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NATURE-BASED SOLUTIONS IN REGENERATION OF PUBLIC OPEN SPACE: CHALLENGES AND PROSPECTS OF IMPLEMENTATION IN THE CITY OF NIŠ

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Abstract

Nature-based Solutions (NbS) are increasingly prioritized in the contemporary urban planning of residential areas, as they offer sustainable and resilient responses to environmental and social challenges, by integrating nature to enhance the climate adaptation, biodiversity, and human well-being. Given their crucial role in enhancing the public open space (POS), multiple (re)development projects for residential POSs integrate NbS measures and elements into the planning and design concepts.

This paper presents the experience of the City of Niš, Serbia, in regeneration of POS within a multi-family residential neighbourhood through a case study. Due to its evolving legislative and planning frameworks that increasingly recognize the importance of NbS in urban development, Niš represents a suitable research ground. The selected study site is a residential neighbourhood within a large housing estate, which has recently undergone a significant POS redevelopment. This area illustrates both a rare local example of NbS implementation, and the consequences of the subsequent intervention that disregarded NbS principles. The paper explores the key factors influencing implementation outcomes, as well as the opportunities and challenges for advancing NbS in the local context.

The study finds that implementation is hindered by regulatory and funding gaps. A successful rain garden project highlights NbS benefits, though it requires further support for a long-term impact. In contrast, the subsequent POS regeneration in the neighbourhood without NbS reveals the negative consequences of passive planning, limited community involvement, and non-compliance with strategic goals. The findings highlight the need for a more integrated, participatory and sustainability-focused approach to urban regeneration.

Key words: *Public Open Space, Multi-family Housing, Residential Neighbourhood, Rain Garden, Citizens' Participation, Nature-based Solutions*

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1. INTRODUCTION

Nature-based Solutions (NbS) is the umbrella concept of ecosystem-based approaches that have emerged over the last few decades to address crucial societal and environmental challenges of urban development. According to the International Union for Conservation of Nature (hereinafter: IUCN) [1], NbS are “actions to protect, sustainably manage and restore natural and modified ecosystems, which address societal challenges effectively and adaptively, providing human well-being and biodiversity benefits”. These solutions are also considered to be one of the key measures of disaster risk reduction and climate change adaptation and mitigation in the New Urban Agenda [2].

NbS play a vital role in shaping the public open space (POS), offering sustainable, resilient and affordable solutions to challenges such as heat stress, urban flooding and air pollution [3,4]. Aside from environmental gains and climate change mitigation, reintroducing nature into the residential fabric also brings direct benefits to people’s health and well-being, by supporting recreation and setting the context for the social life. NbS create versatile spaces that seamlessly integrate housing, nature, play and recreation, fostering vibrant and appealing communities, while promoting the ecological diversity. Therefore, contemporary urban planning and design concepts for reclaiming POS in residential areas prioritize the implementation of NbS [5].

The City of Niš, Serbia is committed to sustainable development, aiming to harmonize economic growth with environmental protection. With multiple challenges stemming from the post-socialist urbanization, in the last couple of decades the city has dedicated efforts to guide the urban development while minimizing the environmental impact. A noteworthy progress has been made concerning the NbS concept at the local level in the legislative and planning framework, as part of the efforts to harmonize strategic documents of the city with the national legislation and the overall European integration process. The significance of NbS is highlighted in the strategic documents of urban development and urban planning. At the level of strategic planning, the importance of NbS is acknowledged in the Development Plan [6], within a measure that promotes the creation and of green and blue infrastructure, as well as the investments in green infrastructure in public spaces with the development of the cadastre of green areas for the urban and rural core. The measure relating to green infrastructure is further supported in the Urban Development Strategy [7], which prioritizes roof gardens and gardens in neighbourhood greenery. Although the General Urban Plan of Niš 2010-2025 [8] and its four amendments and supplements do not explicitly mention the term NbS, greenery is discussed in detail within the framework of spatial and environmental protection, highlighting its significance for satisfying sanitary-hygienic-recreational conditions. Within the urban planning at the local level, the Plans of General Regulation and Plans of Detailed Regulation even increase the share of green surfaces to 25% for the residential land use, out of which 10% are in a direct contact with the ground, which is a step forward in setting the context for quality POS with NbS elements. It is also favourable that legal acts of the city of Niš, such as the Environmental Protection Program [9], thoroughly incorporate the topic of NbS, review and adopt the measures from strategic and planning documents.

Although the legislative and planning frameworks in Niš favour NbS implementation, recent regeneration practices concerning POS regeneration that

occurred in multi-family housing areas in Niš showcase poor integration of NbS elements. The situation is particularly complex in residential neighbourhoods within large housing estates (LHEs) inherited from the socialist past, which are pressured by intense urban densification in the post-socialist period. Therefore, the overall objective of this research is to explore and determine the potentials and limitations for the implementation of NbS in POS (re)integration at the neighbourhood level in the City of Niš, Serbia, in order to foster sustainable development of POS in multi-family housing zones.

2. METHODOLOGY AND MATERIALS

This study uses the empirical research and review of relevant literature and web sources. The methodological framework is conceptualized on a single-case study, involving a description and analysis of implemented actions and projects in Niš relating to NbS, complimented by a semi-structured interview and field observations.

The research begins with an overview of the NbS concept, outlining its main principles and typology elements. NbS characteristics and benefits are determined on the basis of scientific findings presented in academic literature, as well as data from web sources involving frameworks, programs and guidance documents provided by diverse sustainability-oriented actors and organizations.

Next, the research explores the example of good practice implemented in Niš involving a rain garden in a residential neighbourhood of an inherited LHE. Furthermore, the study critically reviews the non-implementation of NbS in a large-scale regeneration project of the same neighbourhood that followed the rain garden initiative, while reflecting on the effects on POSs. For this purpose, aside from site visits and field observations, a semi-structured interview is conducted with an employee of the City Administration for Construction, who provided valuable input on the course of these projects. Examining both a successful and unsuccessful practice provided a deeper understanding of NbS implementation in a real-world setting, thereby identifying the specific contextual factors that influenced the outcomes. The implementation of NbSs in analysed cases is reviewed based on the POS typology established within the RePOS project [10].

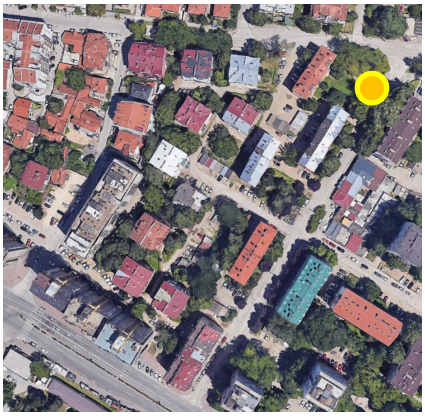
Finally, the synthesis of study findings is used as a basis for discussing the opportunities and constraints for NbS implementation within residential POSs in the City of Niš and Serbian context.

2.1. Study area

This research selected a representative study area within an inherited multi-family residential setting that originally contained substantial POSs between buildings. The choice of the neighbourhood is related to the fact that it recently underwent a significant transformation of the open space. Moreover, the study area showcases a rare example of NbS application in Niš, as well as the implications of NbS non-implementation in the following POS redevelopment, which was performed contrary to NbS principles adopted in the strategic and planning documents of the city. The redeveloped neighbourhood analysed in this study is part of the LHE along Zorana Đinđića boulevard in the City of Niš. The neighbourhood is framed by

Pasterova, Dragiše Cvetković and Rentgenova streets, as well as Zorana Đinđića boulevard (Figure 1).

(a) Cadastral-topographic plan
Source: Urban Design Project, 2019



(b) The neighbourhood before POS renovation and the position of the rain garden
Source: Google maps, 2023

Figure 1. The analysed residential neighbourhood, as a segment of the LHE along Zorana Đinđića boulevard, city of Niš

The subject neighbourhood and the LHE were developed during the socialist period in the 1960s, in line with CIAM's principles. Residential buildings are positioned in an open system of spatial organization, with row buildings (linear block buildings) framing the urban block in the SE, SW and NW direction, and detached buildings inside the block. The neighbourhood was characterized by the anthropometric scale of the open space with the public access and recreational use, also featuring l the imited motor traffic and vast green areas. In such a setting, POS was considered an integral part of the residential environment of buildings.

The neighbourhood underwent significant urban densification during the post-socialist period in the 1990s. The majority of multi-storey residential buildings were upgraded by constructing additional floors on top of them, thereby significantly increasing residential densities and generating new, extensive parking needs. Increased motorization rates at the turn of the century have further exacerbated the problems caused by densification. All of these transformations have reflected on POSs, and once lavish greenery in the area significantly deteriorated in size and quality. In 2018, the POSs within this housing area were characterized by a high-level of publicity, high levels of physical and visual flow, modest urban furniture, insufficiently maintained greenery, frequent urban flooding, and unclear rights of use. Furthermore, the POSs were burdened with vehicular traffic and unplanned parking lots, resulting in unsafe intersections of pedestrian and vehicle traffic.

3. THEORETICAL FRAMEWORK

3.1. Principles and typology of NbS

According to the IUCN [1], NbS is based on eight main principles:

1. Embrace nature conservation norms,
2. Determined by site-specific natural and cultural contexts,

3. May be implemented independently or in combination with other solutions to social challenges,
4. Produce societal benefits and promotes transparency and participation,
5. Maintain biological and cultural diversity,
6. Applied at a landscape scale,
7. Recognise and address the trade-offs between immediate economic benefits and future options for the production of ecosystems services,
8. Incorporated into overall development policies, and measures or actions to address specific challenges.

While there is a broad consensus that NbS are beneficial and can help tackle major environmental and social issues like climate change, there is a lack of a clear understanding of how NbS functions as a complex and multifaceted intervention [11]. The absence of a simple and clear typology within the NbS concept makes the development of an official systematic classification a challenge [12]. The IUCN defines five categories of approach: 1) ecosystem restoration, 2) issue-specific ecosystem-related, 3) infrastructure-related, 4) ecosystem-based management, and 5) ecosystem-based protection [11].

Depending on how much engineering of biodiversity and ecosystems is involved in NbS, and how many ecosystem services and stakeholder groups are targeted by a given NbS, Eggermont et al. [13] define three types of NbS characteristics: 1) for better use of natural/protected ecosystems, 2) for sustainability and multifunctionality of managed ecosystems, and 3) for design and management of new ecosystems. Type 1 requires the least intervention, while Type 3 involves the highest level of ecosystem intervention. The application of NbS in cities and built environments is categorized as Type 3) Highly intensive ecosystem management or the creation of new ecosystems. Type 3 is often associated with the concept of green and blue infrastructure, and aims to restore severely degraded or polluted areas [13]. Within this category, UNaLab [14] has proposed the technical elements and measures of NbS presented in Table 1.

Table 1. Technical elements and measures of NbS. Source: UNaLab (2022)

Type 3	Sub-type	Element/Measure
Highly intensive ecosystem management or the creation of new ecosystems	Green space	Residential park, Green corridor, Urban garden
	Trees and shrubs	Single line street trees, Boulevards, Group of trees
	Soil conservation and quality management	Living fascine, Revetment with cuttings, Planted embankment mat
	Green built environment	Extensive/Intensive green roof, Constructed wet roof, Smart roof Green façades, Free standing living wall, Mobile vertical greening, Moss wall
	Natural or semi-natural water storage and transport structures	Constructed wetland, Retention/detention pond, Daylighting, Underground water storage
	Infiltration, filtration and biofiltration structures	Bioswale, Rain garden, Infiltration basin, Permeable paving system, Biofilter (water purification)

3.2. Implementation of NbS in residential neighbourhoods

The implementation of a well-planned and designed NbS can serve to achieve social, environmental, and economic benefits, which represents a great potential for improving the quality of life within a local community. Therefore, the application of NbS is beneficial in many ways for all stakeholders in the process of shaping residential environment: planners incorporate contemporary sustainable planning solutions that result in quality urban settings, residents gain a healthy and attractive environment, local utility and service companies have less work in maintaining spaces where NbS are implemented, and less problems related to damages from natural disasters (urban flooding, heat islands), while local politicians get the opportunity to promote their work that is supported by local citizens, and thereby achieve political benefits. Although the NbS may initially be more demanding and expensive for development, they are also more sustainable in the long run, considering climate change mitigation and the overall urban development issues. Thus, these solutions may even provide economic benefits for the local community, which is a crucial asset that needs to be pointed out to all stakeholders in the process of shaping residential neighbourhoods.

The multiple benefits of NbS enable that their elements and measures be applied in multi-family residential areas on three levels, in line with the RePOS project typology [10]: 1) Building-oriented POS, 2) Common POS on the micro level of the area, involving a cluster of buildings, and 3) Neighbourhood POS on the macro level of the residential neighbourhood. On a single building basis, NbS measures such as green roofs, green walls, and mini rain gardens can be applied. In common and neighbourhood POSs, a variety of technical measures and NbS elements given in Table 1 can be implemented in order to achieve functional, ecological, socio-cultural, and aesthetic benefits for the local community.

Furthermore, multiple NbS elements may also be implemented in other POS types in residential neighbourhoods, involving: 1) Open space allocated for mobility routes, both vehicular and pedestrian, 2) Greenery as nature space, and 3) Spaces designated for a potential POS space, such as services and utilities.

4. RESULTS AND DISCUSSION: REGENERATION OF PUBLIC OPEN SPACE IN A MULTI-FAMILY RESIDENTIAL NEIGHBOURHOOD IN NIŠ

4.1. Initiative for the regeneration of neighbourhood POSs and the planning framework

Having in mind the issues and reduced quality of life within the neighbourhood, the City of Niš initiated a cooperation with the Faculty of Civil Engineering and Architecture of Niš regarding the arrangement of neighbourhood POSs. The idea was carried out through the engagement of students of the IX semester of the study program Architecture, within the elective course “Urban Design and Composition”. The most successful student proposal was awarded, and incorporated into the official Urban Design Project as a Conceptual Solution (Idejno rešenje - IDR), authored by the students and their mentors. The Urban Design Project (Urbanistički projekat) for the “Urban-architectural design of public open space in the wider area

of Pasterova street in Niš" was prepared by the Urban Planning Institute of Niš, and adopted in 2019 [15].

When conceptualizing the urban-architectural solution for POSs, the focus was on resolving the conflict between the pedestrian and car traffic, introducing new amenities for all user categories, and organizing and arranging green areas (Figure 2). The design envisioned removing the unplanned parking spaces and organizing parking more efficiently. Vehicular access to all residential buildings was provided through driveways, parking lots and shared streets, without introducing traditional streets with traffic segregation, or fragmenting the urban block space. Moreover, the design favoured pedestrian traffic. By implementing green areas and installing mobile planters, vehicle traffic was disabled within pedestrian areas inside the urban block. In case of an emergency, necessary access and unimpeded flow of emergency service vehicles were enabled directly to the buildings, by moving planters and driving over the green areas.

Figure 2. The urban-architectural solution for the neighbourhood, elaborated through the Urban Design Project.

Source: Urban Planning Institute of Niš, 2019.

The design solution in the project also prioritized preserving the existing green spaces as much as possible, including grass, hedges and trees, due to social and environmental benefits of these NbS elements. The surroundings of existing trees within paved areas were to be remodelled and paving removed. Regarding the type of greenery, local species suited to the climate conditions were recommended. The plants were also to have a decorative function in order to enhance POS appeal. The selection of plant species was to be made in line with the conditions of the habitat and with respect for the winter landscape. This implied the inclusion of conifers, because of their significant role throughout the year. It was defined that 200-250 tree seedlings must be planted on 1 ha of green space, out of which 70% deciduous trees and 30% conifers, as well as 1,500-2,000 pieces of shrubs. Flower beds were to cover no more than 2-2.5% of the green space within the urban block. It was suggested that flowering plants and aromatic herbs be placed in planters and in elevated areas designed for seating.

Interlock pavers of 8 cm thickness were suggested as the paving material, as they are adequate for both pedestrian and vehicle traffic. This paving material was selected in order to create a permeable surface and thus contribute to a better stormwater drainage, since the neighbourhood experienced frequent urban flooding. It was also envisioned to set up a system for collecting and recycling stormwater for future reuse.

4.2. Regeneration of public open spaces in multi-family residential neighbourhood

The regeneration of POS in the neighbourhood along Zorana Đinđića boulevard involved two individual, non-related actions: 1) development of a rain garden, as a small-scale intervention implemented within the project of a private company A1 (Figure 1b), and 2) a large-scale city-led regeneration of neighbourhood open spaces, which followed the works on the rain garden (Figure 1b).

4.2.1. Implementation of a Nature-based Solution

The city of Niš gained its first rain garden in 2023, which was realized as a part of the socially responsible project “Sprouted like me” (Niklo kao ja). The project of implementing rain gardens in public open spaces in ten Serbian cities was initiated by the company A1, together with the European organization Propulsion, and in cooperation with the Faculty of Forestry, University of Belgrade [16].

In February 2023 the city received a formal invitation to participate in the project. The project team met with the city officials in March 2023 to explain the overall concept of rain gardens and discuss a potential implementation in Niš. The stakeholders that attended the meeting involved the representatives of the Urban Planning Institute, Local Economic Development Office and Chief Urban Planner with her associates. The A1 company required the support of the city regarding the potential site for the rain garden, obtaining permits from the city's municipal services, and providing safety measures that must be abided by in the field work [17]. The city was asked to propose up to three green areas that could accommodate this NbS element. The criteria for selecting a potential location included the following [17]:

- Scale of green area not larger than 10x10 meters;
- Green area located within a densely populated area or busy area;

- Green area preferably located within residential communities, urban blocks, etc.;
- Access to water and electricity near the green area preferred, but not mandatory;
- Condition of the green area not necessarily perfect.

City representatives have jointly decided to implement the rain garden in the territory of the city municipality Medijana as the most densely populated area of Niš, and reviewed the Plan of General Regulation for this city municipality in search of suitable locations. Initially, three sites that complied with the listed criteria were proposed, all involving green POSs owned by the City of Niš, located in multi-family housing areas, and publicly available to all users [18]: 1) along Rentgenova street in the inherited LHE, 2) along Ljudevita Gaja street in the same inherited LHE, and 3) in the urban block adjacent to the elementary school Duško Radović in Duvanište district. Finally, the site along Rentgenova street was selected. An influential factor in decision-making was the existing Urban Design Project for the redesign of this LHE, which was adopted in 2019. Other factors that favoured the selection of this particular site involved the proximity of a school, kindergarten and public hospital, easy access and visibility of the site, and presence of two existing pedestrian paths [18].

The realization of this NbS element in Niš is an example of collaborative action involving multiple stakeholders. The material and all necessary resources for developing this rain garden were provided by the A1 company. The company's team of gardeners, consisting of landscape architects, agronomists and biologists, have designed the garden that is adapted to the specific conditions of Niš, with the implementation of local materials and seedlings (plants, soil, tools, etc.) [17]. One of the pre-conditions for project realization, set by the initiators, was the participation of the residents and users of open space in the process of designing, developing and maintaining the rain garden. The main idea was to create a space that is tailored to the needs of local community, and thus ensure the support of all stakeholders in the process. The residents demanded that the fig tree be cut before developing the rain garden, as it was positioned close to the buildings and was endangering the foundation of the building. One of the key partners in the realization of this project was the Jedi Movement (Džedajski pokret), a youth association that deals with various issues of social importance. Another crucial point is related to the involvement of utility companies of the city as valued stakeholders. Public Utility Company Mediana Niš supported the rain garden project by providing necessary mechanization, and sharing their extensive experience in planting at the local level.

The A1 company also wanted to donate urban furniture to implement in the POS, but the residents decided against it. Their motif was to avoid gathering of problematic individuals and vandals in the vicinity of their homes. However, the residents agreed upon setting up bird and bee houses next to the rain garden, in order to promote biodiversity.

The field works on the rain garden began in August 2023, and were completed in September 2023, resulting in an attractive NbS element of 21 m^2 surface area (Figure 3a). The Jedi Movement actively contributed to planting the rain garden. The A1 company's team revisited the site in November 2023 to check the seedlings, and keep up with rain garden maintenance. It was envisioned that the garden would continue to be maintained and cared for by the residents and the local community.

In July 2024, the rain garden was supplemented with new types of plants, and transformed into a biodiversity garden (Figure 3b). These works are also part of the same project (Niklo kao ja). This action was being implemented by the A1 company, in cooperation with the Citizens' Association Ekonaut and local self-governments. The biodiversity garden is conceived as a three-part allotment, which contains [19]: 1) a shady area with evergreen plants as a hideout for birds, 2) a garden with fruit-bearing plants that provide food for birds and other small animals, and 3) an aromatic garden that is important for attracting insects and pollinators. All three segments are connected by corridors - grass belts, which act as animal paths. Houses for birds and insects are also located in the proximity of the garden.

The rain garden is supposed to become self-sustaining after two years. However, it remained unclear how its maintenance would be performed until then, and who would perform periodic checks of the garden after the two-year period has expired.

Regarding POS typology, the rain garden is related to the function Recreation and gathering, and located in "building-oriented" space, which is associated with a multi-family residential row building, having two row buildings and two building entrances (Rentgenova street 11 and 13). The rain garden maintenance by the residents is currently not being controlled or evaluated, and it appears to be a bit neglected. Moreover, the effects of implementation of this NbS element are unknown, since there is no monitoring of the stormwater drainage at the site. However, the rain garden is located in proximity of the the pocket park, which is a busy area. Therefore, it does have an educational purpose, but requires additional efforts in urban design to fully fulfil its role, such as signage and explanation of the rain garden use.

(a) Developed rain garden in May 2024 Source: Authors, 2024

(b) Biodiversity garden in February 2025 Source: Authors, 2025

Figure 3. Rain garden along Rentgenova street in Niš

4.2.2. City-led regeneration of public open spaces

The large-scale transformation of neighbourhood open spaces took place in 2023, completely ignoring the standing Urban Design Project and the solutions proposed for the POSs. The POSs in this neighbourhood were in very poor condition, with deteriorated pathways and devastated green areas. These were exacerbated with bad weather conditions, when rain and snow resulted in muddy areas that hindered access to buildings. The residents were dissatisfied and pressured the authorities to improve the living conditions in their neighbourhood [18].

They particularly complained about the lack of parking spaces, and usurpation of public areas for parking by unscrupulous citizens that was not being resolved by the authorities [20]. All of these issues reemerged when the rain garden project, initiated by the A1 company, became topical in 2023. On that occasion, the residents reminded the city officials of long-lasting issues in their living environment.

The renovation activities began in November 2023. The intervention was realized as part of program activities of the Local Economic Development Office, with this office serving as the implementing entity [21]. The funding for the arrangement of inner-block spaces was provided through the "Program for the arrangement of building land and maintenance of communal infrastructure for the year 2019" (Program uređivanja građevinskog zemljišta i održavanja komunalne infrastrukture za 2019. godinu).

After the works on the arrangement of POS began, the residents expressed concern about introducing new streets and fragmenting the urban block area [22]. They had no insights into the actual Project of Implementation (Projekat za izvođenje), which appeared to be significantly different from the adopted Urban Design Project. As they felt insufficiently informed on the project realization, and were not involved in the process of shaping their immediate living environment, the residents decided to prevent further development by blocking the work of construction machinery. After talking to the city authorities, the protests were terminated, and the renovation of POSs in this neighbourhood continued. However, it appears that the works were performed in a rather ad hoc manner. The standing Urban Design Project was not consulted at all, while the Project of Implementation was never available to the general public on the websites of relevant city institutions.

The works only involved paving activities, while no action was taken concerning greenery and urban furniture. Furthermore, the driveways, pedestrian pathways and open spaces for gathering and recreation were fully paved with asphalt coating, which is a non-permeable material. Equally important, the existing pathways were widened to reach street width, and new parking spaces were designated in previously green areas (Figure 4a). Some smaller green surfaces were therefore extinguished. All this resulted in paved areas that are much more extensive compared with the original urban setting. Moreover, the parking issues still persist, as the majority of the site does not have organized parking. Designated pedestrian spaces were poorly designed, and usurpation of POS with vehicles occurs even now (Figure 4b). Segregation of pedestrian and vehicle traffic was performed inefficiently. New pathways were not developed as shared streets, given the asphalt coating that is associated with roadways. Some of these new routes are paved in large widths, which was unnecessary because there was no need to enable vehicle transit. Since pedestrian paths and vehicle routes still crosscut, it can be stated that the safety was not improved. Aside from the rain garden initiated by the A1 company, no other NbS elements were implemented in the renovation of neighbourhood POSs.

In line with the established typology of POS, it is observed that the interventions in regeneration were quite extensive, and related to several POS functions and types:

1. Mobility (vehicular traffic and pedestrian movement): Former inner pedestrian-vehicle streets and pedestrian paths;
2. Services and utilities as potential POS (parking): Outdoor parking lots and above-ground garages; and

3. Recreation and gathering (building-oriented POS): Immediate surroundings of multi-family residential building with unlimited access.

All of these actions exacerbated the already poor stormwater management, resulting in an extensive urban flooding of POS in June 2024 [23] (Figure 4b). The residents and users of POS are also dissatisfied with this action and the final result. The rain garden has somewhat mitigated the effects of flooding by absorbing some of the stormwater, since this part of the neighbourhood was not severely flooded. However, the exact contribution of this NbS element is not known because there is no monitoring of rain garden performance. Furthermore, this single element cannot significantly contribute to stormwater management given the size of the area. Multiple NbS elements distributed across the neighbourhood would however provide better responses to flooding events. Such poor effects of regeneration discourage the residents from caring for their living environment, making it difficult to maintain the building-oriented POSs particularly. It can therefore be stated that significant potential for reshaping POS within this regeneration action was wasted in a rather laissez-faire approach taken by the authorities of the City of Niš.

a) Paving of green areas for parking
Source: Authors, 2024

(b) Urban flooding after POS renovation, 2024
Source: https://niskevesti.rs/rentgenova-pliva-stanari-zgrada-21-i-23-zarobljeni-potrebna-hitna-sanacija/

Figure 4. Effects of POS renovation in the analysed residential neighbourhood in Niš

5. CONCLUSION

The City of Niš recognizes the importance of NbS in its strategic urban development documents, but explicit references to NbS remain limited. Although the development of the cadastre of green areas is a well-identified key measure, accelerating its development and integrating it into the city's GIS system is necessary to support the NbS implementation. In dense residential areas, various limitations hinder the NbS implementation, including the lack of NbS-specific legal references, regulatory gaps, weak monitoring system, and limited funding.

The implemented pilot project of the rain garden in Niš is a showcase example of good practice. This implemented NbS element contributed to creating an educational environment for the general public, and helped in adopting the NbS principles by the local residents. As a successful example of NbS implementation, the rain garden serves an educational purpose, but needs enhancements in signage and accompanying information to maximize its effectiveness. The rain garden along Rentgenova Street highlights the potential benefits of NbS in urban sustainability, offering solutions for stormwater management, biodiversity enhancement, and

microclimate improvement. Despite initial successes, challenges such as long-term maintenance, monitoring, and integration into the broader urban landscape remain.

On the other hand, the unsuccessful further regeneration of neighbourhood' POSs in Niš without implementing NbS showcases how a passive approach taken by the local authorities brings very little benefits to the environment and social life of the community. Aside from the obvious issue of non-compliance with the adopted project, the ineffective regeneration without citizen participation discourages residents from engaging with their environment, making it especially challenging to maintain building-oriented POSs. Non-implementation of NbS in neighbourhood regeneration may even exacerbate existing issues with stormwater management, as seen in this case. The insufficient awareness of local decision makers on the importance of NbS is therefore identified as another key barrier to successful NbS implementation. The non-implementation of NbS in this regeneration project demonstrates the missed opportunity for sustainable urban development. A lack of adherence to original urban designs, poor integration of NbS elements, and insufficient community involvement have resulted in negative consequences, including exacerbated urban flooding and safety concerns.

Both analysed examples underscore the importance of a comprehensive approach to urban planning that prioritizes ecological sustainability and social well-being, to ensure successful, long-term regeneration and resilience in urban environments.

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For further reading on reclaiming public open space in residential areas, please visit the RePOS project website: https://www.repos-project.rs/

REFERENCES

[1] IUCN: **WCC-2016-Res-069-EN Defining Nature-based Solutions**. 2016. https://portals.iucn.org/library/sites/library/files/resrecfiles/WCC_2016_RES_069_EN.pdf (18.11.2024.)

[2] United Nations: **New Urban Agenda**. 2017. www.habitat3.org (18.11.2024.)

[3] https://research-and-innovation.ec.europa.eu/research-area/environment/nature-based-solutions_en (18.11.2024.)

[4] Dorst Hade, van der Jagt Alexander, Raven Rob, Runhaar Hens: **Urban greening through nature-based solutions – Key characteristics of an emerging concept**. Sustainable Cities and Society, Vol. 49, 101620, 2019.

[5] Dinić Branković Milena, Milanović Danijela, Ljubenović Milica, Mitković Mihailo: **Nature-based solutions for reclaiming public open space in multi-family residential neighbourhoods: The experience of Kronsberg**. 5th International Conference on Urban Planning - ICUP2025, 10-11th April 2025, Niš, Serbia, 473-481, 2025.
[6] **Development Plan of the City of Niš 2021-2027**. Official Gazette of the City of Niš, No. 36/2021
[7] **Urban Development Strategy of the City of Niš and the Municipalities of Svrljig, Merošina and Gadžin Han**. Official Gazette of the City of Niš, no. 42/2024
[8] **General Urban Plan of Niš 2010-2025**. Official Gazette of the City of Niš, no. 43/11
[9] **Secretariat for Environmental Protection: Environmental protection program of the City of Niš with Action plan 2017-2027**. 2017. https://www.gu.ni.rs/wp-content/uploads/Program-zastite-zivotne-sredine-Grada-Ni%C5%A1a-2017-2027.pdf (25.02.2025.)
[10] https://www.repos-project.rs/pdf/pos-typology.pdf (07.07.2025.)
[11] Jones Laurence, Anderson Sally, Læssøe Jeppe, Banzhaf Ellen, Jensen Anne, Bird David Neil, Miller James, Hutchins Michael G., Yang Jun, Garrett Joanne, Taylor Tim, Wheeler Benedict W., Lovell Rebecca, Fletcher David, Qu Yueming, Vieno Massimo, Zandersen Marianne: **A typology for urban Green Infrastructure to guide multifunctional planning of nature-based solutions**. Nature-Based Solutions, Vol. 2, 100041, 2022.
[12] European Commission: Directorate-General for Research and Innovation, Mačiulytė, E., Durieux, E.: **Public procurement of nature-based solutions - Addressing barriers to the procurement of urban NBS: case studies and recommendations**. Publications Office of the European Union, 2020. https://data.europa.eu/doi/10.2777/561021 (18.11.2024.)
[13] Eggermont Hilde, Balian Estelle, Azevedo Jose Manuel N., Beumer Victor, Brodin Tomas, Claudet Joachim, ... & Le Roux Xavier: **Nature-based solutions: New influence for environmental management and research in Europe**. GAIA-Ecological perspectives for science and society, 24(4), pp. 243-248, 2015.
[14] UNaLab: **Nature-based Solutions Technical Handbook Factsheets**. UNaLab URBAN NATURE LABS, Institut für Landschaftsplanung und Ökologie – ILPÖ, 2022.
[15] Urban Planning Institute of Niš: **Urban Design Project for the urban-architectural design of public open space in the wider area of Pasterova street in Niš**. 2019. http://www.eservis.ni.rs/urbanistickiprojekti/ (20.02.2025.)
[16] https://svetkakavzelis.rs/ (21.02.2025.)
[17] Personal communication of the City of Niš with A1 and Propulsion, February 24, 2023. Courtesy of the City of Niš.
[18] Personal communication of the authors with an employee of the City Administration for Construction, December 26, 2024.
[19] https://niskevesti.rs/nis-dobio-vrt-biodiverzitet/ (21.02.2025.)
[20] https://www.juznevesti.com/drustvo/rentgenova-i-parking-nislija-se-zali-na-uzurpaciju-javne-povrsine-rampama-opstina-mesecima-ne-resava-spor/ (21.02.2025.)
[21] https://dign.rs/program-uredjivanja/ (21.02.2025.)
[22] https://www.juznevesti.com/drustvo/stanari-rentgenove-i-pasterove-ulice-zaustavili-radove-sumnjaju-da-izmedju-zgrada-prave-ulice/ (21.02.2025.)
[23] https://niskevesti.rs/rentgenova-pliva-stanari-zgrada-21-i-23-zarobljeni-potrebna-hitna-sanacija/ (27.02.2025.)