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LANDSCAPES DYNAMICS OF SAMTSKHE-JAVAKHETI, GEORGIA

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ABSTRACT: The given paper was based on the concept of spatial-temporal analysis and synthesis of natural territorial complexes (NTCs) enabling to study of the Nature components by applying the unified methodology. To determine the changes in the structure of landscapes, daily conditions of the landscapes based on the meteorological parameters (air temperature, precipitation, snow cover, etc.) were applied, which is very important for forecasting the trends of physical-geographical processes in the landscapes. This process can enable us to clarify the following questions: Which natural or natural-anthropogenic processes are more obvious? In which landscapes these processes are more intensive and which ones will be changed considerably? How much is rejected the last year's annual dynamics of the NTC from long-term dynamics? All of these issues are very important for determining the resource potential of landscapes and their changes. This issue was investigated according to two stages: I stage – determining the seasonal dynamic of the landscapes; II stage – comparing data from two periods (past and nowadays). To achieve the main objective of the research a great number of meteorological data were analyzed and processed employing GIS technologies. Thus, according to these data, the degree of landscape changes and its spatial distribution was revealed.

Keywords: Landscapes Dynamics, Landscape ethology, Samtskhe-Javakheti, Georgia

1. INTRODUCTION

Landscape ethology is a new field of landscape science that allows us to identify current trends in the geographical environment, through the study of elementary parts (geomasses), vertical structure, and function. Its practical significance lies primarily in the fact that it forms the theoretical basis for the spatial-temporal analysis of the landscapes and the physical-geographical regions, focusing on the provi-sion of the information on the average annual and potential status of -NTCs, and most importantly in the develo-p-ment of environmental management systems [1].

Landscape dynamics are driven by land use land cover (LULC) changes due to anthropogenic activities that affected ecology, biodiversity, hydrological regime, and people's livelihood. There have been increasing risks of environmental degradation, depletion of natural resources due to uncontrolled anthropogenic activities, and its consequences on the long-term sustainability of socio-economic systems around the world. This necessitates an understanding of the landscape dynamics and the visualization of likely changes for evolving appropriate strategies for the prudent management of natural resources [2, 3].

The study of landscape dynamic issues is of great theoretical and practical importance. It can be used to determine the physical-geographical or anthropogenic processes taking place in the landscapes and in the geographical environment in general. Their identification plays a certain role in identifying current trends in the environment and revealing the main directions of spatial planning.

The dynamics of the landscapes as a whole have been repeatedly studied around the world. For example, the books [4-9] provide an overview of the ecological indicators of landscape dynamics in the context of geographical landscape integration; principles and methods of the landscape ecology are given; modeling of forest landscape dynamics is proposed; new paradigms and theories of the landscape ecology are shown, as well as their patterns and processes; hydrological and landscape dynamics of wetlands were studied, etc. The landscape dynamic in Georgia, both in a single context and against the background of separate regions has been studied as well [1, 10-12], etc. In these papers, the issues of landscape dynamics are analyzed according to the data of landscape types, subtypes, and basic meteorological stations. Based on this, a fairly clear and complete picture of the annual dynamics of landscapes was created. However, it should also be noted that the landscape types/subtypes combine landscapes that differ from each other in terms of thermal and hydration conditions. Accordingly, it is necessary to study these differences as well. Particularly, it is insufficient to study the issues of dynamics by low-ranking landscape units, as it requires the selection and analysis of not only the base but also several meteorological stations. This will allow us to move to a more detailed stage after the study – particularly to study the issues of dynamics at the level of landscape genera, species, and types of NTCs.

The current research needs much more accurate data to detect climate change trends – both in terms of time and the abundance of meteorological stations/checkpoints. This is also due to the spatial stretching factor of the landscapes (some that follow orthography are of elongated configuration) and one meteorological station does not give a complete view. Therefore, data from twelve meteorological stations are used for the landscape analysis of the Samtskhe-Javakheti region. Thus, the analysis of the climatic characteristics of the landscapes was carried out based on data from several stations.

Landscape dynamics for the whole Caucasus are discussed in N. Beruchashvili's monograph [13], where, based on computer modeling scenarios of the development of landscape-ethological situations under different physical-geographical or anthropogenic impacts, are developed. In particular, what shifts can occur in the landscape structure during the development of the various scenarios of environmental change (global climate change, deforestation, afforestation, or minor glaciation)? This is a general model that can be developed as a result of the natural or anthropogenic impacts on the landscapes of the Caucasus, including Georgia. However, these impacts may not even be real, at least in the recent past, for example, deforestation of the entire Caucasus, or, conversely, complete afforestation of the landscapes, minor glaciation, etc. [10]. Due to the above, it is also relevant not only to study the changes caused by the actual (experimental) processes but also the actual changes in the landscape.

2. RESEARCH SIGNIFICANCE

The data, amassed by branch geographical sources, are scattered in various scientific-research organizations, also different approaches and techniques pose difficulties in their comparison. In this regard, data systematization and the creation of an integrated database are very important. Based on a unified methodology, we can investigate nature components and natural-resource potential, daily condition and physical-geographical tendencies, sensitivity and degree of the anthropogenic transfor-ma-tion of the landscapes, determine the main goals of landscape planning, etc. Moreover, a large-scale inventory of landscapes should become a model for other regions of the country.

3. RESEARCH METHODS AND DATA

Determining the issues of landscape dynamics requires the analysis of average multi-year data of the meteorological parameters. Of particular importance in this regard was the determination of air temperature, atmospheric precipitation, and snow cover. They showed what changes have taken place in the phytogenic, pedogenic, or nival structures of the landscapes. The present study is based on the analysis of these parameters.

For this purpose, data from the meteorological stations related to Georgian landscape genera were used, which was carried out using GIS technologies. However, it is also clear that there is a shortage of data – not all landscapes are equally secure with meteorological data. Accordingly, in the absence of meteorological stations in a certain landscape, we resorted to extrapolation and interpolation methods.

Data from meteorolo-gi-cal stations, which exist throughout their operation, were used to study climate change in Samtskhe-Javakheti. The data for some stations is continuous, though for someones it is discrete, in some cases up to the modern period. For some landscapes, there is almost a continuous chain of data. This applies to the meteorological stations (landscape: lower mountain erosion-accumulation landscape with hornbeam-oak, oak-pine, and pine forests. The denudation-erosion-accumu-lation landscape of mountain depression with steppe, dry shrub, shibliak, and mountain semidesert vegetation; The erosion-denudation landscape of the middle mountain with beech-oak, in some places pine; The shortest periodic data contains information on the years of 1944-1963, such is the Arali meteorological station (the denudation-erosion-accumulation landscape of mountain depression with steppe, dry shrub (phrygana, shibliak, mountain semi-desert vegetation).

The climate change process in Samtskhe-Javakheti and its impact on environmental conditions were assessed by analyzing the following parameters: daily average air temperature, frequency of atmospheric precipitation, wind speed, and height of sustainable snow cover. Based on the multi-year daily data provided by the National Environment Agency, the trends of annual, seasonal, and monthly changes in these parameters were analyzed and evaluated. Data from 12 meteorological stations are used for this purpose: Abastumani, Akhalkalaki, Akhaltsikhe, Bakuriani, Borjomi, Goderdzi, Tsalka, Paravani, Aspindza, Jvari, Minadze, and Arali. However, the available data can be assessed as partially deficient, since: first, meteorological stations do not function in the whole area of the study area (in all landscapes); Second, we do not have complete meteorological data for the existing stations either. Due to the created situation, we considered it expedient to use extrapolation and interpolation methods, as well as temperature and pluvial gradients. This approach was based on general geographical regularities, which took into account the natural conditions of neighboring landscapes. In order to reveal a broad picture/trend, multi-year data was calculated: initially, the average indicators of each year/month, autumn – 10-year periods. Based on the analysis of these periods, the tendency of changes in the climatic indicators of each station (average, absolute maximum, absolute minimum) was determined. In addition, differences between the first and the last decades have been identified. Seasonal data (spring, summer, autumn, winter) were also analyzed and trends were identified, as well as the frequency of extremes.

The study was conducted in 2 stages. Dynamics of daily conditions of landscapes in the first stage based on average multier annual data. This creates a general background and gives us an idea of what features characterize this or that landscape in general. The second stage is based on a comparison of specific periods (earlier and later).

4. RESULTS AND DISCUSSION

4.1 Major Landscapes

The distribution of Samtskhe-Javakheti landscapes is determined by a whole set of factors. This complex includes oro-climatic barriers, heat and moisture distribution, vegetation, paleogeographical development features of the area, and the degree of anthropogenic transformation. All of them are important and affect the territorial distribution of landscapes, and their physical-geographic features. Absolute height plays an important role in the differentiation of Samtskhe-Javakheti landscapes. In particular, the 2600 m altitude range generates great contrasts in terms of landscape, which is related to the sharply defined vertical plane.

The study area is represented by diverse landscapes: 5 types, 9 subtypes, and 13 genera.
I. Type. Mountainous thermo-moderate humid.
Ia.Subtype. Low-mountain forests Colchik Landsc.
1. Genera Low-mountain erosional-accumulative landscapes with Quercus pineberica and Pinus caucasica. Distributed over the river along the Mtkvari gorge. Occupies 0.47 thous. km^2 area.
Ib.Subtype Middle Mountain Forest Landscapes.
2. Genera Middle-mountain erosional-denudational landscapes with beech, Quercus Iberica, hornbeam forest and post-forest meadows, and shrubs.
II. Type. Mountain thermo-moderate semi-humid / Mountainous thermo-moderate semiarid.
IIa.Subtype. Transitional to Thermo-moderate Mountainous Depression with Steppes, Meadow-steppes.
3. Genera – Medium mountainous volcanic landscape with meadow-steppes and arid forests – spread on the northern and eastern slopes of the Erusheti highlands. Occupies 0.19 thous. km^2 area. Type of relief – erosive-denudating, steep and medium slope dominates, climate – moderately warm and transitional to the continent.
III. Type. Mountainous thermo-moderate semiarid.
IIIa.Subtype Transitional to thermo-moderate mountainous depression with steppes, meadow-steppes.
4. Genera – Mountainous depression denudational-erosional landscapes with steppes, partially mountainous semi-desert vegetation – Distributed in 900-1500 m asl. Occupies 0.63 thous. km^2. Characterized by erosive-denudating, partial alluvial-accumulative relief. The climate is transitioning from temperate to warm.
5. *Genera* – High volcanic plateau landscape with steppe and meadow-steppe – distributed on the Javakheti plateau in the range of 1700-1800 m to 2300-2500 m height asl, occupies 1.22 thous. km^2 area. Represents a high plateau, with a straight, in some places with a hilly surface. The climate is moderately cool, transitional to continental. It is dominated by steppe and beech steppe. In the south and southeast, the vegetation becomes more and more xerophilous, with tragacanth steppes and semi-desert mountain vegetation dominating.
IV. Type. Mountainous moderately cold.
IVa.Subtype. Medium mountain coniferous forest.
6. Genera – Middle-mountain erosional-denudational landscapes with dark coniferous, mainly with evergreen undergrowth. Distributed on the northern slopes of the Lesser Caucasus, in the range of 1000(1500)-1800(2000) m asl. Terrain erosive-denudative. Steep and medium slope dominates. The climate is moderately cold humid, marine, and weakly continental with warm summers and long cold winters. Negative average temperatures of the month last for 3-4 months.
7. Genera – Middle-mountain erosional-denudational landscapes with dark coniferous, partially Pinus woods – distributed in the form of fragments. The climate is humid and weakly continental with warm summers and long cold winters. The annual precipitation is 600-900 mm, the maximum falls in spring-summer. For the rest of the year, precipitation is relatively evenly distributed (fig.1).

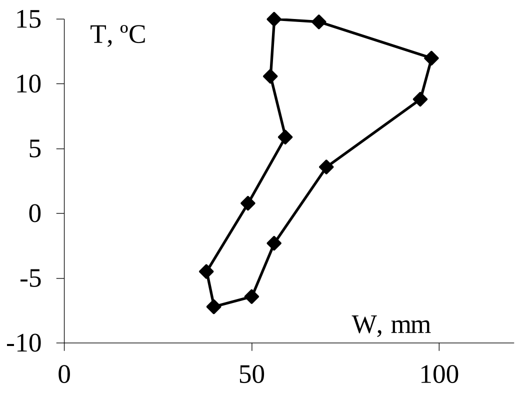

Fig.1 Temperature dynamic of Landscape Genus 7

IVb Subtype. Upper Mountain forest pine and birch.
8. Genera – Upper Mountain erosion-denudation, rarely paleoglacial landscape with birch forests, in some places pine forests and lowlands of Pontic oak – found in the area between the middle and high mountains. In the height range 1700(1900)-2000 (2200) m asl. The relief is erosive-denudative, in some places erosive-accumulative and paleoglacial.

Steep and medium-sloping slopes prevail, in some places flat-surface ridges. The climate is moderately cold and humid. The snow-resistant cover is formed from the third decade of October to the end of April. No humidity deficit has been observed.
V. Type. High mountain meadow.
Va.Subtype. High Mountain subalpine forest-shrub-land-meadow landscapes.
9. Genera – High Mountain denudation and paleo-glacial landscape with a complex of high-grass and high-grass meadows, shrubs, and tanbur forests – distributed mainly on the sloping slopes, in the height range of 1800(2000)-2200(2400) m asl. The relief is mainly denudative, paleoglacial, and erosive-denudative. Dominated by steep and medium-sloping slopes. Remains of the Quaternary glaciation are preserved. The climate is typical of high mountains, cold humid, and marine. Summers are cool and short, winters are long and cold. The annual amount of precipitation averages 1500-2000(2700) mm. The average daily amplitude of air temperature is small, which weakens the physical exhaustion (fig. 2). The vegetation period lasts 2-2.5 months.

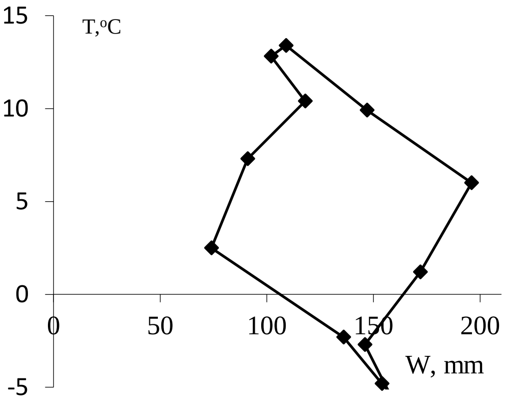

Fig.2 Temperature dynamic of Landscape Genus 9

10. Genera – High Mountain denudational landscape with a complex of subalpine meadows, shrubs, and open woodlands – distributed in the range of 1450-1800 m asl. Denudative relief prevails. Characterized by flattened surfaces at different heights. Remains of Quaternary volcanism are preserved. It is the only part of Georgia in the Lesser Caucasus where Quaternary volcanism is detected. The climate is moderately cold humid and weakly continental. The maximum precipitation falls in May-June, and the minimum – is in December and summer (fig. 3).
11. Genera – High Mountain subalpine landscapes with a combination of meadows, tall-herb communities, elfin woods, and thickets – distributed in the Lesser Caucasus and the highlands of Javakheti in the height range 1700(2000)-1900(2000) m asl. Characterized by relatively steep, rarely steep slopes. The climate is moderately cold humid, semi-humidity, and weakly continental. The annual amount of precipitation is small for the whole year (fig. 4).

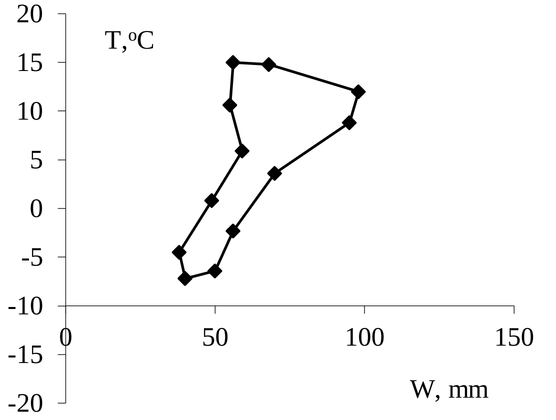

Fig.3 Temperature dynamic of Landscape Genus 10

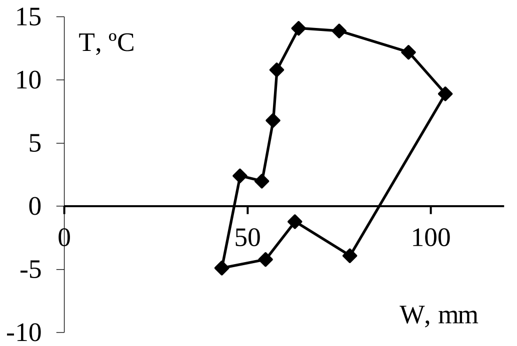

Fig.4 Temperature dynamic of Landscape Genus 11

Vb. Subtype. High Mountain alpine landscapes with grasslands and rhododendron thickets.
12. Genera – High Mountain volcanic alpine meadows – distributed in the Javakheti-Armenian highlands, at altitudes of 2700(2800)-3200(3300) m asl. Occupies an area of 0.51 km^2.
Subtype. High mountainous subnival landscape.
13. Genera – High Mountain volcanic subnival landscapes – distributed as fragments on the high peaks of Erusheti, Nialiskuri, Samsar, and Javakheti ridges. Occupies 0.06 thous. km^2 at the altitudes of 3500-4000 m asl. Represented by volcanic cones and lava plateaus. Rocky outcrops around.

4.2 Multi-year Dynamics of Air Temperature

The meteorological data given below is mainly based on the database of the National Environment Agency, as well as on Georgia's reports to the UNFCCC [12, 14]. Analysis of data from 1986-2015 showed that the average annual air temperature is the highest in the lower mountain forests and mountain hollow landscapes. The average t increased by 0.47ºC compared to 1956-

1986. Temperature increases were recorded by season (Table 1). Separate months' analysis showed that warming is in progress mostly during the summer. Maximum warming was recorded in August, also the warming trend is quite high in Sept.-Oct. The absolute min. t was recorded on Dec. 2016 (-20.7ºC), and the max. t was recorded on July 2018 (36.4ºC). In 2016-2020, compared to previous years, there is a noticeable increase in all seasons.

Table 1 Air temperature dynamics at the certain time intervals (Mountain depression Landscape)

Seasons	1986-2005	Increase compared to 1956-1986
Spring	-8	0.21
Summer	19.7	0.88
Autumn	10.2	0.57
Winter	-1.8	0.2

The High Mountain Plateau increased by 0.47º in 1986-2015 compared to 1986-2015. Here, the place has an increase in temperature for all seasons. Here, also the warming takes place mainly in late summer and early autumn, namely in Aug. the increase is 1.24ºC and in Sept.-Oct. – 0.9ºC. The increase in temperature is noticeable in all seasons, especially in winter. The absolute minimum temperature was recorded in Dec. 2016 (-28ºC); The maximum temperature was 34.3ºC in Aug. 2019.

Approximately the same trend will be observed in other landscapes. There is an increase in temperature everywhere, but with different intensities (Table 2). The rise in temperature occurs mainly in the summer and subsequent months (Jul.-Oct.).

Table 2 Dynamics of the air temperature (ºC) according to the landscapes

Landscapes	1951-1980	1981-2010	Increase in air temperature
Lower Mountain	9.3	10	0.77
Middle Mountain Forest	4.71	5.19	0.48
Mountain depression	8.85	9.02	0.17
High Plateau	5.6	6.36	0.7
High Mountain Subalpine & Alpine	2.39	3	0.6

4.3 Perennial Dynamics of Atmospheric Precipitation

Quite significant changes took place in the annual amount of atmospheric precipitation and its seasonal distribution. For this purpose, we have considered the data series in 4 periods: I (1937-1976), II (1977-1986), III (1987-1996), and IV (1997-2006).

The total amount of atmospheric precipitation on the high mountain plateaus has increased by almost 900 mm (from 5600 mm to 6530 mm), in the II and III periods, its amount has slightly decreased compared to the period I, although in 1997-2006 – increased. Precipitation during the first period – increased from 245 mm to 1004 mm: in winter – from 245 mm to 274 mm, in spring from 275 mm to 859 mm, in summer from 516 to 1.004 mm, in autumn – from 349 mm to 419 mm. The total precipitation of this period is 5633 mm. The same happened in other periods, but one important feature was revealed: we have a min. amount of precipitation in winter in period II – 190 mm, and a max. in period I – 1004 mm. In spring the min. amount of precipitation is in period III – 265 mm, and the max. in period IV – 901 mm. In summer, the min. value is 441 mm in period III, and the max. is 1004 mm in period I. The min. magnitude in autumn is 310 mm in the IV period and the max. is 512 mm in the IV period.

Atmospheric precipitation tends to decrease in high mountain subalpine and alpine meadow landscapes. During periods I (1963-1972) and II (1973-1992) the amount of precipitation decreased by 3,789 mm, from II to III – increased by 770 mm.

The situation is similar in the high mountain plateau landscapes, where there is a decreased trend of the precipitation, namely over 40 years the total precipitation has decreased by 1808 mm. However, during the periods I (1967-1976) and II (1977-1986) the amount of precipitation decreased by 450 mm, and from II to III (1987-1996) it decreased by 1680 mm. The only exception is the period from III to IV (1997-2006) – precipitation increased by 318 mm.

4.4 Multi-year Dynamics of Wind Regime

On the territory of Samtskhe-Javakheti winds of different directions prevail. The peculiar conditions of the terrain have a great influence. Here the main wind directions coincide with the direction of the river valleys. The recurrence of winds in the other directions is negligible. For example, the recurrence of the west direction is only 1%. Akhaltsikhe basin and Javakheti plateau are distinguished by the peculiarity of the relief; The first is closed by ridges, and the second is relatively wide, which gives a special character to the wind regime.

The average annual wind speed in Samtskhe-Javakheti is not the same everywhere, in mountain depressions, it is relatively small and in most parts of the area does not exceed 2.0-2.5 m/sec. As for the high mountain plateau, the wind speed here is relatively high. According to the observation, reach 4 m/sec. The latter, in its central and southern parts, is dominated by winds from the southeast (28%) and northwest (20-24%) during the year, and the south (32%) and east (18%). South-east winds are also relatively frequent in this part of the plateau.

The average wind speed in a significant part of the area is maximum in the winter months, especially during the winter, with relatively weak winds in the spring and summer months. Strong winds (wind speed 15 m/s and more) are small compared to other regions of Georgia. The average number of strong windy days is relatively common in the high plateau landscapes, where it reaches 14 days a year. Such a high number can be explained by its location on the open ground. In the central part of the mentioned plateau, the number of strong windy days is much higher in some years. The maximum number of strong windy days here is 49.

4.5 Analysis of Daily Conditions

Each landscape is characterized by a certain set of daily conditions. However, they are distinguished by the recurrence and duration of daily conditions. In some landscapes, we find only typical conditions for it. However, conditions that are identical for different landscapes are quite long. It is very impor-tant to determine the duration and recurrence of this or that condition of the NTCs for each landscape.

In many landscapes, most time of the year falls in summer and winter, while the daily conditions of spring and autumn are of negligible duration. This will be observed in almost all landscapes of Georgia. It is logical that the duration of the winter, namely the nival states, increases according to the absolute height, while the duration of the pluvial daily states extends from east to west.

Sustainable snow cover in western Georgia is falling relatively slowly. So, the onset and comple-tion of complications of spring phytogenic structure are delayed by 5-15 days. In several landscapes in the eastern part, including Samtskhe-Javakheti, spring conditions are longer than in the western.

Middle mountain forest landscapes, which unite 12 genera of landscapes are spread in the range of 800-2000m altitude above sea level, both in western as well as eastern Georgia – in the Caucasus as well as the Lesser Caucasus. Accordingly, the dynamics of the daily states of the landscapes proceed differently in each of the abovenamed classification units. In general, it can be said that in the middle mountain forest landscapes, there are 30 types of the daily condition of landscapes, 17 of which are dominant and are found every year.

In the middle mountain forest landscapes of Samtskhe-Javakheti, there is a tendency for a sharp increase in atmospheric precipitation for the period of 1936-2014. This was also reflected in the increase in pluvian states. Significant growth was observed from 1998-2004, this increase was also reflected in the increase in nival conditions (Fig. 5).

If we compare different periods, we will see that the situation of atmospheric precipitation sums is very different. There is an increase in precipitation, as well as a decrease in some years. However, during the period 1972-1991, one impor-tant trend has been observed – the amount of precipitation increased sharply during the spring and partly in summer. This difference was 200-250 m per year. Due to the lack of observational data from the 1990s, it is impossible to judge the trends of the last decades. During the same periods, there was no sharp change in air temperature.

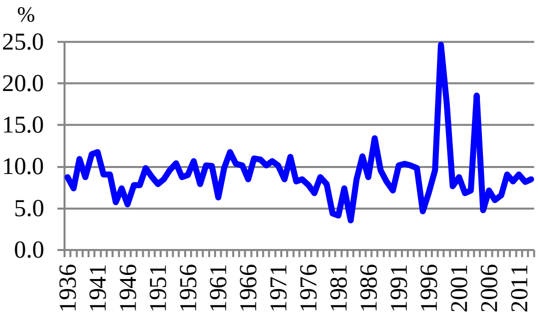

Fig.5 Trend of nival daily conditions (1936-2013)

It is interesting to note that against the back-ground of the increase in pluripotent and nival conditions, there is also a tendency for the growth of semiarid conditions that seems like an unusual situation against the share of humid states is narrowed. This is due to the circumstances of the summer period.

The longest period of the year, about 1/2 comes in the stabilization of the winter structure, and about 1/3 – in the stable conditions of the summer phytogenic structure. Compared to the lower mountain forest landscapes, there are few summer phytogenic structure stabilization conditions Longevity, which is logical, since the increase in absolute height decreases the length of summer, hence the amount of heat. The most deficient in duration is the – phytogenic structural conditions of spring and autumn (-5-5%). The plural position is based on the total longevity of the year ¼ [10]. There is, however, a significant difference according to the genera of the landscapes. In some landscapes of western Georgia, where the annual amount of precipitation is significantly higher than the corresponding rate in eastern Georgia, the duration of these conditions is 34%.

In the lower mountain forest landscapes, the trend of decreasing semiarid conditions is observed in the period 1936-2013, although in some years it has also increased. The duration of semiarid condi-tions increased between 1990-2004, although it declined sharply in the mid-2000s after the mid-period. The sharp downward trend is characterized by the trend of cryo-thermal conditions, although there is a pronounced upward trend in the period from the mid-1980s to the early 1990s (Fig. 6).

The trend of increasing semiarid states in mountain depression landscapes from 1936 to 2013 is characterized by several features: 1. The general trend throughout this period is a slight decrease in semiarid conditions, although it varies greatly from period to period; 2. Aridity was highest during 1995-2001 and lowest during 1981-1985 (Fig. 7). Also, during 1936-2013, the duration of nival states varied at a fairly large interval (Fig. 8). It was maximal in 1938-1940, 1962-1933 and 1987. However, the general trend is declining. Thus, it is true that the share of semiarid states is not increased, although the duration of nival states is reduced at the expense of humidification.

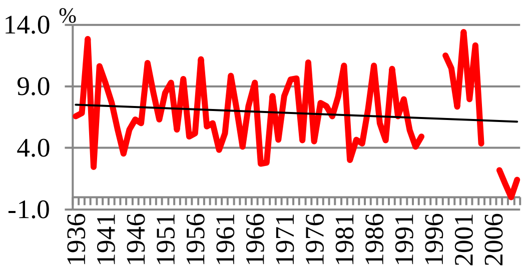

Fig.6 Trend of semiarid conditions (1936-2013)

Landscape-geophysical indicators also change according to the change in the daily conditions of the landscapes. The strength and structure of the vertical structure and the number of geo-masses (especially phytomass and hydromass) undergo significant changes.

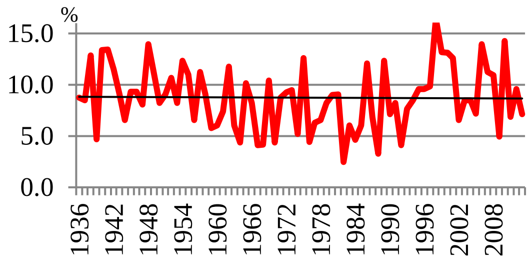

Fig.7 Trend of semiarid conditions (1936-2013)

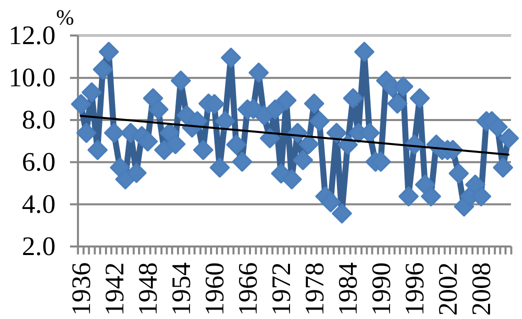

Fig.8 Trend of nival states (1936-2013)

In mid-montane forest landscapes, soil moisture varies with changing daily conditions. It is maximum in May and October, and minimum in the summer months. This rate is high in western Georgia. The same can be said for other landscapes, which suggests that there is no direct link between soil moisture and daily conditions. In addition, the duration of this or that daily conditions and the number of days before the pluvial state should be taken into account.

In winter, due to the dominance of winter structure stabilization (1H), snowmelt and water leakage in the soil are delayed until the second decade of May, so the soil moisture is also low.

In the case of simplification of winter nival structure and complication of spring phytogenic structure, due to snowmelt, soil moisture increases to 37-42% (in 0-50 cm layer). Therefore, from the end of the winter to mid-June, high soil moisture is maintained [10].

A significant correlation was found between the number of phytomass and the average soil moisture. In most landscapes (with the exception of the high mountain subnival, nival and semi-arid landscapes) the amount of phytomass reaches a maximum when the soil moisture is maintained not only in the topsoil but also deeper, In particular, when the 30% isoline passes at 25-35 cm, and the 20% – at a depth of 20-25 cm and deeper. This, obviously, is due to the frequency and duration of humid and pluvial conditions, for example, in the lower and middle mountain forest landscapes, the amount of phyto-mass over 250-300 t/ha is observed where the 30% isoline of soil moisture passes at a depth of 30 cm, and the 20% is deeper than 80 cm [11]. It turned out that it does not really matter where the 30 cm isoline of soil moisture passes deeper than 30 cm, since the amount of phytomass in such conditions is quite large almost everywhere (300-500 t/ha and more).

Different features were revealed in the landscapes where the duration of semi-humid, semi-arid, and arid conditions is much longer. Thus, the foothills landscapes of Eastern Georgia can be inhabited. The maximum of phytomass is observed here where the 30% isoline of the soil passes closer to the surface – at a depth of 15-20 cm, and the 40% isoline should not be close to the surface and it should go much deeper than 15 cm. Where the 30% isoline passes at a depth of 0-15 m from the surface, the amount of phytomass is only 20-25 t/ha on average.

The capacity of the vertical structure varies in some landscapes, and slightly in others. It has to do with what form of life is dominant in the landscape layer. If trees predominate, this change is minimal (up to 1 m) and is mainly due to changes due to tree pollination and defoliation. In forestless NTCs, meadows, and steppes, the capacity can change 2-3 times and more.

Among the landscapes of Georgia, the power of the vertical structure of NTCs is especially significantly reduced in the high mountain subalpine meadow landscapes. The degree of reduction here can be 10 or more. Among non-forested NTCs, capacity varies least in those landscapes (excluding high mountain subnival and nival landscapes) dominated by semi-desert vegetation [10].

The complexity of the vertical structure of NTCs in the average mountain forest landscapes of Georgia is also maximum in summer and minimum in winter. The difficulty becomes particularly easy in forestless NTCs, where only 2-3 of the 4-7 geohorizons present in the summer season may remain. As for forest NTCs, here the reduction has a very different character. The change is particularly significant in the lower and upper mountain forest landscapes. In the middle part of the hypsometric distribution of middle mountain forest landscapes, it is relatively small, however, it is important to consider which types of vertical structures of NTCs (forest or non-forest) predominate. The minimal change is observed in forest NTCs with dead cover, or Colchis undergrowth, and the most – in forest NTCs with grassy or deciduous shrubs.

5. CONCLUSION

- The study identified some of the dynamic features of the landscapes not only by average long-term data but also by years. This allowed us to identify some of the trends taking place in landscapes, as well as the tendency of humidification or aridization, temperature increase or decrease, and in which landscapes these processes are more expressed and which of them are threatened by fundamental structural changes. It became possible to determine what changes are expected according to the landscape-geophysical characteristics (geomasses amount, strength, and complexity of the vertical structure). This allowed us to identify trends in the resource potential of landscapes.
- In Samtskhe-Javakheti, a diverse picture of changes in temperature and atmospheric precipitation was revealed, in particular, there is a sharp variability of air temperature and atmospheric precipitation, with a kind of alternation of warming and cooling.
- The increase in average annual temperatures was observed in the central and northern parts of the High Mountain Plateau landscapes, while the decrease in its southern part. Air temperatures remained almost unchanged in the lower mountain or middle mountain forest landscapes from 1962-2004. As for atmospheric precipitation, in recent years has been particularly expressed in high-mountain plateaus, while diminishing in mountain depression landscapes.

6. REFERENCES

[1] Beruchashvili N.L. Ethology of the Landscape and Mapping of the Natural Environment State. Tb., TSU, 1989, pp.1-198.

[2] Farina A. Principles and Methods in Landscape Ecology. Dordrecht, The Netherlands: Springer, 2006, pp.1-412.

[3] Tappeiner U., Leitinger G., Zariņa A., Bürgi M. How to Consider History in Landscape Ecology: Patterns, Processes, and Pathways. Landscape Ecology, 2021, Vol.36, Issue 8, pp.2317-2328.

[4] Bharath Setturu, Rajan K.S., Ramachandra T.V. Modeling Forest Landscape Dynamics. Nova Science Publishers, 2021, pp.1-249.

[5] Feranec J. European Landscape Dynamics: Corine Land Cover Data, 2016, pp.1-337.

[6] Malan K.M. A Survey of Advances in Landscape Analysis for Optimization. Algorithms, 2021, Vol.14, Issue 2, 40, pp.1-16.

[7] Mukherjee K., Pal S. Hydrological and Landscape Dynamics of Floodplain Wetlands of the Diara Region, Eastern India. Ecological Indicators, 2021, 121, 106961, pp.1-11.

[8] Sahdev S., Singh R.B., Kumar M. Geoecology of Landscape Dynamics. Springer, 2020, pp.1-379.

[9] Wu J., Landscape Sustainability Science (II): Core Questions and Key Approaches. Landscape Ecology, 2021, Vol.36, Issue 8, pp.2453-2485.

[10] Nikolaishvili D. Spatial-Temporal Analysis of the Landscapes of Georgia. Tb., TSU, 2009, pp.1-431.

[11] Nikolaishvili D., Lagidze L., Tsitsagi M., Tskhvaradze M., Kubetsia M. Climate Change Trends in Landscapes of Samtkhe-Javakheti. Proceedings of the 18th International Multi-displinary Scientific GeoConference SGEM2018, 2018, Vol.18, Issue 3.2, pp.765-772.

[12] Lagidze L., Matchavariani L., Paichadze N. The Influence of Circular Processes on Change in Precipitation in the Scope of Climate Change. International Journal of GEOMATE, 2017, Vol.13, Issue 39, pp.213-219.

[13] Beruchashvili N.L. Caucasus: Landscapes, Models, Experiments. Tb., UNEP, GRID, 1995, pp.1-310.

[14] Georgia’s Third National Communication to the United Nations Framework Convention on Climate Change. National Climate Research Centre, Tbilisi, 2015, pp.1-207.