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ASSESSMENT OF DEMOGRAPHIC CAPACITY IN THE CONTEXT OF SPATIAL PLANNING

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The article discusses the issue of demographic capacity assessment in the spatial planning process. Demographic capacity (DC) is the maximum amount of population that can be accommodated in a given area, provided that the daily living requirements of the population are met with local resources, ensuring the ecological balance of the area. The need to calculate the DC stems from the goals and requirements of the proportionately and sustainable development of the area. Due to the complexity of the considered issue, an inventory of the factors determining the DC of the area and justification of their assessment methodology was carried out. DC is a variable quantity that can be changed in the conditions of scientific-technical, socio-economic progress, replenishment of national wealth. In spatial planning, we attach great importance to the integral magnitude of DC assessment. The minimum of the indicators calculated by various factors was accepted as the integrating indicator of the DC. In the article, demographic carrying capacity is calculated according to the following factors: ecological security, territorial opportunities, water resources and recreational resources. As a result of the analysis of private DC, the integrated DC of the studied area is accepted.

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***Keywords*:** demographic capacity, population, appropriated zones, permissible load, spatial planning.

Introduction. In solving the problems of sustainable development of the society, the identification of the demographic capacity (DC) of the area and the assessment of the permissible size of anthropogenic load are important. The solution to this important problem rests on the principle of maintaining the equivalence of ecological security, economic welfare and social justice.

Individual problems of the mentioned paradigm have been discussed by various authors on national and regional scales, but they have received very few complex solutions locally. In particular, in the main project of resettlement of RA, the DC for individual marzes is calculated according to territorial, recreational and water resources, but the problems of DC are not comprehensively analyzed and evaluated. Currently, multifaceted geographical studies of the factors determining the DC of both the entire country and its individual territorial units are becoming very important and urgent.

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The multi-layered and special complexity of the problem requires its gradual, phased study. It is obvious that in order to find a comprehensive and complete solution to the problem and to develop appropriate programs, the identification and assessment of the DC of individual territorial units should be preceded. It can be done at the scientific level, if it relies on a unified theoretical and methodological basis. The development of such a framework, even at the level of a hypothesis, can be based on the example of a study of an individual territorial unit. In that regard, the selection of a territorial unit requires a special justification, the research experience of which can be applied to identify the DC of other areas and determine the permissible anthropogenic load. We have chosen Vayots Dzor as an example, which is a typical mountain area. Here there is the necessary variety of interconnected problems, the level of importance, which together make Vayots Dzor a typical object of geographical research. Such a research can not only be of scientific and methodological interest and useful for the study of the DC of other mountain areas, but also with its practical orientation can contribute to the scientific understanding and solution of the problem of intelligent spatial planning in Vayots Dzor.

The purpose of the work is to identify the demographic capacity of Vayots Dzor, to determine the level of permissible anthropogenic load, using the integrative capabilities of geographical science. Based on the above-mentioned goal, the following problems were set and solved in the work:

- scientific analysis of the concept of DC;
- calculation of private demographic capacities;
- comprehensive DC assessment and zoning.

This work, as the first attempt to determine the DC of a mountainous area, has a certain superiority from a methodological point of view, which can be applied and improved to characterize other similar areas.

Materials and Methods. The methodological basis for the assessment of DC in spatial planning is the comparison of the combinations of natural components and permissible anthropogenic load with the requirements for ensuring the living conditions of the population. Permissible load of ecosystems, territorial possibilities, water and recreational resources are used as main indicators.

In the process of determining the approaches to DC assessment, the international experience was studied and widely used, the framework of environment elements used for the purpose of DC assessment of the territory was defined. When selecting indicators for the assessment of DC, their significance, comparability and data reliability were taken into account. A scale for evaluating the importance of integrated factors of DC was developed for the study region.

In the conditions of Vayots Dzor's complex mountainous relief, the estimation of the DC was carried out by means of 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]. Data were also collected from other scientific and official sources [2–9]. Calculations were made based on perennial average monthly and yearly data.

When discussing the issues of DC of the territory, it is first necessary to calculate the parameters of material, energy and information exchange in natural ecosystems and to determine the permissible anthropogenic load.

Due to territorial possibilities, the DC is calculated according to the target land use index and according to the zone of weak appropriation of resettlement. Targeted land use data are taken from the official bulletin of RA Statistical Committee. Calculations of the area's weak appropriation zone are made by the following formula [7]:

$$\sum T = \sum P_n + \sum P_g \,, \tag{1}$$

where $\sum T$ is the territorial DC; $\sum P_n$ is the population as of 01.01.2024; $\sum P_g$ is the possible population growth.

$$\sum P_g = S_1\,(\gamma c_1 - \gamma_1) \cdot K_n + S_2(\gamma c_2 - \gamma_2) \cdot K_n \,,$$

where S_1 is the intensively assimilated zone area; γc_1 is the marginal population density of intensively appropriated zone; γ_1 is the current population density of the intensively appropriated zone; S_2 is the area of the weakly appropriated zone; γc_2 is the marginal population density of the weakly appropriated zone (200 people/km^2); γ_2 is the current population density of the weakly appropriated zone; K_n is the adjustment coefficients.

Due to water resources, the DC of the territory is calculated according to the water supply and according to the sources of water supply. The water reserves suitable for water supply are calculated by the following formula [7]:

$$\sum D_w = \sum P_i \cdot K / P_s, \tag{2}$$

where $\sum P_i$ is the groundwater and surface water resources; K is the usage factor (0.1–0.7); P_s is the normative index per inhabitant (0.5 m^3/day).

In recreational planning and management of the territory, great importance is attached to the assessment of demographic carrying capacity. Calculations of DC according to recreational resources were carried out in two ways, in which, taking into account existing and prospective resources, the goal is to meet the requirements of organizing short-term recreation. Calculations were made using regulatory coefficients determined by a number of factors [7]:

$$D_1 = \frac{10\,(S\,A + S_g)K_1}{H\,M_1} \cdot K_2 \cdot K_3 \,, \quad D_1' = \frac{10\,(S\,A' + S_g)K_1}{H\,M_1} \cdot K_2 \cdot K_3 \,, \tag{3}$$

where D_1 is the private DC of the area with the organization of recreation in the existing forested areas and river basins, person; D_1' is the private DC of the area with the organization of recreation in prospective forested areas and river basins, person; S is the area , km^2; A is the forested area, %; A' is the prospective afforestation of the area, %; S_g is the areas of river basins, km^2; K_1 is the coefficient of recreation in green zones (0.5–1.0); K_2 is the health resource availability factor (1.05–1.2); K_3 is the factor of availability of tourism resources (1.05–1.2); H per 1000 inhabitants defined recreational area (2 km^2); M_1 is the distribution coefficient of vacationers in the forest and on the banks of water bodies (0.1 for hot climates and 0.3 for temperate climates).

Results and Discussion. The demographic capacity of the territory expresses the characteristics of the conditions limiting the population of the given territory.

According to Golubev [10], the main feature of the concept of DC of the territory is as follows:

- for social systems, the concept is interdisciplinary;
- it has a dynamic characteristic. Over time, both the anthropogenic load and the capacity of the territory change, which mutually influence each other;
- the capacity of the space in the studied system is clearly determined by the limiting factors;
- the capacity of the territory can increase or decrease due to human activities. Capacity increase is explained by efficient use of resources;
- the ability to restore the capacity of a degraded area is more difficult and expensive than its prevention.

Despite the difficulty of unambiguous assessment of the DC of the territory, this concept is the best means in spatial plans for the assessment of the anthropogenic load of the territory and the development of the regional development strategy, as well as for the sustainable development of the society.

According to many researchers, the Earth's population currently fluctuates around the maximum level of environmental carrying capacity. Feedback or other levers that can maintain the best rather than the maximum number level are not sufficiently developed. This is also due to the fact that developed countries are trying to find substitutes for consumed resources and increase their level, while in developing countries, the population is growing rapidly due to social, economic and national reasons. It should be noted that the increase in the level is ecologically very dangerous, it is necessary to stabilize the developing population growth. This situation can be expressed by the example of the problem of providing food to mankind. With modern technology, the distribution and ecological limitation of food use approaches the Earth's maximum carrying capacity. Therefore, any dangerous phenomenon, for example, drought, epidemics, war, can drastically reduce the harvest and cause malnutrition or starvation. If the population exceeds 10 billion if the Earth's carrying capacity is maintained, the quality of life of mankind will decrease, and the stability of the environment will be disturbed [10].

Thus, the DC of the territory can be determined by a set of limiting factors, which imply possible destruction of the ecosystem in case of violation of the permissible amount of their use. Therefore, we emphasize the problem of maintaining the ecosystem structure and stable mode, for the solution of which it is necessary to identify the quantitative and qualitative characteristics of the energy-metabolism of the system, the results created by the mutual connections of the elements of the system. In that sense, the ecological factors are of great importance, as a result of their complex interaction, natural and anthropogenic ecosystems with a certain capacity are formed. The DC of ecosystems is formed by the direct influence of abiotic primary ecological factors. Therefore, the diversity of ecological factors, their multiple direct and inverse relationships increase the DC of mountain ecosystems.

The carrying capacity of natural ecosystems is determined by the amount of biomass and the rate of reproduction. In terms of geo-ecological potential indicator quality, it is accepted as a starting point to calculate the volume of biomass or the

amount of bioenergy generated annually in a unit space. Having data on the bio-efficiency and occupied surface of each ecosystem of Vayots Dzor (which does not include cultivated lands, areas occupied by settlements, roads, various economic facilities), we determined the average amount of bioenergy produced per unit area annually, it is equal to approximately $794.2 \cdot 10^4$ *kcal*/*ha* (176.5 g/m^2). It is known that if the biomass utilization in an ecosystem is around 10%, then the system maintains balance. Therefore, to maintain a stable and balanced state of ecosystems, the use of biomass in Vayots Dzor should not exceed 10% of the average amount of bioenergy generated annually, which is $79.42 \cdot 10^4$ *kcal*/*ha* [3].

In order, to determine the DC of the natural ecosystems of Vayots Dzor, we calculated the amount of anthropogenic load of biotic communities according to the permissible amount of biomass use. Accepting the international average daily amount of food needed by one person is 2385 *kcal* [11], we get the amount of land needed for each inhabitant in Vayots Dzor, which is equal to about 1.1 *ha*. Making a relationship between the total area occupied by the natural ecosystems of Vayots Dzor and the size of the land needed for each resident, we get the best number of population – 173000 people, which can maintain the said area without disturbing the ecological balance of the natural environment. For each natural ecosystem, it will look like this: 2800 people – in semi-desert, 7500 people – in dry mountain steppe, 61400 people – in mountain steppe, 27400 people – in meadow-steppe, 34300 people– in mountain forest, 21000 people – in subalpine, and 18600 people – in alpine.

According to the 2022 census, the population of Vayots Dzor was 43255 [8], so we can say that the human load on natural ecosystems here is four times less than the demographic carrying capacity of the area allows.

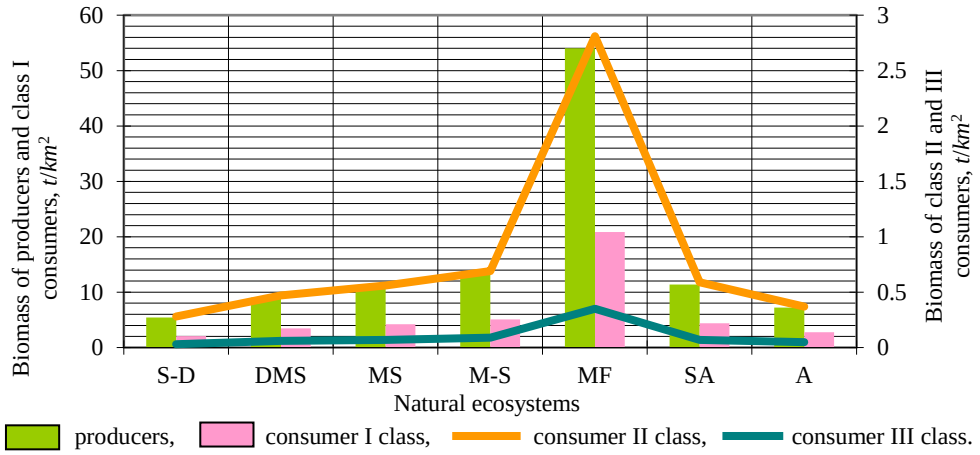

Fig. 1. Permissible levels of anthropogenic impact on natural ecosystems of Vayots Dzor. S-D – semi-desert, DMS – dry mountain steppe, MS – mountain steppe, M-S – meadow-steppe, MF – mountain forest, SA – subalpine, A – alpine.

The permissible amount of anthropogenic influence on each natural ecosystem of Vayots Dzor is calculated and mapped by us according to the food chain levels (Figs. 1–3).

Thus, we can conclude that ecosystems with high bio-efficiency also have high rates of DC potential. This is clearly expressed in Fig. 1 and is explained by the nature of energy-metabolism. High bioefficiency itself is the result of active energy-metabolism. But it should be noted that in the case of violation of the DC, natural ecosystems are subject to degradation and ecosystems with high capacity are violated to a greater extent and intensity than ecosystems with low capacity.

A certain minimum space is needed to satisfy the basic human needs. According to internationally accepted standards, each person needs 250 m^2 of industrial space, 750 m^2 of forest or green space, 2800 m^2 of arable land and 3200 m^2 of pasture, totaling 7000 m^2 [12]. Currently, for each resident of Vayots Dzor there is about 17616 m^2 of agricultural land (the world average is 30000 m^2, in the Republic of Armenia – 4000 m^2, 1300 m^2 of which is arable land) [8], including 4971 m^2 of arable land, 671 m^2 of perennial plantings, 738 m^2 of grassland,11236 m^2 pasture. In the event that the total land area per person is 41214 m^2, if we subtract the environmental, water and forest structure lands from that surface, then each inhabitant will get 39357 m^2 of land area, which is slightly more than the world average.

If we take the mentioned criteria as a basis, then for Vayots Dzor we will get the theoretical index of territorial comfort according to land types and their corresponding population. According to the total size of the minimum area necessary for comfort, the population of Vayots Dzor should not exceed 330000. In the case of that number, 82.4 km^2 of technical area, 247.3 km^2 of forest or green space, 923.2 km^2 of arable land and 1055.1 km^2 of pasture will be needed for human territorial comfort, which will be distributed according to the altitude zones as follows: the low and middle mountain zones will include technical area, forest or green space, the arable land will be completely and partially (464 km^2) pasture, and the high mountain zone will be completely occupied by pasture. At the same time, each inhabitant has 1406 m^2 of mountain meadow, 1210 m^2 of meadow-steppe, 730 m^2 of forest brown soil, 283 m^2 of mountain black soil, 2780 m^2 of mountain brown soil, 60 m^2 of alluvial river valley soils, and 531 m^2 of soilless area. By comparing the obtained indicators with the biological efficiency of the natural ecosystems corresponding to the above-mentioned soil types, we will get the amount of energy reaching each inhabitant, which is approximately equal to $62 \cdot 10^5$ *kcal*/year, which can satisfy 7.1 people. Comparing the current state of land use in Vayots Dzor with internationally accepted standards, it becomes clear that the anthropogenic load of the area is about 1.6 times less. In the case of permissible load defined by international standards, the area will satisfy about 6 times more population. But, obviously, the best population density should be determined based on the quality of the habitat and not the level of food security.

Therefore, based on the need to maintain the balance of natural ecosystems, only 10% of the annual biological productivity can be used, in which case the land area with the aforementioned structure can support approximately 0.7 people.

The obtained result shows the permissible level of anthropogenic load of natural ecosystems of Vayots Dzor according to the comfort index of soil types, according to which the population should not exceed 230000, that is, each inhabitant will have an area of 10000 m^2. But, in order to get a general picture of the permissible population density and to determine the DC of the area, it is necessary to calculate

the efficiency of the agricultural plots, because the agro-ecosystems provide the population with nutritional calories.

Thus, the capacity of natural fodder in Vayots Dzor allows each inhabitant to receive $47 \cdot 10^4$ *kcal* of energy from his share of 3200 m^2 pasture according to the criteria of comfort of the area, which by adding to the amount of energy obtained from arable land, $35 \cdot 10^6$ *kcal*, we will get in case of full use of the potential of agro-ecosystems, the total amount of annual energy to be received per person is $3547 \cdot 10^4$ *kcal* [13]. In the event that for the physiological functioning of each person's organism, about $87 \cdot 10^4$ *kcal* of energy is required annually, and the rest of the energy expresses the economic profit of the society, therefore the level of well-being and standard of living. Thus, humanity produces about $8 \cdot 10^{15}$ *kcal* of energy in the world, but it is extremely unevenly distributed. For example, the energy used by one person in the city is 80 mln *kcal*, from here we can conclude that for all kinds of processes a person spends 80 times more energy than his body needs [14]. Currently, humanity is at the stage of an energy crisis, and the characteristics of the future civilization are determined primarily by energy security.

Due to territorial possibilities, we calculated the DC based on the increase in population density in a poorly developed settlement zone, taking into account the presence of reserve territories within the zone. According to which the density of predominantly poorly developed zones was brought to the minimum environmental standard for the population (200 people/km^2). According to the results obtained, the DC of Vayots Dzor Region was 218000 people.

Each inhabitant of the Earth during the year uses 650 m^3 of water on average [11]. However, it should be noted that 2 *L* to 3 *L* of water are used daily to meet physiological requirements, about 1 m^3 per year. A large amount of water is used in agriculture (69%) mainly for irrigation, 23% of water is used in industry, 6% is used for domestic purposes and 2% for other purposes. According to the UN standards, water availability of up to 500 m^3 per person per year is considered extremely scarce, 500–1000 m^3– very scarce, 1000–5000 m^3– less, 5000–10000 m^3– medium, and more than 10000 m^3– high [15].

Using the aforementioned criteria of population water supply and the data of Vayots Dzor's water resources potential, we calculated the relationship between population growth and water supply in the studied area and the possible state of overload (Fig. 2). Fig. 2 clearly shows the inverse relationship between population growth and water availability. The intersection of the population growth and water supply curves is the limit state from which water scarcity is observed, and the population size at that level is considered the best. At best, the population of Vayots Dzor is about 200000, and the water supply is 2700 m^3/person per year or 7.3 m^3/person per day, which is considered less according to international standards, but it is equivalent to the amount of water supply in the RA. If we take into account all the water resources available in Armenia, 3000 m^3 of water per capita per year in Armenia. And if we take only internal renewable resources, then the amount of water per capita is 2700 m^3. However, regarding water resources, Vayots Dzor has an uneven spatial and temporal distribution.

Currently, the annual theoretical water supply per inhabitant of Vayots Dzor is about 11700 m^3, which corresponds to the high index of the international water

supply standard scale, but in reality it is smaller due to the irregular regime of the rivers flow and non-rational use of water resources. It should be noted that we did not consider wastewater treatment and water reuse in our assessment of water resource potential. In this case, water purification and multiple water use is a highly variable quantity, because over time, due to production methods and scientific and technical progress, the socio-economic requirements for the resource are constantly changing. Since our goal was to identify the allowable amount of use of the water balance potential, therefore, we calculated it according to the maintenance of the sanitary flow.

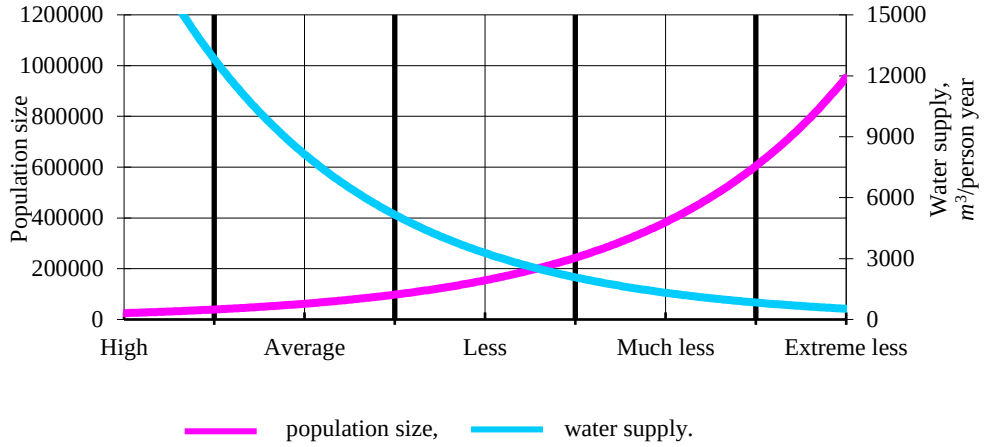

Fig. 2. Dependence of water supply in Vayots Dzor on population size.

From the calculations of the DC of water resources, it turns out that the anthropogenic permissible load of the steady flow of the river in the humid region of Vayots Dzor is 1.91 *t* per year on average, and 0.48 *t* in the arid region. Such a difference in the permissible anthropogenic load is explained by the magnitude of the stable river flow and the rate of water exchange, which also changes in different upstream zones of the same region (Fig. 3).

In recreational planning and management of the area, great importance is also given to the assessment of DC. Calculations of DC according to recreational resources were carried out in two ways, in which existing and prospective resources were taken into account with the aim of meeting the requirements of organizing short-term recreation. As a result of calculations, using the existing recreational resources of Vayots Dzor, the DC is 121000 people, and as a result of prospective development it can reach 280000.

The private DC of the territory have independent significance only during the solution of the corresponding problems of spatial planning. However, as the final DC, we have chosen the average equilibrium value. At the same time, the territorial possibilities were considered a decisive factor, under the condition that the deficit of intensively appropriated zones can be filled at the expense of the territorial resources of the adjacent weakly appropriated zones.

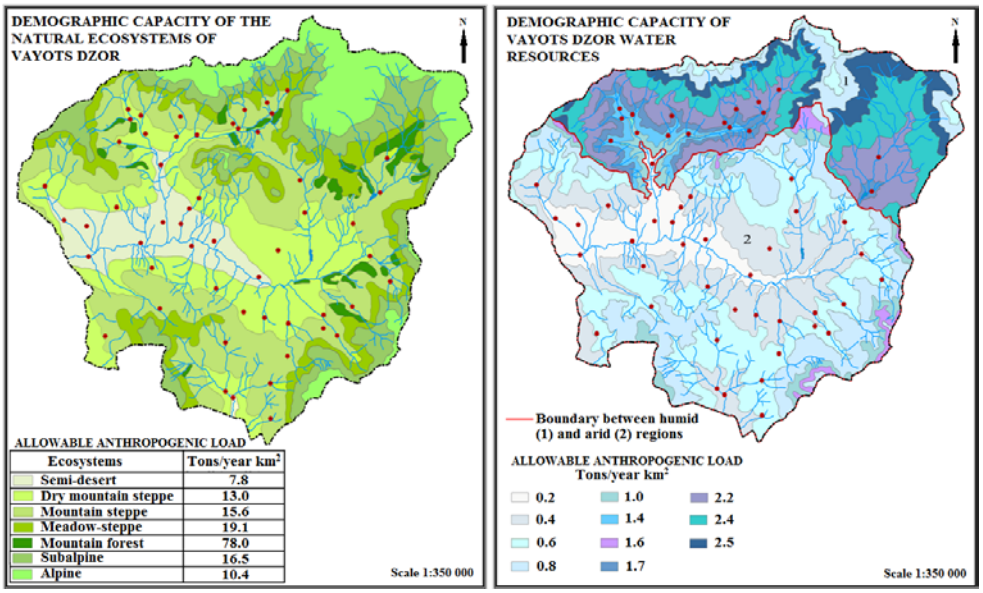

Fig. 3. Demographic capacity of natural ecosystems and water resources of Vayots Dzor.

Conclusion. We have evaluated the DC of Vayots Dzor based on the allowable load of natural ecosystems, because the sustainable development of the society can be ensured only if the balanced state of the natural environment is maintained. Our calculations show that the population capacity of Vayots Dzor for the DC of natural ecosystems is 173000 people. If we take as a basis the population corresponding to the comfort index of land types, then the population of Vayots Dzor should not exceed 230000. When we taken into account the best amount of water supply for the population, the population is 200000 people. It follows that a population of 200000 corresponds to the maximum ecological carrying capacity of the environment. In this case, 173000 is the minimum point of variation for the best population density, and 230000 is the maximum. The best growth rate is 100000 people.

Thus, for the ecologically sustainable development of Vayots Dzor, it is necessary to stabilize the population around 200000, otherwise, when it exceeds the optimal level, there will be a qualitative change in the natural environment, which will have a direct impact on the quality of life.

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ԴԵՄՈԳՐԱՖԻԱԿԱՆ ՏԱՐՈՂՈՒՆԱԿՈՒԹՅԱՆ ԳՆԱՀԱՏՈՒՄԸ ՏԱՐԱԾԱԿԱՆ ՊԼԱՆԱՎՈՐՄԱՆ ՀԱՄԱՏԵՔՍՏՈՒՄ

Ամփոփում

Հոդվածում քննարկվում է տարածական պլանավորման գործընթացում դեմոգրաֆիական տարողունակության գնահատման հիմնահարցը: Դեմոգրաֆիական տարողունակությունը (ԴՏ) բնակչության այն առավելագույն քանակն է, որը կարելի է բնակեցնել տվյալ տարածքում՝ բնակչության ամենօրյա կենսական պահանջները տեղական ռեսուրսներով բավարարելու պայմանով՝ ապահովելով տարածքի էկոլոգիական հավասարակշռությունը: ԴՏ հաշվարկման անհրաժեշտությունը բխում է տարածքի համաչափ և կայուն զարգացման նպատակներից ու պահանջներից: Դիտարկվող հիմնահարցի բարդությամբ պայմանավորված՝ իրականացվել է տարածքի ԴՏ պայմանավորող գործոնների գույքագրում և դրանց գնահատման մեթոդաբանության հիմնավորում: ԴՏ-ն փոփոխական մեծություն է, որը գիտատեխնիկական, սոցիալ-տնտեսական առաջընթացի, ազգային հարստության համալրման պայմաններում կարող է փոփոխվել: Տարածական պլանավորման մեջ՝ մեր կողմից մեծ կարևորություն է տրվում ԴՏ գնահատման ինտեգրալ մեծությանը: Որպես ԴՏ ինտեգրող ցուցանիշ, ընդունվել է տարբեր գործոններով հաշվարկված ցուցանիշներից նվազագույնը: Հոդվածում ԴՏ-ն հաշվարկված է

ըստ հետևյալ գործոնների՝ էկոլոգիական անվտանգության, տարածքային հնարավորությունների, ջրային պաշարների և ռեկրեացիոն ռեսուրսների: Մասնավոր ԴՏ վերլուծության արդյունքում ընդունված է ուսումնասիրվող տարածքի ինտեգրալ դեմոգրաֆիական տարողունակությունը:

Н. А. АРУТЮНЯН

ОЦЕНКА ДЕМОГРАФИЧЕСКОЙ ЕМКОСТИ В КОНТЕКСТЕ ПРОСТРАНСТВЕННОГО ПЛАНИРОВАНИЯ

Резюме

В статье рассматривается вопрос оценки демографической емкости в процессе пространственного планирования. Демографическая емкость (ДЕ) – это максимальное количество населения, которое может быть размещено на данной территории при условии удовлетворения повседневных жизненных потребностей населения за счет местных ресурсов, обеспечивающих экологическое равновесие территории. Необходимость расчета ДЕ вытекает из целей и требований сбалансированного и устойчивого развития территории. В связи со сложностью рассматриваемого вопроса были проведены анализ факторов, определяющих ДЕ территории, и обоснование методики их оценки. ДЕ – переменная величина, которая в условиях научно-технического, социально-экономического прогресса, пополнения национального богатства может изменяться. В пространственном планировании мы придаем большое значение интегральному значению оценки ДЕ. В качестве интегрирующего показателя ДЕ был принят минимум показателей, рассчитанных по различным факторам. В статье ДЕ рассчитывается по следующим факторам: экологическая безопасность, территориальные возможности, водные ресурсы и рекреационные ресурсы. В результате анализа частного демографического потенциала принята интегрированная демографическая емкость исследуемой территории.