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A COMPREHENSIVE ASSESSMENT OF CLIMATE COMFORT OF VAYOTS DZOR

N. A. HARUTYUNYAN *

Chair of Social-Economic Geography, YSU, Armenia

The article discusses the issues of climate comfort assessment in mountainous terrain, the complexity of which requires a spatio-temporal study. Vayots Dzor, which is a typical mountainous area, is chosen as an example in the article. Here there is the necessary variety of interrelated climatic conditions, the level of importance, which together make Vayots Dzor a typical object of geoecological research. Such research is not only of scientific and methodological interest and is useful for the study of climate comfort in other mountain areas, but also with its practical orientation can contribute to the scientific understanding and solution of the spatial planning problem of Vayots Dzor.

The aim of the study is to develop a methodology and methodological approaches for the geoecological integral assessment of the climatic comfort of the Vayots Dzor area, based on the measurability and analysis of the bioclimatic component of its natural resources potential, using integral bioclimatic indicators.

The article presents the results of the calculation and analysis of the spatial-temporal distribution of bioclimatic resources of Vayots Dzor. Equivalent effective temperature, radiative equivalent effective temperature, discomfort coefficient and weather severity were used as the main bio-climatic indices. As a result of the study, some features of the climatic conditions of the area during the last decades were revealed, climatic comfort zones and their territorial distribution in different periods of the year were distinguished. It was found that the distribution of calculated bioclimatic resources in the Vayots Dzor area has significant spatial and temporal heterogeneity, and is also characterized by the formation of small areas, which are caused by local atmospheric circulation processes.

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Introduction. Estimating the climate comfort of the ecological niche of people is considered one of the most important problems of the complex geoecological research of the region. The climate has a significant impact on health conditions, work ability and vitality of the population. The essence of the evaluation of bioclimatic indicators lies in the study of a specific area in order to determine the correlation between its climatic characteristics and the physiological state of the

* E-mail: n.harutyunyan@ysu.am

human organism. The relevance of such studies is explained not only by the inadequacy of subject studies of the climatic factor of separate mountain areas, but also by the emergence of new problems such as:

- economic assessment of climate for social-health sector and heating or cooling cost planning;
- by introducing energy efficiency into settlements floor plans and structure designs;
- assessment of climate comfort for military purposes.

The diversity of aspects of ecological assessment of climate conditions makes it practically difficult to develop a comprehensive climate assessment. Air temperature, humidity and wind speed are the dominant factors of climate. Weather instability, characterized by frequent deviations from annual or perennial values of basic climate parameters, affects human health. The climate comfort assessment methodology allows identifying regional differences in living conditions in mountainous areas, based on universally accepted indicators, which allow, taking into account the characteristics of the studied area, to draw up comparative ecological-geographical characteristics of the climate of different regions. With the aforementioned approach, an assessment and rounding of climate comfort in the conditions of the complex mountainous terrain of Vayots Dzor was carried out.

Materials and Methods. The methodological basis for assessing the climate comfort of the ecological niche of people in the natural environment is the comparison of individual climate factors and combinations of weather elements with the requirements of various aspects of the population's activity. Equivalent effective temperature (EET), radiative equivalent effective temperature (REET), discomfort coefficient (DC) and weather severity (WS) are used as main indicators.

In the process of determining the approaches for assessing the comfort of Vayots dzor climate, the international experience was studied and widely used, the framework of meteorological elements used for the purpose of assessing the comfort of the area was defined. When choosing indicators of climate comfort, their significance, comparability and reliability of observations were taken into account. A scale for evaluating the importance of integrated climate factors was developed for the region.

In the conditions of the complex mountainous terrain of Vayots Dzor, the assessment of climate comfort was carried out using mathematical modeling. The basic data necessary for the calculations are taken from the bulletins developed by the "Hydrometeorology and Monitoring Center" of SNCO, as well as from previously made observations [1–3]. Data were also collected from other scientific sources [4–6]. Calculations were made based on perennial average monthly data.

EET is determined by a combination of the main meteorological elements: air temperature (t), relative humidity (f), wind speed (v), on which the thermal sensitivity of the human body in the shade depends. EET was calculated by the formula proposed by A. Missenard, and the assessment was made using the scale given in Tab. 1.

$$\mathrm{EET} = 37 - (37 - t)/(0.68 - 0.0014\,f + 1/(1.76 + 1.4\,v^{0.75})) - 0.29\,t(1 - f/100),$$

where t is the air temperature, °C; v is the wind speed, *m*/*s*; f is the relative air humidity, % [7].

The effect of solar radiation on people's thermal sensitivity was also calculated: the REET, for which the formula developed by G. Sheleikhovski was used. The assessment of the REET was done using the scale given in Tab. 1.

$\mathrm{REET} = 125\ lg[1 + 0{,}02\ t + 0{,}001(t - 8)(f - 60) - 0{,}045](33 - t)\sqrt{v} + 0{,}185\ \beta]$,

where β is the absorption of solar radiation by the body surface in, kW/m^2 [7].

Table 1

Comfort zones according to the significance of EET and REET [7]

EET, °C	Comfort level	REET, °C
Above 30	strong heat feeling	Above 37
24 to 30	moderate heat feeling	32 to 37
18 to 24	comfortably warm	27 to 32
12 to 18	moderately warm	21 to 27
6 to 12	cool	17 to 21
0 to 6	moderately cool	12 to 17
–6 to 0	very cool	7 to 12
–6 to –12	moderately cold	2 to 7
–12 to –18	cold	–3 to 2
–18 to –24	very cold	–8 to –3
Below –24	it's getting frosty	Below –8

The coefficient of discomfort was calculated by the formula proposed by Arakawa:

$$\mathrm{DC} = 0.81t + 0.01f(0.99t - 14.3) + 46.3.$$

Environmental conditions are evaluated as the most uncomfortable (when the value of DC is less than 34 and higher than 53), slightly uncomfortable (value of DC: 35–45), uncomfortable (value of DC: 46–52) [7].

Weather severity for the cold period of the year is calculated by the Bodman formula, and the assessment is made using the scale given in Tab. 2.

$$\mathrm{WS} = (1 - 0.04\ t)(1 + 0.272\ v),$$

Table 2

Bodman weather severity scale [7]

Cherries	Below 1	1–2	2–3	3–4	4–5	5–6	Above 6
Characteristic	mild	slightly severe	moderately severe	strictly	very strict	most strict	extremely strict

Results and Discussion. Vayots Dzor's diversity and uniqueness of relief create a great variety of climate conditions, causing microclimatic separations that differ in the intensity of the Sun's rays, thermal regime and humidity conditions [8].

The climate comfort assessment of Vayots Dzor according to individual indicators is given in Tab. 3. The main indicators of climate comfort assessment in Vayots Dzor have a pronounced spatio-temporal characteristic of changes, which is explained by the mountainous relief and clear manifestation of the seasons. Thus, for example, the range of the EET indicators at the same altitude during the year is 28°C to 36°C, and in the same month, but at different altitudes, it varies from 24°C to 35°C, or the REET indicators at the same altitude during the year is 21°C to 29°C, and in the same month, but at different altitudes, it ranges from 28°C to 30°C.

Table 3

The main indicators of climate comfort

Absolute height, *m*	Indicators	Months											
		J	F	M	A	M	J	J	A	S	O	N	D
Up to 1000	EET	–7	–3	3	11	18	23	29	29	22	14	5	–3
	REET	8	10	16	22	27	32	37	37	31	24	17	11
	DC	33	37	46	55	62	68	73	73	66	58	47	37
	WS	1	1	1	1	0	0	0	0	0	1	1	1
1000 to 1200	EET	–9	–6	0	8	15	21	27	27	20	11	2	–5
	REET	6	8	13	19	25	30	34	35	29	22	15	9
	DC	31	36	44	53	60	66	71	71	64	56	45	35
	WS	1	1	1	1	0	0	0	0	0	1	1	1
1200 to 1400	EET	–11	–9	–3	5	12	18	24	24	17	9	0	–7
	REET	4	6	11	17	23	28	32	32	27	20	13	7
	DC	30	34	42	50	58	64	69	69	63	54	43	34
	WS	2	2	1	1	1	0	0	0	0	1	1	1
1400 to 1600	EET	–14	–11	–5	2	10	15	21	21	15	7	–3	–10
	REET	2	4	9	15	21	26	30	30	25	18	11	6
	DC	28	32	40	48	56	61	67	67	61	52	42	33
	WS	2	2	1	1	1	0	0	0	1	1	1	2
1600 to 1800	EET	–16	–14	–8	0	7	13	18	18	13	4	–5	–12
	REET	1	2	7	13	19	23	27	28	23	17	9	4
	DC	27	30	37	46	53	59	65	65	59	50	40	31
	WS	2	2	2	1	1	1	0	0	1	1	1	2
1800 to 2000	EET	–18	–16	–11	–3	4	10	15	16	10	2	–7	–14
	REET	–1	0	4	11	17	21	25	26	21	15	8	2
	DC	25	28	35	44	51	57	62	62	57	48	38	30
	WS	2	2	2	1	1	1	1	0	1	1	2	2
2000 to 2200	EET	–20	–18	–14	–6	2	8	12	13	8	–1	–9	–16
	REET	–3	–1	2	9	15	19	23	23	19	13	6	–3
	DC	24	26	32	41	49	54	60	60	55	46	36	28
	WS	2	2	2	2	1	1	1	1	1	1	2	2
2200 to 2400	EET	–22	–21	–17	–8	–1	5	9	10	5	–3	–11	–18
	REET	–4	–3	0	6	13	17	20	21	17	11	4	–4
	DC	22	24	30	39	46	52	57	58	52	44	34	26
	WS	2	2	2	2	1	1	1	1	1	1	2	2
2400 to 2600	EET	–24	–23	–20	–11	–4	2	6	7	2	–5	–14	–20
	REET	–6	–5	–2	4	10	15	18	19	15	9	2	–6
	DC	21	23	27	36	44	49	54	55	50	42	32	25
	WS	3	3	2	2	1	1	1	1	1	2	2	2
2600 to 2800	EET	–26	–25	–22	–14	–6	0	3	4	0	–8	–16	–22
	REET	–7	–7	–5	2	8	13	15	17	13	7	1	–4
	DC	19	21	25	34	42	47	52	53	48	40	31	23
	WS	3	3	3	2	2	1	1	1	1	2	2	2
2800 to 3000	EET	–28	–27	–25	–17	–9	–3	0	1	–3	–10	–18	–24
	REET	–9	–9	–7	0	6	11	13	14	11	5	–1	–6
	DC	17	19	22	31	39	44	49	50	46	38	29	22
	WS	3	3	3	2	2	1	1	1	1	2	2	3
3000 to 3200	EET	–30	–30	–28	–19	–12	–6	–3	–2	–5	–12	–20	–25
	REET	–10	–10	–9	–2	4	8	11	12	9	3	–3	–7
	DC	16	17	19	29	36	41	46	47	43	36	27	20
	WS	3	3	3	3	2	2	2	1	2	2	3	3
3200 to 3400	EET	–31	–32	–31	–22	–14	–9	–6	–5	–8	–15	–22	–27
	REET	–12	–12	–11	–4	2	6	8	9	7	1	–5	–9
	DC	14	15	17	26	34	38	43	44	41	33	25	19
	WS	3	3	3	3	2	2	2	2	2	2	3	3
Above 3400	EET	–32	–33	–32	–23	–16	–10	–8	–7	–9	–16	–23	–28
	REET	–13	–13	–12	–6	1	5	7	8	6	0	–5	–9
	DC	14	14	15	24	32	37	41	43	40	32	24	18
	WS	3	3	3	3	2	2	2	2	2	2	3	3

There are also clearly expressed spatio-temporal separations of the characteristics of the DC and the WS index, which was also characteristic of the EET and REET indicators.

In Vayots Dzor, in general, the most uncomfortable period observed in the hot and cold seasons of the year is about 240 days, and the uncomfortable and mildly uncomfortable period is about 125 days. Mild indicators of weather severity are observed up to the height of 2000 *m*, making about 30 to 150 days, weak severe indicators are observed up to the heights of 3200 *m*, making about 30 to 210 days, moderately severe indicators are observed in zones above 1200 *m*: being around 60 to 180 days, severe indicators are observed in zones above 2400 *m*, being around 60 to 180 days (Tab. 3). Such changes in the main indicators of climate comfort in Vayots Dzor have a direct impact on people's life in general and health in particular.

A point system was used for the complex assessment of climate comfort. Each climate indicator was assessed with a 5-point system and a simple arithmetic average was calculated, the obtained results are in the range of 1 to 4 points:

1) uncomfortable;
2) moderately uncomfortable;
3) moderately comfortable;
4) comfortable.

According to the complex assessment of climate comfort in Vayots Dzor according to the months of the year and high altitude zones, comfortable, moderately comfortable, moderately uncomfortable and uncomfortable regions were distinguished (Tab. 4).

Table 4

Complex assessment of climate comfort (in points)

Absolute height, *m*	Months											
	J	F	M	A	M	J	J	A	S	O	N	D
Up to 1000	3	3	3	3	4	4	4	4	4	3	3	3
1000 to 1200	2	3	3	3	4	4	4	4	4	3	3	3
1200 to 1400	2	2	3	3	3	4	4	4	4	3	3	3
1400 to 1600	2	2	3	3	3	4	4	4	3	3	3	2
1600 to 1800	2	2	3	3	3	3	4	4	3	3	3	2
1800 to 2000	2	2	3	3	3	3	3	4	3	3	3	2
2000 to 2200	2	2	2	3	3	3	3	3	3	3	3	2
2200 to 2400	2	2	2	3	3	3	3	3	3	3	2	2
2400 to 2600	1	1	2	3	3	3	3	3	3	3	2	2
2600 to 2800	1	1	1	2	3	3	3	3	3	3	2	2
2800 to 3000	1	1	1	2	3	3	3	3	3	3	2	1
3000 to 3200	1	1	1	2	3	3	3	3	3	3	2	1
3200 to 3400	1	1	1	1	2	3	3	3	3	2	1	1
Above 3400	1	1	1	1	2	3	3	3	3	2	1	1

The complex assessment of climate comfort in Vayots Dzor (Tab. 4) defines:

- in January, altitudes up to 1000 *m* are moderately comfortable, altitudes between 1000 *m* and 2400 *m* are moderately uncomfortable and zones above 2400 *m* are uncomfortable;
- in February, altitudes up to 1200 *m* are moderately comfortable, altitudes from 1200 *m* to 2400 *m* are moderately uncomfortable, and zones above 2400 *m* are uncomfortable;
- in March, altitudes up to 2000 *m* are moderately comfortable, altitudes from 2000 *m* to 2600 *m* are moderately uncomfortable, and zones above 2600 *m* are uncomfortable;
- in April, the altitude up to 2600 *m* is moderately comfortable, the altitudes between 2600 *m* and 3200 *m* are moderately uncomfortable, and the zones above 3200 *m* are uncomfortable;
- in May, altitudes up to 1200 *m* are comfortable, altitudes from 1200 *m* to 3200 *m* are moderately comfortable, and altitudes above 3200 *m* are moderately uncomfortable;
- in June, it is comfortable up to 1600 *m* and moderately comfortable in zones above 1600 *m*;
- in July, comfortable up to 1800 *m* and moderately comfortable in zones above 1800 *m*;
- in August, comfortable up to 2000 *m* and moderately comfortable in zones above 2000 *m*.
- in September comfortable up to 1400 *m* altitude and moderately comfortable in the zones above 1400 *m*;
- in October, it is moderately comfortable up to 3200 *m* and moderately uncomfortable in zones above 3200 *m*;
- in November, altitudes up to 2200 *m* are moderately comfortable, altitudes between 2200 *m* and 3200 *m* are moderately uncomfortable and zones above 3200 *m* are uncomfortable;
- in December, altitudes up to 1400 *m* are moderately comfortable, altitudes from 1400 *m* to 2800 *m* are moderately uncomfortable, and zones above 2800 *m* are uncomfortable.

Conclusion. The conducted research made it possible to identify some features of the natural conditions of the region and analyze the influence of climatic and meteorological factors on the spatio-temporal distribution of the area's comfort level using actual material. It has been confirmed that the distribution of calculated bioclimatic indicators in the Vayots Dzor area has significant spatial and temporal heterogeneity. In most parts of Vayots Dzor, active synoptic activity during the cold period creates uncomfortable conditions, which is confirmed by the values obtained from the complex assessment of climate comfort. According to the complex assessment of climate comfort, comfortable conditions begin to form in May, maximum in July. In the low, middle and high mountain zones of Vayots Dzor, the weather conditions with a comfortable and moderately comfortable index increase during the "June-September" period. According to the obtained results, the values of the complex assessment of climate comfort in the winter months in the mountain and

high mountain zones correspond to the moderately uncomfortable and uncomfortable gradation. During the winter months, climatic discomfort occurs under the influence of low temperatures and strong winds.

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Ն. Ա. ՀԱՐՈՒԹՅՈՒՆՅԱՆ

ՎԱՅՈՑ ՁՈՐԻ ԿԼԻՄԱՅԻ ՀԱՐՄԱՐԱՎԵՏՈՒԹՅԱՆ ՀԱՄԱԼԻՐ ԳՆԱՀԱՏՈՒՄԸ

Ամփոփում

Հոդվածում քննարկվում են լեռնային ռելեֆի պայմաններում կլիմայի հարմարավետության գնահատման հարցերը, որի բարդությունը պահանջում է իրականացնել տարածաժամանակային ուսումնասիրություն: Հոդվածում որպես օրինակ ընտրվել է Վայոց ձորը, որը տիպիկ լեռնային տարածք է: Այստեղ առկա է կլիմայական փոխկապակցված պայմանների այն անհրաժեշտ բազմազանությունը, կարևորության այն մակարդակը, որոնք Վայոց ձորը դարձնում են երկրաէկոլոգիական հետազոտության տիպիկ օբյեկտ: Այդպիսի

հետազոտությունը ոչ միայն գիտամեթոդական հետաքրքրություն է ներկայացնում և օգտակար է այլ լեռնային տարածքների կլիմայի հարմարավետության ուսումնասիրության համար, այլև իր գործնական ուղղվածությամբ կարող է նպաստել Վայոց ձորի տարածական պլանավորման հիմնախնդրի գիտական ճանաչողությանն ու լուծմանը:

Ուսումնասիրության նպատակն է մշակել Վայոց ձորի տարածքի կլիմայական հարմարավետության գեոէկոլոգիական ինտեգրալ գնահատման մեթոդաբանություն և մեթոդաբանական մոտեցումներ՝ հիմնված նրա բնական ռեսուրսների ներուժի կենսակլիմայական բաղադրիչի չափելիության և վերլուծության վրա՝ օգտագործելով ինտեգրալ կենսակլիմայական ցուցիչներ:

Հոդվածում ներկայացված են Վայոց ձորի կենսակլիմայական ռեսուրսների տարածաժամանակային բաշխման հաշվարկի և վերլուծության արդյունքները: Համարժեք արդյունավետ ջերմաստիճանը, ճառագայթային համարժեք արդյունավետ ջերմաստիճանը, անհարմարավետության գործակիցն ու եղանակի խստությունն օգտագործվել են որպես հիմնական կենսակլիմայական ինդեքսներ: Ուսումնասիրության արդյունքում բացահայտվել են տարածքի կլիմայական պայմանների որոշ առանձնահատկություններ վերջին տասնամյակների ընթացքում, առանձնացվել են կլիմայական հարմարավետության գոտիները և դրանց տարածքային բաշխվածությունը տարվա տարբեր ժամանակահատվածներում: Պարզվել է, որ հաշվարկված կենսակլիմայական ռեսուրսների բաշխումը Վայոց ձորի տարածքում ունի զգալի տարածական և ժամանակային տարասեռություն, ինչպես նաև բնութագրվում է փոքր տարածքների ձևավորմամբ, որոնք առաջանում են տեղական մթնոլորտային շրջանառության գործընթացներով:

Н. А. АРУТЮНЯН

ИНТЕГРАЛЬНАЯ ОЦЕНКА КЛИМАТИЧЕСКОЙ КОМФОРТНОСТИ ВАЙОЦ ДЗОРА

Резюме

В статье рассматриваются вопросы оценки климатического комфорта в горной местности, сложность которых требует пространственно-временного исследования. В качестве примера в статье выбран Вайоц Дзор, который представляет собой типичную горную местность. Здесь имеется необходимые разнообразие взаимосвязанных климатических условий, уровень значимости, которые в совокупности делают Вайоц Дзор типичным объектом геоэкологических исследований. Подобные исследования представляют не только научно-методический интерес и полезны для изучения климатического комфорта в других горных районах, но и своей практической направленностью могут способствовать научному осмыслению и решению проблемы пространственного планирования Вайоц Дзора.

Целью исследования является разработка методологии и методических подходов геоэкологической интегральной оценки климатического комфорта Вайоцдзорской территории на основе измеримости и анализа биоклиматической составляющей ее природно-ресурсного потенциала с использованием интегральных биоклиматических показателей.

В статье представлены результаты расчета и анализа пространственно-временного распределения биоклиматических ресурсов Вайоц Дзора. В качестве основных биоклиматических показателей использовались эквивалентная эффективная температура, эквивалентная радиационная эффективная температура, коэффициент дискомфорта и суровость погоды. В результате исследования выявлены некоторые особенности климатических условий местности за последние десятилетия, выделены зоны климатического комфорта и их территориальное распределение в разные периоды года. Установлено, что распределение расчетных биоклиматических ресурсов на территории Вайоц Дзора имеет значительную пространственную и временную неоднородность, а также характеризуется образованием небольших площадей, что обусловлено локальными процессами атмосферной циркуляции.