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NATURE-BASED SOLUTIONS AS URBAN CLIMATE ADAPTATION TOOLS FOR ARMENIAN CITIES

M. V. CHAKRYAN *

Chair of General Geography, YSU, Armenia

The ongoing process of urbanization significantly affects environmental quality, particularly in the context of global climate change. The Republic of Armenia (RA) is no exception, as urban development continues without strategic planning, leading to adverse impacts on the urban microclimate and reducing resilience to the negative effects of climate change.

Drawing on international experience in implementing nature-based solutions (NbS) in urban areas, this study aims to demonstrate their potential, as well as the feasibility and effectiveness as key climate adaptation tools for urban settlements in Armenia using case studies, expert interviews, and policy analysis. However, the effective implementation and advancement of NbS are hindered by limited knowledge and experience, as well as the absence of a strategic approach and an adequate legal framework for their integration into the urban planning process.

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***Keywords*:** nature-based solutions, climate change, urban heat island, climate adaptation, urban resilience.

Introduction. More than half of the world's population, 4.6 billion people, currently lives in urban areas [1]. According to forecasts, this number has a growing trend and it is expected that the urban population will double by 2050.

According to the 2022 Population census of the RA, about 64% of the population lives in cities [2]. The vast majority of industrial production and transportation infrastructure are concentrated in cities. Since 2015, when the RA Government's decision enabled individuals to purchase apartments in multi-apartment residential buildings-either completed or under construction-by refunding income tax paid on mortgage loan interest [3], construction activity has intensified even further. They have already expanded beyond Yerevan to small towns such as Abovyan, Ashtarak, Dilijan, Vanadzor, etc.

Recent studies confirm, climate change studies demonstrate that long-term trends in heat waves (HW) are noticeable in some regions of Armenia. Research findings indicate that HW are becoming increasingly frequent and intense, with some areas experiencing higher occurrence and greater persistence [4]. A significant

* E-mail: mari.chaqryan@ysu.am

increasing trend in annual maximum temperatures (T_{max}) and observed HW was also recorded between 1955 and 2019. The increase in temperature is accompanied by an increase in HW, especially at altitudes up to 1250 *m* above sea level, where the majority of the population is concentrated [5].

The urban temperature is dependent on global development. In the cities, rising temperatures are supplemented and fortified by additional, city-derived factors. The urban heat island is a resulting effect which is seen as a major problem of urbanization [6].

Urban areas Like Yerevan, where buildings, roads, and other infrastructure are densely concentrated while natural landscapes, green spaces, and blue infrastructure are scarce, become "heat islands" with significantly higher temperatures compared to surrounding areas (Fig. 1). Yerevan experiences prolonged and extreme heat during the summer months. Between 1993 and 2022, temperatures here increased, especially in the summer. Exceptionally high temperatures were recorded for several years.

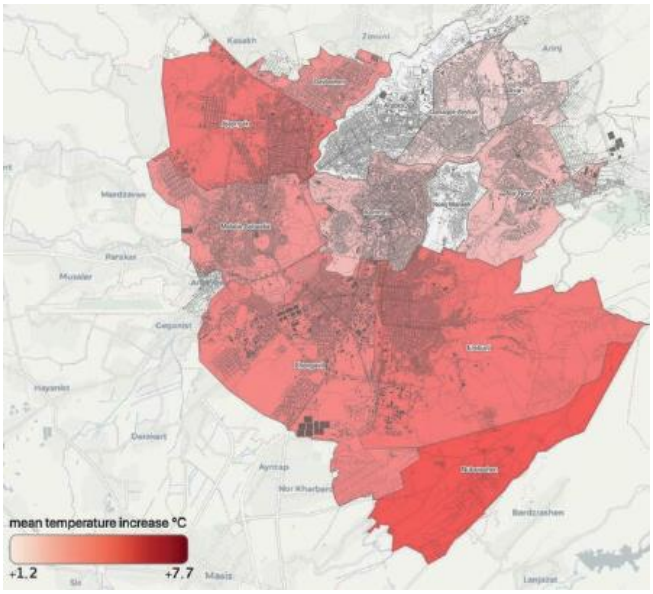

Fig. 1. Map-scheme of urban heat islands in Yerevan City [7].

In the May-September period, compared to the 1981–2010 norm, the longest HW in 2023 were observed in Gyumri – 12 days, and in Aparan – 11 days. The average number of HW days exceeded the norm by 1–2 days [8] (Fig. 2).

At the same time, heavy rains have become more frequent in recent years. Several times, daily precipitation has reached or exceeded 100% of the monthly norm. For example, in May 2024, due to heavy rains in Yerevan, streets were flooded, roads became impassable, even for cars, as the city's infrastructure is unable to absorb such a volume of runoff.

Green spaces play an important role in the resilience of urban areas, especially to the listed and other impacts of climate change. However, studies have demonstrated that, for example, the area of green spaces in Yerevan has decreased significantly over the past three decades [9].

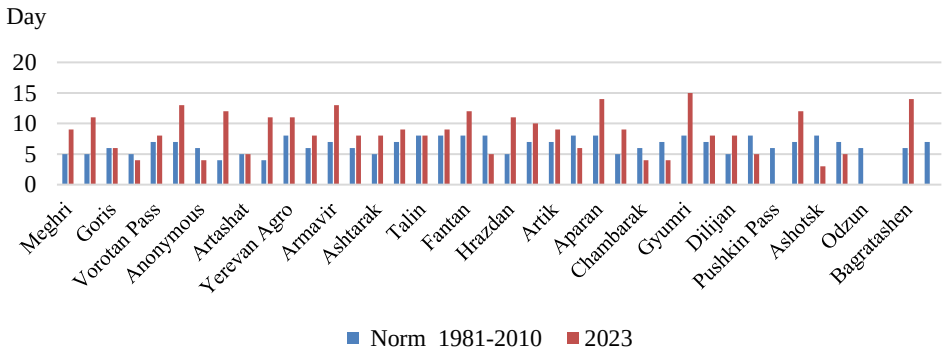

Fig. 2. Number of heat wave days in 2023 and the 1981–2010 norm according to "Armydromet" SNCO.

Recent studies suggest that simply having green spaces is insufficient. In recent years, the experience of developed countries and international policies have increasingly promoted the implementation of NbS in cities in terms of mitigating environmental challenges, such as heat stress and heat island effect, biodiversity loss and resource degradation, water and green space management [10]. NbSs offer many advantages to address the challenges of sustainable urban development by enhancing the natural defenses of ecosystems, that is recognized internationally [11]. However, the implementation of NbS in urban areas still faces obstacles, that must be addressed to enhance the climate adaptation of Armenian cities.

Research Methods. From the perspective of climate change adaptation, the implementation of NbS requires an interdisciplinary approach, incorporating perspectives from the sciences involved in the study of the environment: geography, climatology, biology, as well as law and other scientific fields. Therefore, our studies have been based on both physico-geographical and socio-economic comprehensive research methods and toolkits. Open data has been used for spatial mapping of problems and for proposing practical solutions.

To consider the opportunities for implementing NbS from the perspective of urban climate change adaptation, legal data were also reviewed, and a systematic content and national environmental policy gap analysis was conducted to identify key policy directions, gaps, and opportunities for integrating NbS.

The Delphi method has been used for collecting and analysis of experts' opinions on the issue. A total of 6 experts were invited to participate in the Delphi survey. Of these, 5 responded, yielding a response rate of 85%. Participants included professionals from academia, municipal planning, and environmental NGOs with direct experience in NbS implementation. The questions focused on four main directions: policy, financial, technical, and social barriers.

The case study method was used to identify lessons learned and best practices relevant to Armenian cities. Several successful examples of NbS implementation in Armenia and internationally, particularly in European countries, were selected and studied. Several potential areas for NbS implementation in Yerevan were mapped.

A comparative analysis method was used to assess effectiveness, challenges, and scalability.

The scheme proposed by the International Union for Conservation of Nature and Natural Resources (IUCN) has been used to emphasize the importance of the NbS contribution (Fig. 3).

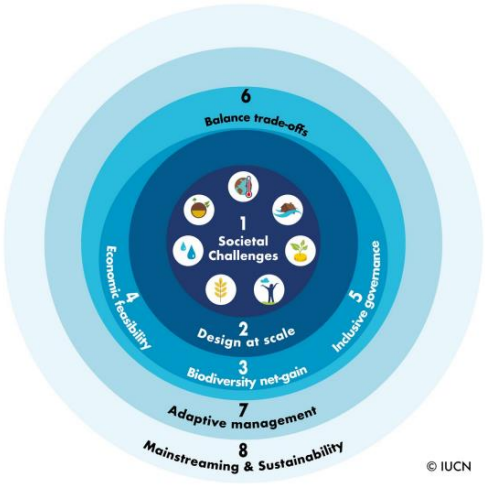

Fig. 3. Scheme of the Global Standard for NbS (IUCN, n.d.)

Results and Discussion. While the concept of NbS has only recently emerged in Armenia's environmental discourse, the region has a long history of harmonizing with natural systems. Ancient communities skillfully utilized geographic features to enhance ecosystem functions without degrading the environment. A notable example is the Dalma rock-hewn canal, constructed during the Kingdom of Van in the 8th century BC, which continues to operate today (Fig. 4).

Fig. 4. Dalma Canal in the Ajapnyak administrative district of Yerevan City, on the right bank of the Hrazdan River.

During the Soviet period, such solutions were also used, especially for the purpose of landscaping cities, as well as creating urban water infrastructure, but they were considered as urban planning elements rather than NbS.

The point is that all over the world, NbS have taken on a new meaning. The IUCN defines NbS as actions to protect, sustainably manage and restore natural

or modified ecosystems that effectively and flexibly address societal challenges while providing benefits for human well-being and biodiversity conservation [12].

Sustainable Development Goal (SDG) 11: Sustainable Cities and Communities, aims to make cities and human settlements inclusive, safe, resilient and sustainable. This goal has also served as a basis for various programs to accelerate the development of knowledge and practical dissemination of this new approach. However, existing policies, governance structures, and financing mechanisms often fail to fully recognize urban NbS, their objectives, and their benefits, which presents significant challenges for the advancement of NbS projects. To address this about 3 years ago, the United Nations (UN) Environment Assembly of the UN Environment Programme adopted a Resolution on supporting the SDGs through NbS highlighting their importance in addressing social, economic and environmental challenges [11].

Of the 23 urgent biodiversity targets set out in the Kunming-Montreal Global Biodiversity Framework, Target 11 emphasizes the improvement of ecosystem services-such as air, water, and climate regulation, soil health management, and disease risk reduction-through NbS and an ecosystem-based approach for the benefit of both people and nature. Target 8 also calls for actions that, through NbS and/or an ecosystem-based approach, minimize the negative impacts of climate action on biodiversity while fostering positive outcomes [13].

The RA has adopted a climate adaptation policy. National Action Plan for Climate Change Adaptation was adopted by the Government decree, which emphasizes the ecosystem approach, as well as ecosystem-based adaptation [14].

Currently, the National Biodiversity Conservation Strategy and national targets are being developed. At least two of them are expected to include actions aimed at promoting NbS, including in urban environments, as they will be based on the aforementioned Global Biodiversity Framework.

According to the interviewed experts, although there are not many examples of NbS in Armenia, especially in urban environments, they do exist, and the results are measurable and visible. For example, the Center for Ecological-Noosphere Studies (CENS) of the National Academy of Sciences of RA in the frame of European Union's H2020 Connecting Nature research and innovation project, together with the Yerevan Municipality, selected a kindergarten, where they created a green wall to reduce pollution infiltration into the kindergarten. The results indicated that implementing this local NbS could improve air quality, increase access to green open spaces and awareness of NbS, increase social interaction, and promote well-being [15].

As a result of restoration activities using NbS in a total of 1.61 *ha* of the Khor Virap Marsh, wetland ecosystem recovery and increased biodiversity have been recorded in a short time [16]. However, the potential benefits of planning and implementing NbS were not considered during the preparation and execution of the Yerevan Lake restoration project [17]. As a result, the potential flow of ecosystem services from the lake has been halved.

International experience is also crucial, as it offers valuable opportunities to adapt the approaches used in other countries to address environmental challenges and apply them in shaping climate adaptation actions. Singapore's vertical gardening experience [18], and the implementation of green infrastructure through NbS in

Copenhagen, Denmark, are considered exemplary. Thanks to NbS, flood resilience and access to recreational areas have increased in Copenhagen. Examples of NbS in the City of Poznan, Poland include the creation of open gardens that combine the concepts of social gardens and natural playgrounds, accessible to both children and adults-especially [19]. Other similar, integrated actions have been implemented in the city, not only increasing green and blue infrastructure to enhance the urban environment but also creating additional opportunities to boost adaptive capacity. The modeling of efficiency of NbS to decrease extreme summer-time heat in dense urban environment on example of Vienna demonstrated that the NbS has a moderate cooling effect even in densely built environment, where their implementation is physically limited [20].

Madrid Rio project has demonstrated the powerful role of water body restoration in mitigating urban heat and enhancing climate resilience [21]. The renaturalization of the River Manzanares not only reduced surrounding surface temperatures by up to 4℃, but also revitalized biodiversity, increased public engagement, and improved urban air quality. Similar approaches could be adapted to Lake Yerevan, combining shoreline green infrastructure, public accessibility, and ecological restoration, as well as to reduce surrounding surface temperatures, and contribute to the improvement of the microclimate (see Table).

Potential benefits of Lake Yerevan in case of NbS project implementation compared to River Manzanares in Madrid

	Madrid Rio Project, Spain	Potential for Lake Yerevan, Armenia
Context	Degraded riverbank along River Manzanares, surrounded by urban heat zones	Underutilized artificial lake with limited ecological or recreational function
Main Interventions	Riverbanks' restoration, planting over 30 000 trees, creation of wetlands, pedestrian and bike zones	Improved wetlands, green buffers, open-air public space, pedestrian and bike zones
Stormwater Control	Improved flood absorption via wetlands and permeable surfaces	Can reduce urban flooding with shoreline bioswales
Surface Temperature Reduction	2–4℃ reduction in surrounding neighborhoods	Potential 2–3℃ reduction of temperature locally with strategic green-blue integration
Biodiversity	Return of birds, aquatic life, native vegetation	Enhances ecosystem services, revive aquatic biodiversity
Public Impact	Park usage increased by 150%, boost in health and tourism	Could activate a public waterfront zone, boosting urban well-being

All 5 experts surveyed are confident that the multifunctionality of NbS allows cities to address multiple crises simultaneously, not only building resilience and adaptation to changing climate conditions, but also improving the quality of life of the growing urban population, as well as creating new jobs and sustainable livelihoods.

Conclusion. Thus, considering, that Armenia's urban population continues to grow increasingly facing the problem of managing the risks exacerbated by climate change, due to irregular development, absence of a strategic approach, the integration of NbS into city planning and development becomes increasingly vital.

These can include stormwater and urban wastewater management, the increase and preservation of green spaces, etc.

The case of Yerevan City and other urban areas demonstrates that it is crucial to address the combined impacts of rising temperatures, urban heat islands, and extreme weather events such as HW and flooding. Even with the historical and cultural examples of nature use in Armenia, the modern application of NbS remains limited. In Armenia, the level of awareness, necessary knowledge and experience regarding NbS is currently low, and the introduction of NbS is not actively encouraged. However, there is positive experience.

Although the National Action Program of Adaptation to Climate Change does not directly mention NbS, it emphasizes the importance of the ecosystem-based approach, providing a foundation for actions to integrate NbS, particularly for climate change adaptation. Hence at the national level we have at least two strategic documents that address/could adress NbS and can serve as a basis for the mainstreaming of NbS and the proper implementation of the international commitments undertaken by the RA in the field of environmental protection and climate change adaptation.

International examples offer valuable insights for tailoring effective NbS projects within Armenian contexts.

Thus, we believe that by including NbS into urban development strategies and environmental policies, Armenia can strengthen the adaptiveness of cities. NbS can contribute to microclimate regulation, temperature control, climate resilience, improving air quality and water systems, protecting biodiversity and providing access to green spaces, making cities healthier, more sustainable, and better prepared for the impacts of climate change. These findings imply the following:

– Building on the recommendations adopted and promoted by international environmental policy, expand the prerequisites for the dissemination and application of knowledge about NbS in national policies and strategies.

– Incorporate NbS into regional and local climate change adaptation programs to practically address climate change challenges. Allocate sufficient funding from state and municipal budgets, as well as other sources for this purpose.

– Emphasize the promotion of NbS in the strategy being developed based on the global biodiversity framework, focusing on both protecting ecosystems and expanding green spaces in urban areas, as well as ensuring biodiversity. This will contribute to inclusive and sustainable urbanization, while also enhancing ecosystem functions and services.

– Revise the local environmental plans, such as Green City plans, giving more emphasis to NbS.

– Introduce clear mechanisms and regulations for the implementation and development of NbS.

– Promote engagement in the planning and maintenance of NbS projects to ensure sustainability and climate resilience.

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ԲՆԱՀԵՆ ԼՈՒԾՈՒՄՆԵՐԸ ՈՐՊԵՍ ՀԱՅԱՍՏԱՆԻ ՔԱՂԱՔՆԵՐԻ ԿԼԻՄԱՅԻ ՀԱՐՄԱՐՎՈՂԱԿԱՆՈՒԹՅԱՆ ԳՈՐԾԻՔ

Ամփոփում

Ուրբանիզացման ներկա ընթացքը էական ազդեցություն է թողնում շրջակա միջավայրի որակի վրա, հատկապես կլիմայի գլոբալ փոփոխության պայմաններում: Նման իրավիճակ է նկատվում նաև Հայաստանի Հանրապետությունում, որտեղ քաղաքների զարգացումը տեղի է ունենում ռազմավարական պլանավորման բացակայության պայմաններում՝ բացասական ազդեցություն թողնելով քաղաքային միկրոկլիմայի վրա, ինչպես նաև նվազեցնելով դիմակայունությունը կլիմայի փոփոխության բացասական ազդեցության հետևանքների նկատմամբ:

Հետազոտության նպատակն է ցույց տալ քաղաքային միջավայրում բնահեն լուծումների (NbS) անհրաժեշտությունը՝ հաշվի առնելով այդ ուղղությամբ միջազգային փորձը: Բնահեն լուծումները կարող են լինել Հայաստանի քաղաքային բնակավայրերի կլիմայի հարմարվողականության հիմնական գործիքները: Սակայն, մեր հանրապետությունում NbS-ի ներդրմանն ու առաջխաղացմանը խոչընդոտում են ինչպես գիտելիքի և փորձի, այնպես էլ քաղաքային պլանավորման գործընթացում դրանց ինտեգրման ռազմավարական մոտեցման և անհրաժեշտ իրավական հիմքերի բացակայությունը:

М. В. ЧАКРЯН

ПРИРОДНЫЕ РЕШЕНИЯ КАК ИНСТРУМЕНТ АДАПТАЦИИ ГОРОДОВ АРМЕНИИ К ИЗМЕНЕНИЮ КЛИМАТА

Резюме

Современные процессы урбанизации оказывают значительное влияние на состояние окружающей среды, особенно в условиях глобального изменения климата. Республика Армения не является исключением: развитие городов здесь часто осуществляется без должного стратегического планирования, что

негативно сказывается на городском микроклимате и снижает устойчивость к климатическим рискам.

Целью данного исследования является обоснование необходимости внедрения природных решений (NbS) в городскую среду Армении на основе международного опыта. NbS обладают потенциалом стать ключевым инструментом адаптации городских территорий к изменению климата. Однако их реализация в Армении осложняется нехваткой профессиональных знаний и опыта, отсутствием стратегического видения в градостроительной политике, а также недостаточной нормативно-правовой поддержкой.