Monitoring the species composition of the undergrowth in some regions of Armenia and central Russia

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Abstract. Changes in the species composition of tree species of the undergrowth, the tasks of preserving biodiversity in clearing areas and under the influence of climate change, are of theoretical and practical scientific interest. The main goal of this study was to monitor the species diversity of dominant undergrowth species in the forests of some regions of Armenia and central Russia under conditions of climate change and human activity. In Armenia, research was carried out in Lori and Tavush regions. In Russia, research was carried out in the Kostroma and Moscow regions, located in the center of the Russian Plain. The studies were carried out using route, semi-stationary, stationary methods using generally accepted methods. Field work was carried out during growing seasons from 2019 to 2023. Field surveys were carried out in the most typical forest types for the regions. In the Lori region, 14 families were identified, which include the dominant species of undergrowth, in the Tavush region - 11 families and in the regions of central Russia - 11 families. For all objects of study, the largest number of species contains the *Rosaceae* family. The main factors influencing understory biodiversity are human activities (logging, recreational impacts, etc.) and climate change. Thus, changes in the climate system of the regions of Armenia and central Russia in the future create new risks for the sustainability of undergrowth biological diversity in forests.

1 Introduction

The current state of forests is the result of the relationship between forests, people and climate. Studies of forest biological diversity in recent decades have established that changes in biodiversity occur as a result of the destruction of forest cover and the formation of secondary communities [1, 2]. Clear cuttings lead to dramatic changes in biological diversity in forests. Studies in taiga forests show that after their implementation, an increase in biodiversity may be observed due to the emergence of new species from meadow and weed flora, but at the same time there is a reduction in the number of forest plant species [3].

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According to some researchers, as a result of human activity, an increase in the concentration of carbon dioxide contributes to an increase in atmospheric temperature and directly affects the intensity of physiological processes in plants, in particular, a change in the growth rate of plants is observed [4, 5, 6]. Climate change leads to changes in productivity and species composition of forests. This in turn leads to changes in the ranges of plant species [7]. In boreal forests and the Mediterranean, ongoing climate change is increasing the risks of wildfires and pest and invasive species outbreaks [8]. Thus, climate change directly or indirectly affects the biodiversity of forest ecosystems.

Changes in the species composition of tree species of the undergrowth, the tasks of preserving biodiversity in clearing areas and under the influence of climate change, are of theoretical and practical scientific interest. The main goal of this study was to monitor the species diversity of dominant undergrowth species in the forests of some regions of Armenia and central Russia under conditions of climate change and human activity.

2 Materials and methods

In Armenia, research was carried out in Lori and Tavush regions. For stationary research, forest communities were selected in the vicinity of the villages of Margaovit, Lermontovo, and Fioletovo if Gugark district of Lori region. The mixed forests of the Vanadzor gorge of the Gugark district, located on the southern steep slopes (25°) of the Pambak ridge, at an altitude of 1100-2200 m above sea level, were also studied. The forested territories of the Gugark district are characterized by a pronounced altitudinal zone, a special geographical location, altitude above sea level, variegated relief and, in accordance with this, rich biodiversity. Tavush region is located in the northeast of the republic. It includes the territories of Ijevan, Dilijan, Noyemberyan and Berd (Shamshadin). Tavush region extends to the outer range of the Caucasus Range (mountains Viraayots, Gugarats and Miapor). The lowest point relative to sea level is in the village of Debedavan is 380 m above sea level, the highest is the mountain of the same name in the Miaporsky ridge is 2993 m.

In Russia, research was carried out in the Kostroma and Moscow regions, located in the center of the Russian Plain. The forests of the Kostroma region belong to the southern taiga zone [9]. The forests are formed by such tree species as *Pinus sylvestris* L., *Picea abies* (L.) H.Karst., *Picea ×fennica* (Regel) Kom., *Betula pendula* Roth, *Betula pubescens* Ehrh and *Populus tremula* L. Field research was carried out in the Kologrivsky and Mantrovsky districts of the Kostroma region, as well as in the Kologrivsky Forest Nature Reserve. The forests of the Moscow region belong to the zone of coniferous-deciduous forests [10]. The tree species involved in the formation of forests are *Pinus sylvestris* L., *Picea abies* (L.) H.Karst., *Betula pendula* Roth, *Betula pubescens* Ehrh, *Populus tremula* L., *Tilia cordata* Mill., *Quercus robur* L. and *Acer platanoides* L. In the Moscow region, field research was carried out in the Sergiev Posad, Pushkin, Mytishchi districts and in the Losiny Ostrov National Park.

The study regions differ significantly in climatic parameters and forest conditions. In the regions of Armenia there are mainly mountain forests, and in the regions of central Russia are lowland forests. Some main long-term climatic characteristics are given in Table 1. The regions of central Russia are characterized by colder winters and less warm summers, and the average duration of the growing season is significantly shorter than in the regions of Armenia.

The studies were carried out using route, semi-stationary, stationary methods using generally accepted methods [11, 12, 13]. Field work was carried out during growing seasons from 2019 to 2023. Field surveys were carried out in the most typical forest types for the regions.

Table 1. Climatic characteristics of some regions of Armenia and central Russia.

Climate variable	Armenia		Russia	
	Lori region	**Tavush region**	**Kostroma region**	**Moscow region**
Average January temperature, °C	+1.5	0.0	-11.9…-14.0	-9.0…-12.0
Average July temperature, °C	+23.0...+24.0	+23.0...+24.0	+17.0…+18.5	+18.0…+20.0
Annual precipitation, mm	600…700	500…700	530…600	500…700
Duration of the growing season, days	170	115…225	110…140	125…140

3 Results and discussion

The flora of the forests of the Lori region is mainly represented by Caucasian and Boreal elements. The main forest-forming species are *Fagus orientalis* Lipsky, *Quercus macranthera* Fish & C.A.Mey and *Quercus iberica* Steven. Accompanying species are representatives of the genera linden, ash, birch, maple, elderberry and others. Due to illegal, massive logging, the range of *Fraxinus excelsior* L., *Acer trautvetteri* Medw and *Ulmus laevis* Pall. has decreased. In some places of the undergrowth, habitats of shrubs appeared and spread: *Lonicera caucasica* Pall., *Rosa canina* L., *Cornus mas* L., *Mespilus germanica* L., *Sambucus nigra* L. and others [14].

In Tavush region there is an intensive distribution of undergrowth species. It was recorded that *Rubus idaeus* L. and *Sorbus aucuparia* L. grow in the undergrowth. *S. aucuparia* L. has been suffering from dry air in recent years. Over the past 4-5 years, the *Rubus caesius* L. has appeared in the Lori region, and the range of different life forms of the *Sambucus nigra* L. species has expanded. Previously undocumented herbaceous forms of *Sambucus ebulus* L. have spread throughout the region and a shrub variety of *Sambucus nigra f. laciniata* (L.) Zabel. Basically, the *Rubus caesius* L. began to be often found at the end of the 20th century, in areas where clear cuttings were carried out.

From Table 2 it can be seen that representatives of the *Rosaceae* family make up the majority in the undergrowth of the forests of Lori region. They create a microclimate for other species and form the "core of the undergrowth". Thanks to the different life forms, the layered structure of the undergrowth is clearly visible. The height of shrubs reaches up to 150 cm, dwarf shrubs are 15-35 cm. Basically, shade-tolerant mesophytes are widely represented, but they also actively grow on illuminated edges. Within altitudes from 1300-2300 m above sea level in illuminated areas, the species *Rosa canina* L. forms shrub communities.

Research shows that in the last decade, in the understory, some species have reduced their distribution range due to warming, air pollution, such as *Sorbus aucuparia* L., and other species *Grossularia reclinata* L., *Rubus vulgaris* Weihe & Nees, *Viburnum lantata* L. on the contrary, they have spread.

Table 2. The most common species of undergrowth plants in the forests of Lori region, Armenia.

Family	Genus	Species
Juglandaceae Lindl.	*Juglans* L.	*Juglans regia* L.
Salicaceae Lindl.	*Salix* L.	*Salix alba* L.
	Populus L.	*Populus tremula* L.
Rosaceae Juss.	*Pyrus* L.	*Pyrus caucasica* Fed.
	Malus Mill	*Malus orientalis* Uglitzkich ex Jus.
	Sorbus L.	*Sorbus aucuparia* L.
	Mespilus L.	*Mespilus germanica* L.
	Crataegus L.	*Crataegus kyrtostyla* Fingerh.
	Rosa L.	*Rosa canina* L.
	Prunus Mill.	*Prunus cerasifera* Ehrh.
	Cerasus Mill.	*Cerasus avium* (L.) Moench
		Cerasus incana (Pall.) Spach
	Rubus L.	*Rubus caesius* L.
		Rubus idaeus L.
Elaeagnaceae Juss.	*Hippophae* L.	*Hippophae rhamaoides* L.
Grossulariaceae D.C.	*Grossularia* Mill.	*Grossularia reclinata* (L.) Mill.
Sapindaceae Juss.	*Acer* L.	*Acer campestre* L.
		Acer trautvetteri Medw.
Caprifoliaceae Juss.	*Lonicera* L.	*Lonicera caucasica* Pall.
		Lonicera xylosteum L.
Berberidaceae Torr. et Gray	*Berberis* L.	*Berberis vulgaris* L.
Cornaceae Bercht. & J.Presl	*Cornus* L.	*Cornus mas* L.
Oleaceae Lindl.	*Fraxinus* L.	*Fraxinus excelsior* L.
Adoxaceae E.Mey	*Sambucus* L.	*Sambucus nigra* L.
		Sambucus Ebulus L.
		Sambucus nigra f. laciniata (L.) Zabel.
	Viburnum L.	*Viburnum lantana* L.
Ulmaceae Mirb.	*Ulmus* L.	*Ulmus laevis* Pall.
Malvaceae Juss.	*Tilia* L.	*Tilia cordata* Mill.
Betulaceae Gray	*Betula* L.	*Betula litwinowii* A. Doluch.

Tavush region is the most forested in Armenia. There are 160 plant species in the forest, of which 77 species are trees, 51 species are shrubs, 32 are subshrubs. In the 90s of the 20th centuries, massive deforestation was also carried out here. Nowadays, the basis of forests in the region is secondary forest. It should be noted that the forests of Tavush region are rich in fruit and berry species. Species of the genus *Rosa* L. (*Rosa canina* L.), *Rubus* L. (*Rubus idaeus* L., *Rubus vulagris* Weihe & Nees) and others are common here [15].

The results of the study of the undergrowth of mixed forests in the vicinity of Dilijan of Tavush region are shown in Table 2. Comparing the data on the species composition of the undergrowth of the Lori and Tavush regions, we came to the conclusion that species of the *Rosaceae* family dominate in the undergrowth of the two regions. However, due to the warmer climate, in the forests of the Tavush region there are almost three times more representatives of *Rosaceae* than in the Lori region.

Table 3. The most common species of undergrowth plants in the forests of Tavush region, Armenia.

Family	Genus	Species
Juglandaceae Lindl.	*Juglans* L.	*Juglans regia* L.
Rosaceae Juss.	*Amelanchier* Medik.	*Amelanchier ovalis* Medik.
	Amygdalus L.	*Amygdalus fenzliana* (Fritsch) Lipsky
	Cerasus Mill.	*Cerasus avium* (L.) Moench
		Cerasus incana (Pall.) Spach
	Cotoneaster Medik.	*Cotoneaster integerrimus* Medik.
		Cotoneaster multiflorus Bunge
		Cotoneaster suavis Pojark
	Crataegus L.	*Crataegus orientalis* Pall.
		Crataegus pentagyna Waldst. & Kit.
	Malus Mill.	*Malus orientalis* Uglitzkich ex Jus.
	Mespilus L.	*Mespilus germanica* L.
	Padus Mill.	*Padus racemosa* (Lam.) Gilib.
	Prunus Mill.	*Prunus cerasifera* Ehrh.
		Prunus spinosa L.
	Pyrus L.	*Pyrus caucasica* Fed.
	Rosa L.	*Rosa boissieri* Crepin
		Rosa canina L.
		Rosa corymbifera Borkh.
		Rosa iberica Stev.
		Rosa pulverulenta M. Bieb.
	Sorbus L.	*Sorbus armeniaca* Hedl.
		Sorbus aucuparia L.
		Sorbus graeca (Spach) Hedl.
		Sorbus torminalis (L.) Crantz
	Rubus L.	*Rubus caesius* L.
		Rubus caucasicus Focke
		Rubus idaeus L.
Elaeagnaceae Juss.	*Hippophae* L.	*Hippophae rhamnoides* L.
Betulaceae Gray	*Corylus* L.	*Corylus avellana* L.
Berberidaceae Torr. et Grazy	*Berberis* L.	*Berberis orientalis* C.K. Schneid
		Berberis vulgaris L.
Sapindaceae Juss.	*Acer* L.	*Acer campestre* L.
		Acer hyrcanum Fisch. et Mey
		Acer ibericum M.
		Acer platanoides L.
		Acer trautvetteri Medw.
Adoxaceae E.Mey	*Sambucus* L.	*Sambucus nigra* L.
		Sambucus ebulus L.
	Viburnum L.	*Viburnum lantana* L.
Rhamnaceae R. Br.	*Paliurus* Mill.	*Paliurus spina-christi* Mill.
	Rhamnus L.	*Rhamnus cathartica* L.
		Rhamnus depressa Grubov
		Rhamnus microcapra Boiss.
		Rhamnus pallasii Fisch. et Mey
Thymelaeaceae Juss.	*Daphne* L.	*Daphne glomerata* Lam.
		Daphne mezereum L.
		Daphne transcaucasica Pobed.

Ulmaceae Mirb	*Celtis* L.	*Celtis caucasica* Willd.
	Ulmus L.	*Ulmus carpinifolia* Rupp. Ex Suckow.
		Ulmus glabra Huds.
Grossulariaceae D.C.	*Ribes* L.	*Ribes orientale* Desf.
		Ribes achurjani Mulk.
		Ribes alpinum L.
		Ribes biebersteinii Berl. ex DC.
	Grossularia Mill.	*Grossularia reclinata* (L.) Mill.

The results of studies to identify the most common species of undergrowth in the regions of central Russia are shown in Table 5. In the Kostroma and Moscow regions, the dominant species in the undergrowth are *Sorbus aucuparia* L., *Prunus padus* L., *Rubus idaeus* L., *Juniperus communis* L., *Lonicera xylosteum* L. *Rubus idaeus* L. are often found in forests with disturbed structure, for example, in clearings and windfall areas. Species such as blah, *Corylus avellana* L., *Chamaecytisus ruthenicus* (Fisch. ex Woł.) Klásk. are more typical for the Moscow region. In the forests of the Kostroma region, they are found to a limited extent in its southern part. *Salix cinerea* L. is confined to waterlogged habitats in central Russia. The dominant family among the identified species of undergrowth is *Rosaceae*.

Table 4. The most common species of undergrowth plants in the forests of central Russia regions.

Family	**Genus**	**Species**
Rosaceae Juss.	*Rosa* L.	*Rosa majalis* Herrm.
	Sorbus L.	*Sorbus aucuparia* L.
	Prunus Mill.	*Prunus padus* L.
	Rubus L.	*Rubus idaeus* L.
Cupressaceae Bartlett	*Juniperus* L.	*Juniperus communis* L.
Caprifoliaceae Juss.	*Lonicera* L.	*Lonicera xylosteum* L.
Thymelaeaceae Adams	*Daphne* L.	*Daphne mezereum* L.
Grossulariaceae D.C.	*Ribes* L.	*Ribes nigrum* L.
		Ribes spicatum E.Robson
Betulaceae Gray	*Corylus* L.	*Corylus avellana* L.
Adoxaceae E.Mey	*Viburnum* L.	*Viburnum opulus* L.
Rhamnaceae Juss.	*Frangula* Mill.	*Rhamnus frangula* L.
Salicaceae Mirb.	*Salix* L.	*Salix cinerea* L.
Fabaceae Lindl.	*Chamaecytisus* Link	*Chamaecytisus ruthenicus* (Fisch. ex Woł.) Klásk.
Celastraceae R.Br.	*Euonymus* L.	*Euonymus verrucosus* Scop.

A comparison of the undergrowth taxonomic categories of the study regions is given in Table 5. The number of identified species of undergrowth in the regions of central Russia is significantly less than in Armenia, where conditions are more favorable for the formation of high biological diversity. In the Lori region, 14 families were identified, which include the dominant species of undergrowth, in the Tavush region - 11 families and in the regions of central Russia - 11 families. For all objects of study, the largest number of species contains the *Rosaceae* family.

The diversity of plant species in the understory of the study regions is influenced by human activities. According to rough estimates, in the Lori region of the Gugark district of Armenia in 1992. About 10 thousand hectares of forest were cut down. Those forests that are located near populated areas were especially affected. During this period, no destructive anthropogenic impact is observed on the territory of the Lori region. Individual forest areas

inaccessible to humans have not been disturbed [16]. In the Kostroma region of Russia, clear-cutting has an impact on biological diversity, especially in old-growth forests. In the conditions of the Moscow region of Russia, a factor that has a strong negative impact on the diversity of species in the undergrowth is recreational forest management and aerotechnogenic emissions. Uncontrolled recreation leads to disruption of the functioning of forest ecosystems with a decrease in their biodiversity.

Table 5. Comparison of taxonomic categories of undergrowth species of some regions of Armenia and central Russia.

Family	Number of species		
	Armenia		Russia
	Lori region	Tavush region	Central regions
Adoxaceae	4	3	1
Berberidaceae	1	2	-
Betulaceae	1	1	1
Caprifoliaceae	2	-	1
Celastraceae	-	-	1
Cornaceae	1	-	-
Cupressaceae	-	-	-
Cupressaceae	-	-	1
Elaeagnaceae	1	1	-
Fabaceae	-	-	1
Grossulariaceae	1	5	2
Juglandaceae	1	1	-
Malvaceae	1	-	-
Oleaceae	1	-	-
Rhamnaceae	-	5	1
Rosaceae	11	27	4
Salicaceae	2	-	1
Sapindaceae	2	5	-
Thymelaeaceae	-	3	1
Ulmaceae	1	3	-

In addition to anthropogenic pressures, the impact of climate change on biodiversity has become significant in recent decades. From 1935-2016 in the northern, southern and central regions of Armenia the climate became drier. For the territory of Armenia, from 1961-1990, the average temperature increased by 5.5°C, in 2040 the average annual temperature is expected to increase by 1.6°C, in 2070 by 3.3°C and in 2100 by 4.7°C. In the case of precipitation, compared with 1961-1990 (average annual precipitation 592 mm), a decrease in annual precipitation is expected in 2040 by 2.7%, in 2070 to 5.4% and in 2100 up to 8.3% [17]. In the regions of central Russia, since the 1980s, there has been an increase in the average annual air temperature against the backdrop of rising concentrations of greenhouse gases in the atmospheric air [18]. Forecasts until the end of the 21st century indicate continued climate warming unless carbon dioxide emissions are reduced. Thus, changes in the climate system of the regions of Armenia and central Russia in the future create new risks for the sustainability of undergrowth biological diversity in forests.

4 Conclusions

In recent decades, the key factors influencing the species composition of the understory forests of Armenia and central Russia are anthropogenic impacts and climate warming. In the undergrowth of the forests of Lori region, the most common species (32) belonging to 16 families. The largest number of species (47) belongs to the family *Rosaceae* (34%). The species *Rubus caesius* L. was not previously known in the surrounding forests of Vanadzor.

Climate warming and massive logging in the Lori region have affected its spread. The undergrowth flora of the surrounding forests of Dilijan is represented by 13 families with 57 species. The understory of the surrounding Dilijan forests is also dominated by species of the family *Rosaceae* (27). In the forests of central Russia, 15 main species of undergrowth have been identified, 27% of which belong to the *Rosaceae* family.

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