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Learning from Nature: Recommendations for the Process of Rebuilding Antakya After the 6th February Earthquakes

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Abstract: Nature-based planning and design approaches have become one of the main strategies for the reconstruction of cities under disaster risk in terms of sustainability and resilience principles. In this study, the spatial relationship between ecological vulnerability and earthquake risk in the Antakya district of Hatay province, which was severely devastated by the Kahramanmaras-centered earthquakes that occurred on February 6, 2023, was revealed, and ecological vulnerability areas under earthquake hazard were mapped with Geographic Information Systems (GIS)-based analyses. The method used in the study is based on multi-layered spatial analysis. Layers such as CORINE land use, lithology, slope, and distance to fault lines were weighted by expert assessments. Analytic Hierarchy Process (AHP) and weighted registration methods were applied. Building data digitised from Google Earth Pro images and post-earthquake demolition data (Basarsoft) were overlaid, and the level of overlap of the structures destroyed in the earthquake with both physical risk and ecological sensitivity areas was evaluated. According to the findings, 18.7% of the structures are located in high-risk areas in terms of earthquakes, while 9.4% are located in ecologically sensitive areas. These results emphasize the necessity of nature-based spatial decision support systems in reducing disaster risks. The model presented in this paper is expected to guide both post-disaster urban planning and the protection of ecological integrity and enable the development of concrete recommendations for a sustainable, nature-sensitive and resilient Antakya.

Keywords: Design with nature, Nature-based solutions, Resilient cities

Introduction

The destruction caused by disasters is not only limited to physical losses but also causes serious disruptions in natural systems. Large-scale disasters in recent years have revealed that cities should be shaped not only with engineering-based solutions but also with ecologically based planning strategies integrated with nature. Especially in areas that are under urbanisation pressure and ecologically sensitive, the risk of disasters increases even more, which necessitates the importance of nature-sensitive holistic approaches in planning (Elmqvist et al., 2019).

In line with sustainable urbanization goals, Nature-Based Solutions (NBS) have become widespread in the literature and policy documents in the last decade and have started to be seen as an effective tool to reduce disaster risks and make cities more resilient (Nesshover et al., 2017). According to the definition of the European Commission, NBS are practices that aim to produce solutions to socio-ecological problems through the imitation or direct use of natural systems and processes (EC, 2015). In this context, solutions such as wetland restoration for flood control, vegetation rehabilitation to combat erosion, and green infrastructure systems to reduce the impact of urban heat islands are presented as examples (Kabisch et al., 2016). However, studies on how to position NBS at the planning level in the face of sudden and destructive hazards such as earthquakes are limited.

This study proposes a model for the use of nature-based spatial strategies in the reconstruction of the city of Antakya, after the earthquakes of February 6, 2023. The aim of the study is to reveal the spatial interaction between ecologically sensitive areas and earthquake-prone elements and to develop nature-sensitive, risk-reducing planning recommendations based on this interaction. For this purpose, GIS-based spatial analyses were used to overlay fragile ecosystems such as wetlands, river corridors, forested areas and protected areas with earthquake risk-related parameters such as slope, lithology and distance to fault lines. The data used in the analyses were obtained from multiple sources, and decision support outputs were produced.

Similar studies can be found in literature. For example, Shi et al. (2023) produced a regional sensitivity map using Shannon diversity index, patch density and fractal dimension analysis to determine the intersection of ecological vulnerability with earthquake risk areas in the Gannan region of China. Similarly, Wang et al. (2017) showed that the identification of ecological boundaries in the Zibo region with geographical information systems (GIS)-assisted analysis provides important contributions to regional planning decisions. However, there is no direct integration of post-earthquake destruction data in these studies. In this respect, this study, which was conducted in the case of Antakya, makes a unique contribution to literature in terms of testing spatial modelling with real destruction data and trying to carry nature-based solution proposals to the planning scale.

The scope of the study is limited to Antakya district center located within the borders of Hatay province. The area within this boundary is one of the most critical urban areas in Türkiye in terms of both its ecological diversity and its level of vulnerability to the 2023 earthquakes. The study only covers terrestrial ecosystems; marine environments and coastal areas are excluded from the assessment. The limitation is also based on data reliability; only publicly available or institutionally verified data were used. The spatial resolution of the data was the main limitation determining the level of detail of the analyses. However, the provision and verification of building demolition data (Basarsoft and Google Earth Pro) strengthened the applied aspect of the project.

The model proposed in this paper is not only an academic analysis framework but also a tool that can guide decision makers in the fields of disaster management, spatial planning and environmental sustainability. In this respect, the study both contributes to the planning literature with an exemplary analysis model that evaluates the interaction between ecological vulnerability and disaster risk and makes a concrete contribution to the nature-based approach practices that are lacking in Türkiye, especially in post-disaster reconstruction processes.

Materials and Method

In this study, a GIS-based methodological approach is adopted to establish a spatial relationship between disaster risk and ecological vulnerability and to model this relationship as a basis for nature-based planning decisions. The methodological framework is based on the integrated application of the Analytic Hierarchy Process (AHP), a multi-criteria decision-making system, and weighted overlay analysis. The method is structured according to a five-step work package structure, with each step producing measurable outputs based on spatial analysis.

Antakya city centre of Hatay province was selected as the study area. This area was one of the most severely affected areas by the February 6, 2023, earthquakes and also has ecologically highly vulnerable features such as wetlands, river basins, forested areas, agricultural lands and protected areas. This geographical structure requires the area to be analysed in terms of both earthquake risk and environmental vulnerability.

- The first step of the methodology is to define ecological vulnerability zones. The layers used in this context are CORINE 2018 land use data, protected areas and national parks (General Directorate of Nature Conservation and National Parks), wetlands, rivers, pastures and forested areas. Vector and raster data for these layers were obtained from Copernicus and EarthData platforms and reclassified at the attribute level in ArcGIS 10.8 software for analysis in the GIS environment.

- In the second step, earthquake-vulnerable elements were identified. In this context, two main parameters were focused on. Fault lines were taken from the Türkiye Resilient Fault Map, multiple buffer zones were created around these lines at 1000-meter intervals, and the zones were reclassified and scored according to their spatial risk level. The slope layer was derived from the digital elevation model (DEM) and divided into four classes: 0-5%, 5-15%, 15-30% and over 30%. In this grouping, higher slope values are organised in such a way that they receive higher disaster risk scores.
- In the third step, AHP method was applied. In order to determine the relative weight of each layer in the spatial analysis, comparative questionnaires based on expert opinions were prepared, and the priority levels between layers were evaluated on a scale of 1-9. The consistency ratio was ensured to be $CR < 0.10$, and the final weights of the layers were obtained. In this step, the proposed AHP methodology was applied following the decision support principles defined by Malczewski and Rinner (2015) and Ozsahin (2013).
- In the fourth step, "Ecological Vulnerability Map under Earthquake Hazard" was created by weighted overlay method. Each layer was normalised and reclassified in raster format, and the resulting data layers were overlapped according to the determined weight scores. Thus, spatial risk intensities were modelled with numerical scores ranging from 0 to 10. The resultant map holistically revealed the areas where earthquake and ecological risks overlap.
- In the fifth step, the spatial distribution of structures destroyed in the earthquake was used to test the accuracy of the analysis. Pre-earthquake building stock was digitised via Google Earth Pro and matched with post-2023 demolition data provided by Basarsoft Information Technologies. The resulting spatial database shows the level of overlap of demolished structures with both earthquake risk and ecological vulnerability. With this overlap, the accuracy of the model for the site was tested.

Data processing was carried out in ArcMap 10.8 and Microsoft Excel, and spatial statistics were supported by SPSS 26 software. As a result of the analysis, a decision support model has been developed that can both form the basis for nature-based strategy generation and contribute to disaster risk management and sustainable spatial planning.

Results and Discussion

The spatial analysis model developed within the scope of the study successfully identified ecological vulnerability zones under earthquake hazard in Antakya district centre. In the map produced as a result of the weighted overlapping analysis, regions where both ecological and seismic risks overlap were clearly identified and these areas were recommended as priority intervention areas for spatial decision- making processes. The main findings are presented in a structured manner below:

- As a result of the overlap analysis, it was determined that approximately 34.78% (1685 buildings) of the total building stock in Antakya was completely destroyed in the February 6, 2023 earthquakes. The number of pre-earthquake structures was determined as 4844, which was confirmed by digitisation through Google Earth Pro images.
- Approximately 18.7% of the collapsed structures (approximately 316 structures) are located in areas classified as "high earthquake hazard" zones by GIS analysis. These areas stand out as high slope areas with alluvial soils, especially those located closer than 2000 meters to fault lines. This finding confirms the determinants of soil amplification effect, liquefaction potential and topographical fragility on structural damage.
- 9.4% of the collapsed structures (approximately 158 structures) were located in ecologically sensitive areas. These areas consist of wetlands, forest edges, river zones and agricultural lands, representing spaces that are subject to settlement pressure but need to be protected in terms of ecosystem integrity. This situation reveals the impacts of disasters not only on the human-built environment but also on ecological systems.
- 12.3% of the buildings are located in areas with unsuitable or limited land use capability. This rate shows that criteria such as soil characteristics, slope and proximity to water are not sufficiently taken into account in planning processes. Especially in areas defined as class IV or special protection areas according to the Land Use Capability (LUC) classification, construction significantly increased the rate of demolition.
- When the ecological sensitivity layers and the earthquake susceptibility map are overlaid, it is determined that 8.5% of the areas classified as "very high risk" carry both ecological and seismic risk. These areas are particularly concentrated around the Asi River, the foothills of Habibi Neccar Mountain and the old settlements on the northwestern border of Antakya.

One of the unique outputs of the study is the "Map of Ecological Sensitivity to Earthquake Hazard". This map categorises spatial intervention priorities with different sensitivity zones and identifies areas where NBS strategies can be applied in the reconstruction process. It is suggested that development should be limited in high-risk areas, green buffer zones should be created and risk-reducing ecosystem services (e.g. natural water retention, erosion prevention, bioswales) should be integrated into the planning process. In conclusion, the findings suggest that disaster risks should be assessed not only with physical parameters but also with indicators of ecological sensitivity. This model is a powerful analytical tool that can guide spatial planning processes in terms of both increasing urban resilience and protecting ecosystems.

Conclusion

This study has demonstrated with concrete data that nature-based solutions for disaster risk reduction can increase not only environmental sustainability but also the resilience capacity of cities. The spatial analysis of Antakya shows that there is a direct relationship between ecological vulnerability and earthquake risk, and that the destruction is more severe when construction decisions do not take into account these two vulnerabilities at the same time. The results obtained in this context offer important contributions to both theoretical knowledge production and spatial planning practices.

The practical impact of the study is to demonstrate the usability of decision support systems based on nature-based strategies in urban reconstruction. The "Ecological Vulnerability Map under Earthquake Hazard" developed in GIS environment provides a model that can be applied not only for Antakya but also for other cities with similar geological and ecological characteristics. This model is functional in terms of directing construction in urban transformation projects, determining building prohibition zones, planning green corridors and designing post-disaster rehabilitation areas according to ecosystem services. Therefore, the study provides a concrete tool for sustainable and socially just planning approaches in harmony with nature in disaster-prone areas.

At the theoretical level, the study presents a new methodological approach at the intersection of disaster management, sustainable urbanisation and ecological planning disciplines. Considering that NBS are mostly associated with flooding, inundation and climate change in the literature, this research fills an important gap by demonstrating that nature-based analyses are also possible and necessary for sudden and destructive disaster types such as earthquakes (Shi et al., 2023; Wang et al., 2017). Moreover, the integration of AHP-based decision support process with spatial analysis to provide an intellectual and technical basis for post-disaster reconstruction decisions adds a methodological novelty to the literature.

The study provides a scientific infrastructure that can serve to develop an interdisciplinary common language especially among planners, disaster managers, ecologists and local government representatives. At the same time, considering the fact that post-disaster planning in Türkiye has been based on technical and structural interventions for many years, the approach proposed by this study will contribute to a stronger inclusion of nature-based solutions in legal legislation and urban planning norms.

As a result, the spatial model proposed in this study demonstrates that post-disaster planning is not only about reconstruction, but also about restoration of ecological and social systems, and reconstruction in harmony with nature. The findings obtained in Antakya, where the model was piloted, provide a framework that can be applied in all cities and regions with similar risks, and constitute an important step towards building a more disaster-resilient, sustainable and ecologically holistic urban future.

Recommendations

In line with the findings of this study, it has become clear that a holistic approach based on nature-based strategies should be developed in the planning of ecologically sensitive areas under earthquake risk. This approach, which is applicable not only to Antakya but also to all cities with similar risk profiles in Türkiye brings a new perspective to post-disaster reconstruction processes from a spatial, environmental and social perspective. Below, recommendations developed in the light of the results of the study are presented in a way to guide both practical interventions and future research.

Not only geological and engineering data, but also ecological sensitivity data should be taken into account when making spatial planning decisions in settlements at risk of disaster. Especially in areas such as wetlands, forest edges and river corridors, construction should be limited; these areas should be protected as natural buffer zones.

Building ban decisions should be evaluated not only with geological factors such as fault lines, but also with ecosystem-based risk maps. Identifying natural thresholds and building regulations based on these thresholds will reduce both loss of life and ecological destruction.

NBS (e.g. natural water retention basins, permeable soil systems, green corridors) should be integrated into development plans as mandatory design principles in areas to be reconstructed. In urban planning processes, LUC analyses should be made a prerequisite for building license processes. Such analyses can turn into an effective early warning system not only for post-disaster but also for pre-disaster risk mitigation.

Spatial data production and management capacities of local governments should be increased, and qualified personnel and software infrastructure for such analyses should be encouraged. Post-disaster reconstruction policies should be carried out with the principles of social justice; settlement models that support nature-based, cultural and economic sustainability should be developed for groups at risk of displacement.

In this study, only land ecosystems and built-up areas were emphasized, while marine and coastal areas were left out of the scope. Future studies can develop models that analyse hazards such as tsunamis and sea level rise with nature-based planning tools, especially for coastal cities.

The analysis used in the study was based on decision support techniques such as AHP and weighted registration. The predictive capacity of the model can be further strengthened with artificial intelligence-supported spatial decision systems (e.g. random forest, support vector machines, deep learning algorithms).

Integration of community participation in spatial planning can make such models more applicable and acceptable in the local context. In future studies, it is recommended to collect quantitative and qualitative data on public perception of disasters, ecosystem values and settlement preferences. This study only provided validation on building destruction. However, in the future, different types of impacts such as building damage types, loss of life, transportation interruption, and service infrastructure collapse can be integrated into the model. In this way, multi-scale risk scenarios can be produced.

Testing the model in different geographies and climate zones (e.g. Black Sea Region, Aegean coasts, Central Anatolian arid basins) and conducting comparative impact analyses will be useful to test the generalizability of the model. Conducting applied research on how to integrate nature-based solutions to disaster risks into local government policies is a critical future research area to bridge the gap between scientific modelling and managerial practice. In addition, integrating the model into disaster education programs and turning it into visual, participatory and instructive modules especially for school-age children and post-disaster migrant communities can be considered as a new area of contribution.

Scientific Ethics Declaration

* The authors declare that the scientific, ethical and legal responsibility of this article published in EPESS Journal belongs to the authors.

* In this study, artificial intelligence was used solely to enhance the language and clarity of the manuscript; it did not play any role in the analysis, interpretation, or generation of the results

Conflict of Interest

* The authors declare that they have no conflicts of interest.

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