000-1100 m above sea level), potato, vegetable, fruits and berries in the given zone. It is also possible to grow root crops for cattle and to develop hay meadows and pastures.

The V zone spreads in the extreme eastern part of the region and a small part of it spreads north-east of it. It is located at 1500-2000 m above sea level. During the vegetation period, the zone obviously lacks warmth. The soil types are not diversified. Brown acid soils are spread in the west, and brown podzolized soils are spread in the north and east. The following crops are perspective to grow in the zone: vegetable (coriander, fennel, garlic, fenugreek, beet, etc.) and berries (blackcurrant, chokeberry, sea-buckthorn cultural variety, etc.). The given zone is favorable to grow juicy root crops for cattle and for hay meadows and pastures.

The relief in **Apkhazeti** region is hilly, mountainous or high-mountainous (2000 m above sea level and more) and presents a low plain location along the Black Sea coastline, which spreads more extensively south-east (50 m above sea level) [12]. The region is bordered by Russia from the north-west, it is bordered by Caucasioni Ridge from the north, by Samegrelo-Zemo Svaneti region from the east and the Black Sea from south-west. Apkhazeti is located in the humid, subtropical climatic zone of West Georgia. Therefore, the agroclimatic conditions of this region are favorable to develop intense subtropical farming (tea, citruses, oil-bearing and essential-oil-bearing, vine, continental fruit, etc.), (Table 6).

The I zone covers the plain zone of the Black Sea coast and hilly locations at 250-300 m above sea level. The soil types spread in the given zone are typical to the subtropical zones, in particular, subtropical podzols, red-podzolized, yellow-podzolized, and partially, alluvial soils. Yellow and red soils are spread in Gali municipality, as well as subtropical podzols and subtropical gley soils. Subtropical podzol, subtropical gley soils and brown podzolized soils are spread in Gulripshi region. There are alluvial-calcareous and yellow soils north of Sokhumi, while subtropical gleysols are spread north-east of Gudauta municipality. Subtropical podzol, yellow- and brown yellow-soils are spread south-east of Gagra [7, 8]. The agroclimatic conditions of the given zone are favorable to grow tea, citruses, vine, tung, kiwi (actinidia), feijoa, nut, subtropical persimmon, fruits, as well as cereals (corn, wheat) and vegetables and watermelons. In this zone, it is also possible to grow essential-oil-bearing crops and to gain two harvests of geranium. The first harvest is gained at the end of the III decade of July and the second harvest is gained from October 15 until the onset of frosts. In some years, it is also possible to gain two harvests of East Indies basil. Jessamine and essential-oil-bearing rose can also be grown. In the given zone, where the average absolute min-

Table 4. *Agroclimatic zones characteristics of Racha-Lechkhumi - Kvemo Svaneti region*

Agroclimatic zones Abkhazia region	Sum of active temperatures (>10°C)	Atmospheric precipitations (mm)		Frosts		Duration of periods without frost (day)
		Cold period	Warm period	First frost	Last frost	
I - zone	>4000	730-970	710-1010	13.XII-25.XII	10.III-20.III	269-291
II - zone	3000-4000	850-950	1100-1400	2.XII-6.XII	25.III-28.III	251-260
III - zone	2000-3000	900-1000	1000-1300	7.XI-26.XI	3.IV-18.IV	238-202
IV - zone	1000-2000	800-1300	900-1100	14.X-5.XI	22.IV-8.V	157-198
V - zone	<1000	850-1400	1150-1200	20.IX-7.X	14.V-28.V	144-113

imum temperature of -5°C is observed, it is not recommended to grow lemon unless it is protected against the frost, while in Gagra, Sikharuli, Bichvinta, Akhali Atoni, Eshera and Gulripshi (with the temperature of -4°C) lemon can be grown successfully, without any protection.

The II adjoins the I zone from the north and is located at 350-500 m above sea level. It spreads from Gali municipality to Psou River. The following types of soils are spread in the region: red-soil-podzolized, Raw Humus Calcareous, brown acid, rendzic leptosols, yellow-podzolized, subtropical podzol and yellow soils. In the given zone, it is possible to grow early varieties of mandarin. Production of oranges and grapefruit is limited due to the lack of the necessary sum of active temperatures. Lemon needs annual protection against frosts. Mandarin, orange and grapefruit may be damaged once or twice in every 10 or 15 years. The zone is favorable to grow and gain rich harvest tea, vine, cereals, fruits, vegetable and other crops.

The III zone covers the area adjoining the II zone from the north and is located in the center of the region, at 600-1000 m above sea level. The following types of soils are spread in the zone: mountain-meadow turf, brown acid and brown podzolized. The following crops can be grown successfully in the given zone: fruits, vine (early varieties), cereals, legumes and vegetable. In the piedmonts, it is possible to grow geranium and essential-oil-bearing rose. One harvest of them can be gained from the first decade of October.

The IV zone also includes the area adjoining the III zone from the north and is located at 1050-1500 m above sea level. The following soil types are spread in this zone: mountain-forest-meadow peat and mountain-meadow turf soils, as well as brown acid soils. The following agricultural crops can be grown in the given zone: cereals (wheat, oats, barley), early corn (1000-1100 m above sea level), potato, vegetable, continental fruits (apples, pear), stony fruits (plum, etc.) and berries (black-currant and redcurrant, etc.), as well as root crops for cattle-breeding and beside, hay meadows and pastures can be developed successfully.

The V zone spreads in the extreme northern area adjoining the IV zone and is located at 1600-2000 m above sea level. The following types of soils are spread in the zone: mountain-meadow turf, brown acid and podzolized soils. The following crops are perspective to grow in the given zone: vegetable and berries (black currant, sea-buckthorn, etc.), as well as root crops for cattle-breeding and besides, hay meadows and pastures can be developed.

Conclusion and recommendations

Due to the climatic, orographic and other conditions on the territory of West Georgia, the distribution of agroclimatic resources is different. Efficient use of agroclimatic resources is of a particular importance to make farming profitable. Successful

farming basically depends on the rational distribution of the agricultural crops in the specific area by considering their demands to agroclimatic conditions. Based on the data of 60-year-long meteorological observations, depending on the sum of active temperatures (>10°C) and atmospheric precipitations (mm), for the 6 regions in West Georgia, the following agroclimatic zones were identified based on vertical zoning, in particular, 6 agroclimatic zones for Samegrelo-Zemo Svaneti, 5 agroclimatic zones for Guria, 5 agroclimatic zones for Imereti, 4 agroclimatic zones for Racha-Lechkhumi-Zemo Svaneti, 6 agroclimatic zones for Ajara and 5 agroclimatic zones for Apkhazeti. By considering the given zones, it is possible to develop branches of agriculture (grain-growing, tea-growing, citrus-growing, vine-growing, fruit-growing, vegetable-growing, potato-growing, cattle-breeding, etc.). For the agroclimatic zone identified in each region, the parameters of atmospheric precipitations (in the cold and warm periods), frosts (the first and the last one), period without frost, as well as relevant soil types were specified. The sums of active temperatures (>10°C) used to evaluate the thermal regime in the vegetation period varies by ±300-400°C and more. The lack of the given sum results in a sharp reduction of the harvest, and vice versa.

It should be noted that in the agroclimatic zones, where the negative impact of frost is expected on the agricultural crops, it is necessary to apply physical and biological methods against the frost. Consideration of the recommended agroclimatic zones and climatic parameters will help the farmers select perspective agricultural crops to grow specific crops, plan their farming in an expedient manner and select the right type of agricultural production.

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