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Ranking of Feijoa (FEIJOA Sellowiana) in Subtropical Humidified Zone of Adjara and Forest Ecosystem by Multiple-Factor Approach

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Abstract

It was elaborated a method of agro-ecosystem ranking for feijoa culture and forest ecosystem in one of regions of Western Georgia—Adjara subtropical humidified zone. On the basis of mineralogical and morphometric analysis (biometric parameters, beginning and end of growth, beginning of fruit ripening and mass ripening, frost resistance etc.) of feijoa culture (Feigoa selliowiana) and by multiple-factor approach we have evaluated culture's rational disposition and optimal environment for development of land. The main accent was made on geomorphological (relief, inclination, exposition) and agro-climatic (sum of active temperatures, hydrothermal coefficient, temperature conditions, physical and chemical features of soil) factors. As a result of implemented zoning a landscape zone with agricultural resources potential and hypsometrical levels optimal for development of feijoa culture was revealed. During the research we also revealed corresponding agro-ecosystem zone, compatible with feijoa zone, evaluation of quality of forest land and determination of ecosystem and its indicating character. For determination of compatibility of feijoa plants and distribution of forest ecosystem we have created a map of large-scale ecosystems and geo-information system. By Cartometric and geographic-informational analysis, it became possible to find information about types of forest ecosystems, areas occupied by them and their share in researched zone.

Keywords

Agriculture, Forestry, Resource Potential, Control Sorts, Geography, GIS

1. Introduction

One of the main priorities for economic development of Georgia are agricultural ecosystems, which are represented in diversity on the territory of Georgia (Agricultural Sector, 2011; Agriculture of Georgia, 2011) and it's natural, as local nature preconditions optimal development of multi-field agricultural, including subtropical cultures (in Western Georgia).

Further adaptation and intensification of agricultural resources require in-depth study of agricultural ecosystem and scientific analysis of intensity of ongoing natural processes and mapping, which shall promote system sustainability and keep natural balance, as well as introduction of cultural vegetation cultures and elaboration of successful agrotechnical measures. All the above shall represent a reliable ground for increase effectiveness of agriculture production.

For spreading of subtropical cultures in Georgia, especially against the background of global climate change, reaction of landscapes towards the problem is very important (Seperteladze et al., 2012; Elizbarashvili et al., 2014; Seperteladze et al., 2014a; Seperteladze et al., 2015a; Seperteladze et al., 2015b; Seperteladze et al., 2017; Seperteladze et al., 2019). In addition, reaction of humidified landscapes in Western Georgia is different from reaction of semiarid and arid landscapes in Eastern Georgia. Namely, the tendency of decrease of precipitations in humidified landscapes in Western Georgia, minor increase of air temperature and other negative natural processes should be considered during determination of plantation and frost resistance of citrus plants.

Citrus planting in Georgia is considered to be high-intensity and commercial field (Klitsunova, 2007; Nikolaishvili, 2008). Among citrus cultures, tangerine is on the first place the area of spreading and importance, which is preconditioned by its significantly high frost resistance and profitability. As to FEIJOA Sellowiana, it came to Georgia from the beginning of the 20th century and at that time its amount was 200 shrubs. Afterwards area occupied by the culture increased and currently feijoa occupies about 500 hectares.

2. Study Area

Feijoa is a plant with a long span of life. It is confirmed by 48 - 50 years plants, which have no sign of aging. In Georgia requirements of the crop for development and fruit-bearing are completely satisfied by physical-geographical, namely agricultural and climatic conditions of Adjara, Guria, Abkhazia, Imereti and Samegrelo regions.

Among agricultures of humid-subtropical zone Feijoa Sellowiana is distinguished by its taste, its nourishing and medical features. Thus, introduction of feijoa of South American origin in European, Mediterranean countries, USA, New Zealand, Crimea and the Black Sea coast in Caucasus, namely in Georgia may be considered only as a positive event.

Trial plots of feijoa culture have been functioning over the years in one of Georgian regions—Adjara, where a group of authors (Seperteladze et al., 2012;

Seperteladze et al., 2014b) successfully supervises the culture; however these plantations do not comply with corresponding requirements, which is caused by diversity of sort and inefficiency of agro technical measures and apart of that, in our opinion it is caused by unintended corresponding environment and ecology (plant requirement to environment conditions).

We consider the following agro-chemicals as agricultural climate index for widespread of FEIGOA Sellowiana culture:

- Sum of active temperatures: 2500˚ - 3000˚
- Hydrothermic coefficient: 2.5 - 3
- Annual precipitation: 1800 - 2500 mm
- Average minimum of absolute minimal temperature: −6˚
- Average annual temperature: 12˚ - 13˚
- Average temperature of the coldest month: 3˚ - 5˚
- Highest hypsometric level: 700 m (where temperature of the coldest month is positive)
- Fruit ripening period (from blossoming to ripening): 120 - 170 days
- Soil PH-factor: 5.5 - 7.6

Sandy light and alluvial soils are optimal and best condition for high yield of feijoa (also it easily gets used to and grows well in oxyphilous, less oxyphilous and red soil with alkaline reaction, subtropical podsol and turf-carbonate soils (Nikolaishvili & Matchavariani, 2010; Urushadze et al., 2012).

One of the main geomorphological factors of optimal conditions for spreading feijoa is inclination and decomposition of relief, exposition and hypsometry. Area for spreading feijoa is represented by hilly, shrubbery landscapes to the South, South-West and South-East plateaus, total area of which in the research region makes up to 41% (**Figure 1**). Feijoa may also be planted on 5˚ - 10˚, 10˚ - 15˚, and 15˚ - 25˚ inclination plateaus, total area of which amounts to 88% (**Figure 2**). Under optimal plantation of feijoa, it should be also considered that relief of hilly, shrubbery areas is divided by gorges, that's why for planting we should use foothills and not bottom of gorges and plains.

3. Methods of Research

It is known that spreading and fruit-bearing of agricultural crop is firstly determined by warmth and humidity, namely: correlation of temperature indices and coefficient of humidity, i.e. hydrothermal coefficient (**Table 1**), however along with that, other physical-geographical conditions (hydrographic and edaphic) play an important role as well. Western part of Georgia, namely Adjara is distinguished with the above-mentioned conditions, namely: excessive humidity, high temperature, sun radiation and high rates of luminescence duration, seasonal change of western and eastern winds, advection of cold air masses, which causes abrupt change of weather conditions, etc. (Meladze & Meladze, 2012; Seperteladze et al., 2012). All of that has a particular impact on growing and development of agriculture, productivity and geographic widespread and distribution.

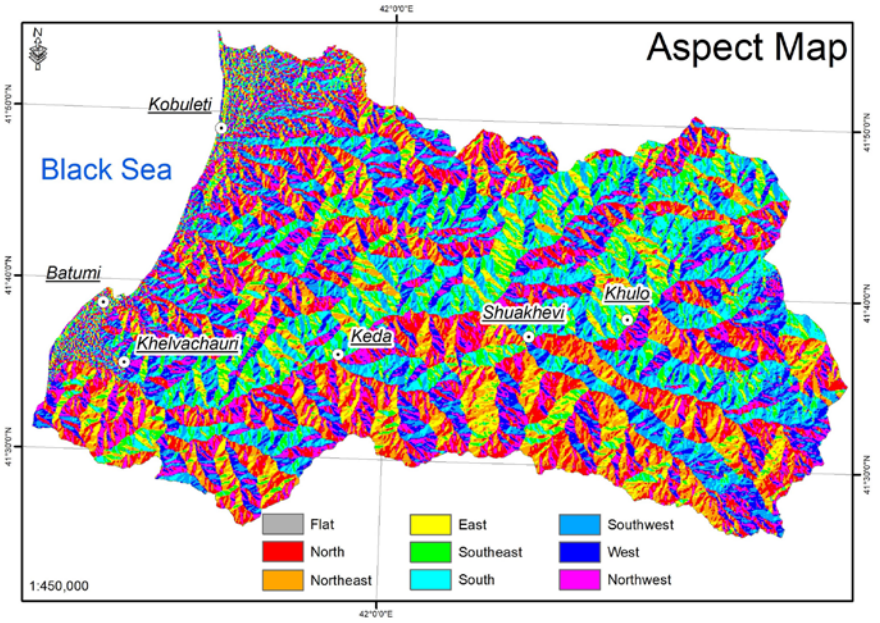

Figure 1. Aspect map.

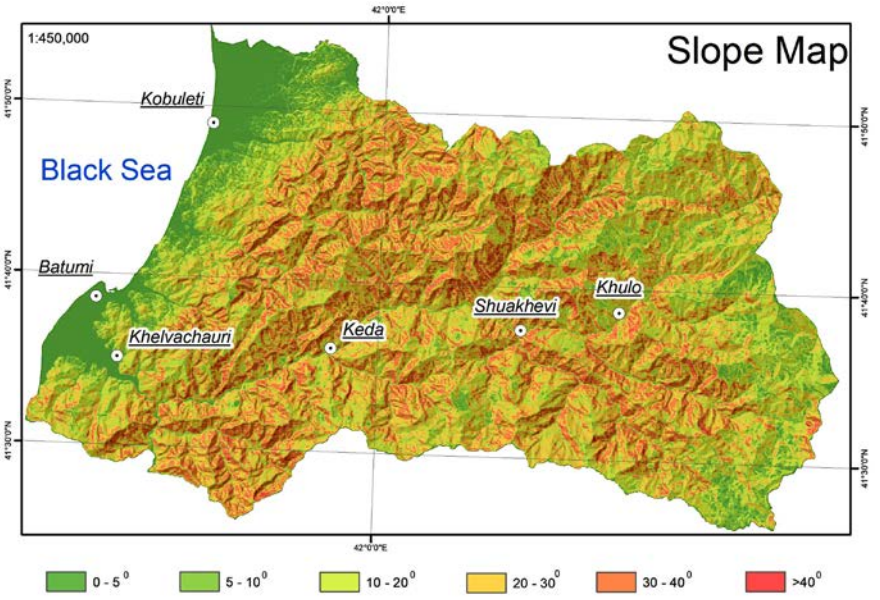

Figure 2. Slope map.

Table 1. Different provisions of the hydrothermal coefficient (HTC) in the vegetation period of Feijoa.

HTC	Provision (%)				
	90	75	50	25	5
1.5	1.0	1.3	1.5	1.9	3.1
2.0	1.5	1.8	2.0	2.6	4.7
2.5	1.9	2.3	2.5	2.9	5.0
3.0	2.2	2.6	3.0	3.6	5.5
3.5	2.5	3.0	3.5	4.0	5.9

Notwithstanding the fact that Adjara is characterized by high overcast and excess of precipitations, sun luminescence here is higher and ranges between 1800 - 2300 hours, total radiation of sun per year amounts to 120/130kkal/cm^2.

Considering critical temperatures (**Figure 3**), namely, according to probability of these temperatures, a probability of damage of citrus plants was revealed in Adjara and we have received the following picture: in −4˚ temperature zone (Black Sea coast) damage of lemon is forecasted once in 4 years (25% probability), in −6˚ zone orange Washington Neville may be damaged once in four years, and tangerine Unshiu is damaged quite rarely—once in 20 years (5% probability). As to feijoa, as compared to other subtropical cultures it is more frost resistance and is used to −12˚ (Davitaia & Seperteladze, 2009), its 2 - 3 years old branches are used to 13˚ - 14˚, and in conditions of −15˚ - 17˚ the surface of any soil is frozen, however during the next spring it gives sprouts and harvest in two years.

One of the factors of frost resistance is considered to be preparation of plant for winter, i.e. tempering, which can be successful when seasonal temperature is lowered gradually. Also, additional measures must be taken: selective, agrotechnical and ecological. In the present article, we will focus on the last two factors in relation to FEIJOA Sellowiana culture. We have studied some economic and biological peculiarities of some feijoa fruit (The Conception of the Development of Agriculture of Georgia, 2012; Seperteladze et al., 2014b) afterwards the state Georgian agricultural products picking commission introduced it into citrous zone in Adjara-Guria and Samegrelo.

Natural (landscape), namely agriculture climate resources (duration of sun luminescence, sum of active temperatures, precipitations, humidity of soil and air, etc.) of the territory should be used for maximal profitability of agriculture, which may be effectively used in some regions for growth and development of agricultural crops and their rational disposition-distribution (zoning). From this point of view, we (Kozarenko, 1980; Seperteladze et al., 2012) have separated 7 agro climatic zones (**Table 2**) in Western Georgia.

4. Results and Discussions

As a result of implemented researches, on the basis of received database it was determined that most suitable physical and geographical (soil climatic) conditions for spreading of citrus plants in Western Georgia are revealed in 3 hypsometric agroclimatic zones (I, II, III) and from regions—Adjara (**Figure 4**).

For the growth and development of citrus cultures Adjara is the most favorable natural conditions. In general, 5 agro-climatic zones are allocated in Adjara, on the basis of which only two agro-ecosystem zones are currently allocated for the growth and development of citrus. D. 30 - 500 m a.sl. range:

I zone (at 30 - 200 m)—the sum of active temperatures exceeding 40,000; Number of atmospheric precipitations in the warmest period is 1360 - 1500 mm; Last froze—4. III—15. III, first froze—2. XII—7. I.; Number of days of freezing—246 - 304; The prevailing soil type—subtropical, red and alluvial;

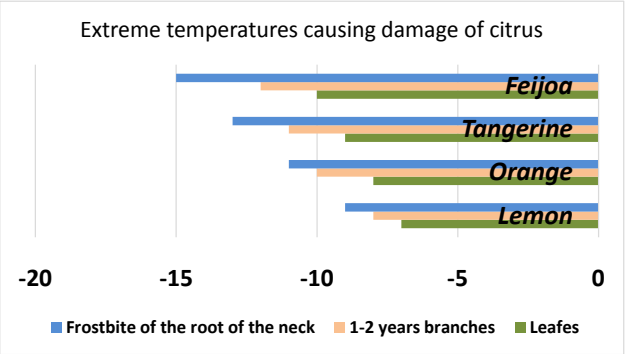

Figure 3. Extreme temperatures causing damage of Citrus.

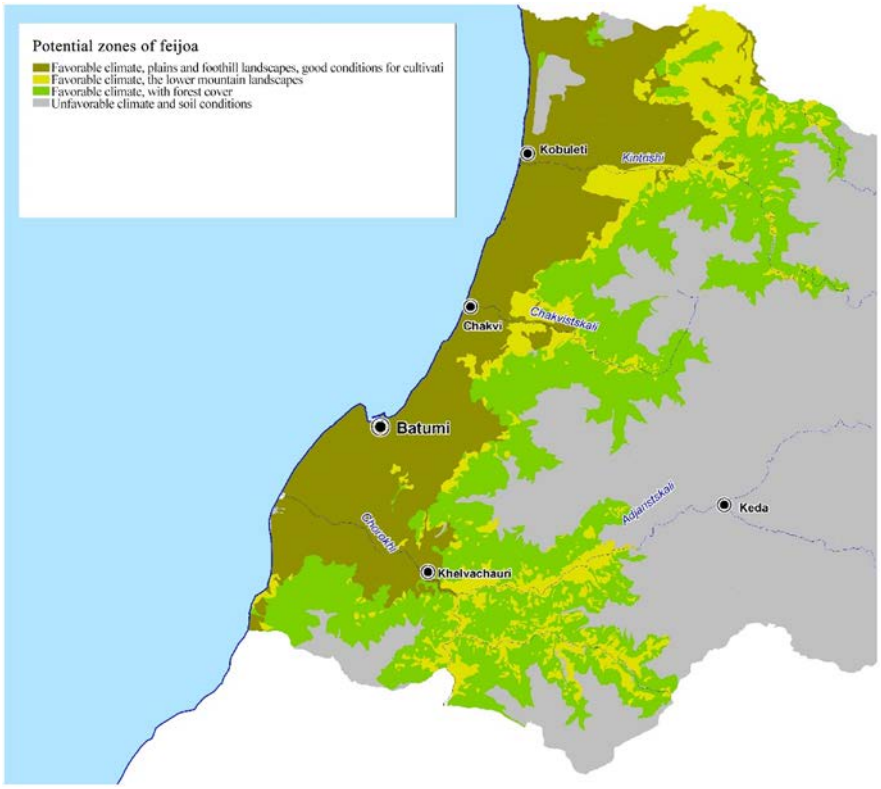

Figure 4. Potential zones Feijoa plants spread in Adjara.

Table 2. Agro-Climatic zones in Western Georgia.

Zone	Altitude from sea level (m)	Actual temperature total (more than 10%)	Average of absolute and minimal temperature (˚C)	Nonfreezing days
I	30 - 200	4000 - 4500	−3	**280 - 310**
II	200 - 500	3000 - 4000	−14 - 16	**190 - 275**
III	500 - 700	2500 - 3000	−18 - 8	**186 - 267**
IV	700 - 990	2500 - 3000	−12 - 22	**175 - 216**
V	991 - 1250	2000 - 2500	−14 - 23	**140 - 205**
VI	1251 - 1750	1500 - 2000	−15 - 28	**120 - 180**
VII	**1751 - 2100**	**1000 - 1500**	**−19 - 29**	**100 - 150**

The II zone (200 - 500 m asl) is more extensive and consists mostly of sloping plains and adjoining hills. The sum of active temperatures is 3000 - 40,000; Number of atmospheric precipitations in the warmest period of 800 - 1330 mm; Last froze—13. III—26. III, First froze—6. XII—1. I. The number of days of freezing—255 - 273. The prevailing soil type—red and yellow.

As for the III agro-ecosystem zone recommended by us, it applies to the 500 - 700 m asl, covering mainly the foothills and lowlands. Sum of active temperatures from 2500 to 30,000; Number of atmospheric precipitation in the warmest period of 1600 - 2300 m; Dependency coefficient—2 - 3; Average temperature of January 0 - +30, average temperature of July is 20 - 220, the prevailing soil type - yellow, the number of humus is high (8% - 10%), rich in nitrogen, relatively low in phosphorus, has high water efficiency, which is important in terms of slow down erosion processes. Number of freezing days—200 - 210. Abs. Minimum temperature is −12 - 170 (rarely only anomalous case).

The agro-climatic characteristics therefore satisfy the optimal conditions for the growth and development of Feijoa (forest-free territories and separate sections of the river valley), III to allocate agro-ecosystem zone, which naturally increases the area and therefore yield.

Based on Climatic and landscape features of study area, Colchis evergreen, humid landscape is favorable for feijoa plants, which occupies hill and foothill zone of Achara region. It is restricted by Achara-Imereti ridge south slope and Achara cavity, because of oro-climatic barriers, there is a sharp decrease of precipitation, which is unfavorable for Feijoa plants (Seperteladze, 2009; Urushadze et al., 2012).

In Achara plain restricted zone for Feijoa plants are soil moisture and soil-edaphic factors. There is a soil swamping. Swampy ecosystems plays a role for existence of swamp ecosystems, flora and fauna and their ecological cycle are associated with these ecosystems, so their deterrence and replacement of any kind of plants (including feijoa) are a major mistake, as there are a number of negative effects that can be expected, which affect adjacent ecosystems and society.

Thus, of the cultivation of plants Feijoa part of its territory is inexpedient. However, the Feojoa Zone itself, which covers 30.5% of the Adjara region, is divided into separate categories, subzones (**Table 4**), which are caused by climatic, edaphic and relief factors, also existing vegetation, which is covered by natural forest and its maintenance is necessary for the region (Agriculture of Georgia, 2011; Urushadze et al., 2012).

It was created a table, containing precise areas of the above zones (calculated by means GIS technologies) and their specific share (**Table 3**) out of total area of the region. Also, we have created maps depicting spreading of feijoa zone and its categories.

First category region occupies 14.32%, which approximately makes up 43,414.39 ha. It corresponds to mountainous hilly shrubbery landscapes, slightly inclined and sloping plateaus, at places mildly inclined territories with annual

Table 3. Feijoa plants afforestation (ecosystems areas (ha) and the percentage (%) of the total area).

Zone	Ecosystem area, ha	The share% (total area of)
Unfavorable climatic and soil-edaph conditions	210,663.89	69.488
The climate is favorable, the land is covered by forests Fund	34,726.26	11.455
The climate is favorable, it is possible landscape planting in lower mountain	14,357.75	4.736
The climate is perfect, cultivation is possible in plain and foothill hillside landscapes	43,414.39	14.321
Sum	303,162.29	100

and perennial plants and settlement (it is possible to plant fruit in yards). The second category is represented by meadows located in the zone of foothills and territory covered by plants. Planting is advisable in the above zone; however, it should be considered that vegetation period will be reduced and presumably productivity will be comparably low as apposed to the first zone. This category occupies 14,357.747 ha, which makes up 4.736% of the total area of the region. The third category has comfortable climate for growing and development of feijoa fruits, however their growing is impossible as the area is actually covered with natural forest and its maintenance represents necessity for the region. In total this area makes up 34,726.259 ha, which amounts to 11.454% of the research region (**Figure 4**).

Climatic and edaphic and landscape indicator for zoning of feijoa planting (Seperteladze, 2009; Seperteladze et al., 2012) may be considered forests, spread in the same landscape zone and same edaphic-hydrothermal conditions, required by feijoa plants. Under conditions of Kolkhetian landscapes floristic and ecologic indicator of feijoa plants and this ecosystem may be used in other regions, where feijoa is planted or there is a corresponding recommendation for its planting.

For revealing ecosystem, corresponding for zone of spreading feijoa plants, we have established a map of large-scale ecosystems and geo-informational system. It was interesting to reveal ecosystem of a corresponding forest in the above-mentioned zone and their indicator character.

As a result of cartometric-geo-informational analysis we elaborated a table, which informs us about types of forest ecosystems, areas, occupied by them, and their specific share (**Table 4**).

Climatic-edaphic zone compatible with feijoa plants in total amounts to 92,498.40 ha, from here slightly more than half of its area, i.e. 46,342 ha is woodless, occupied by settlements, arable land, meadow and other type of lands. Woodless territories in some areas are occupied by Kolkhetian polydominant forests amount to 5323.1455 ha, which makes up 5.75% of the total area of the zone. Kolkhetian polydominant forests, share of which exceeds 35% of the zone

and its different types (evergreen, undergrowth, shrubs and arable lands) create separate, slightly different ecosystems. Not such a small area is occupied by alder-grove forests, forest ecosystems, represented by forest ecosystems in meadows and arable complexes. Mainly they follow river grooves and sometimes occupy slopes above the grooves in conditions of excessive moist, high amount of precipitations. In the upper, in some areas of extreme part hornbeam, Oak and Hornbeam, Chestnut-beech and Beech, rarely Alder-dark coniferous forest ecosystems are found, however, they are not creating background and it is possible that zone, compatible with feijoa plants and similar ecosystems correspond to each other, however their spreading is connected to transversal extremities of the zone, where amount of precipitations and necessary warmth decreases and ecosystems become middle forest zone (**Figure 5**), which is widespread in Western and Eastern Caucasus.

The climatic and landscape indicator (Seperteladze, 2009; Seperteladze et al., 2012) of Feijoa planting zones may become forests that extend to the same landscape zone and the same edaphic-hydrothermal conditions as Feijoa plantations require. These ecosystems are the florist-ecological indicators of Feijoa plants in the terms of Colchic landscapes and this approach can be used for other regions where Feijoa plantations are grown or are relevant recommendations for their cultivation.

Table 4. Forest ecosystems in Adjara "feijoa zone" (Area, ha; the share % of total area).

Forest ecosystem	Area, ha	The share % (total area of)
Botanical Garden area	65.3	0.07
Colchis polydominant forest, Buxus colchica	2905.9	3.14
Colchis polydominant woods, with evergreens	27,513.5	29.74
Colchis polydominant woods, meadows and lands	2221.4	2.40
Area without vegetation	33.6	0.04
Alder-dark coniferous forest	11.5	0.01
Alder forests	2497.3	2.70
Alder forest with meadow-lands	2266.9	2.45
Hornbeam-oak forest	220.5	0.24
Hornbeam forest	517.3	0.56
Rhododendron ponticum	369	0.40
Area without forest	46342	50.1
Area is small forest, fragments of the Colchian forest	5323.1	5.75
Area is small forest, with alder forest fragments	1510	1.63
Beech and chestnut-beech forest	700.7	0.76
Total	**92,498.4**	**100**

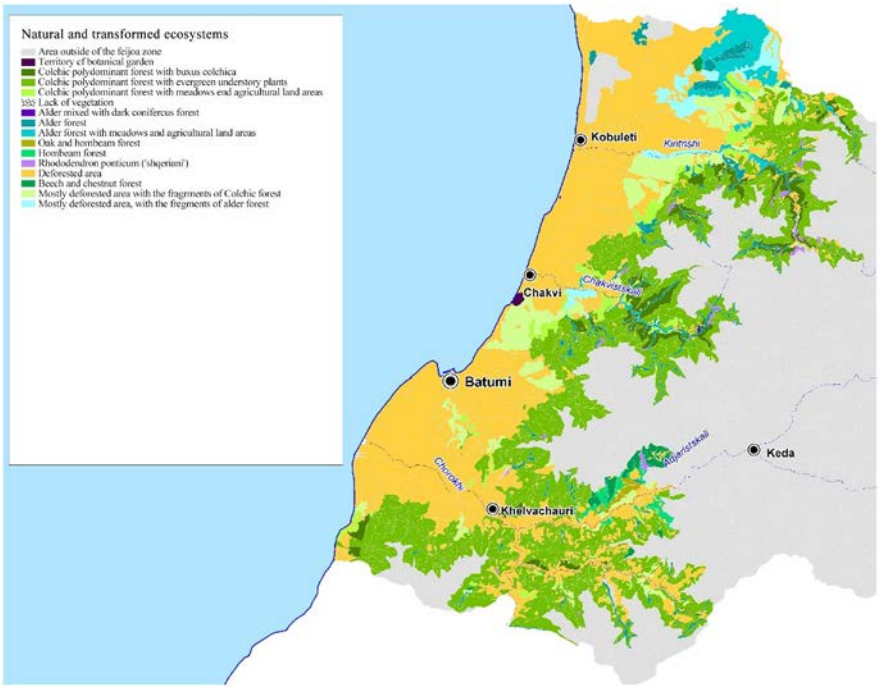

Figure 5. Forest ecosystems spread in Adjara "feijoa zone".

Large-scale map in Geo-information system was created to determine the ecosystems corresponding to the Feijoa plantation zone. It was interesting to reveal forest ecosystems relevant to the zone and to determine their indicator character. The table was created based on Cartographic-geo-informational analysis of the map that describes the type of forest ecosystems, their areas of occupation (**Table 4**).

Geographic and physical evaluation of any phenomenon and process is a quite complicated task as it requires simultaneous consideration of multiply factors. Characteristics of the above factors are of different dimensions and quite big range. Based on the above it is advisable to use such multiply factor method (Klitsunova, 2007; Nikolaishvili et al., 2013), which will give us an opportunity of handling of big amount of data with different range. Naturally, multiply factor approach is not limited by one particular method as natural environment is a whole organism with correlation of composite components, events and processes. With the given approach, evaluation of main features of similar geographic objects was implemented by means of comparative analysis, which enabled classification (standardizing) of separate zones of the region and detection of experimental plots of land. By means of analytical method it became possible to evaluate and range climatic and geographic features, and by synthetical method—comparison of received results and elaboration of complex map (**Figure 1**). By modeling methods, it is able to verify frost resistance of some sorts of Feijoa (in conditions of gradual lowering of temperature in the laboratory of modeling of artificial climate). By means of computer software we created GIS base and mapping of geography agro systems. Namely, for determination of the corresponding ecosys-

tem in the zone of spreading feijoa plants we elaborated a map of large-scale ecosystems and GIS. We have determined ecosystem of the forest corresponding to feijoa zone, character of forest land and current condition of ecosystem and character of their indication (Seperteladze et al., 2012, Nikolaishvili et al., 2013). As a result of cartometry-geoinformational analysis of the elaborated map, we have elaborated a table, containing an interesting information about types of ecosystems of forests, area, occupied by them, and their share in the research zone.

5. Conclusions and Recommendations

As a result of experimental morphological researches and physical-geographical zoning it was received following results:

- Using Landscape-multi-factoral method, it was implemented morphologic analysis of some morphometric features (biometric, beginning and end of first and second growth, beginning and end of blossoming, beginning and end of ripening of fruit and massive ripening, mechanical and biochemical content of fruit, evaluation by tasting, storage of fruit, frost resistance, etc.) of selective sorts of FEIJOA Sellowiana;
- For the study area maps of morphometric characteristics (inclination and exposition) relied on the selection of optimal natural conditions for the distribution of agro-cultures;
- Based on analysis of created large-scale forest ecosystem map, it was determined Correlation between forest ecosystems and "feijoa zone", which enabled us to determine the potential area of the "feijoa zone";
- After determination of the potential area, cased on carto metrical analysis it was determined area occupied by feijoa plants;
- On the basis of geomorphological factors and analysis of agro-climatic characters we have elaborated scientifically proven recommendations for zoning of agro-ecosystems, according to which it is quite possible that two already existing agro-climatic zones (30 - 200 m; 200 - 500 m) are added by the third zone in the range of 500 - 700 m, which shall increase area of increasing of Feijoa and most importantly this shall facilitate high-yield of this culture.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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