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Article

Transforming Public Space with Nature-Based Solutions: The Urban Forest of Lorca, Spain

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Abstract

Mediterranean cities are increasingly exposed to climate hazards, water scarcity, and social vulnerabilities, demanding integrative approaches for sustainable regeneration. This study examines how participatory governance and co-design processes can shape nature-based solutions (NbS) for climate resilience in Barrios Altos, a socially and environmentally fragile district of Lorca, Spain. Within the framework of the NATUR-W project, the interventions reimagine a degraded hillside and adjacent public spaces into a multifunctional urban forest, complemented by green retrofits of social housing and the adaptive reuse of a historic prison. Methods combined baseline community assessments, stakeholder mapping, co-design workshops, and the establishment of a multi-stakeholder governance board, ensuring inclusive participation from residents, civil society, and municipal authorities. Results demonstrate that the co-created design addressed key community priorities—such as shade provision, safe accessibility, cultural venues, and child-friendly spaces—while integrating sustainable water management systems for irrigation and stormwater control. The participatory process enhanced local ownership, balanced technical feasibility with community aspirations, and fostered governance structures that increase transparency and accountability. Overall, the study illustrates how NbS, when embedded in collaborative governance frameworks, can deliver climate, social, and cultural co-benefits while advancing resilient, inclusive, and human-scale urban environments.

Keywords: nature-based solutions (NbS); participatory governance; co-design processes; urban regeneration; Mediterranean cities; inclusive public spaces

1. Introduction

As climate change impacts are experienced with increasing prevalence around the world, cities are more frequently prioritising nature-based solutions as an adaptation approach in their policy agendas [1,2]. Urban centres, which concentrate the world's population, economy, and infrastructure, face growing risks from climate-related hazards such as floods, heatwaves, and droughts [3], as well as increasing socio-spatial inequalities [4]. Nature-Based Solutions (NbS) are increasingly promoted by international institutions (e.g. EU, UN-Habitat and UNEP, The World Bank, The Organisation for Economic Co-operation and Development) as multi-functional tools [5] that can enhance urban resilience, directly address and mitigate climate risks [6], and deliver co-benefits such as biodiversity, social equity, livability, public health and well-being [7,8]. Southern Europe region is identified as a

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climate change hotspot, experiencing a rate of warming that surpasses the global average [9]. Given the region's elevated exposure to climatic hazards and intrinsic socioeconomic fragilities, its urban centers are exceptionally vulnerable to the impacts of climate change, a vulnerability intensified by the heightened thermal trend [10]).

A growing body of scientific literature has underscored the significant potential of NbS to enhance climate resilience in Mediterranean cities by simultaneously addressing adaptation and mitigation challenges [11,12]. NbS are considered dually beneficial, offering a viable approach to combating water scarcity while simultaneously advancing sustainability goals [13]. They have also been found to be effective in overcoming social inequalities in Mediterranean cities [14]. While their implementation is increasing, NbS have yet to be fully integrated into conventional urban development frameworks [15,16]. Particularly challenging is designing collaborative governance and effective citizen participation for delivering NbS in cities [17].

Nowadays, it is well established that citizen participation and participatory governance are fundamental to the long-term sustainability and effective implementation of NbS [18,19]. Several authors have advocated for effective governance practices characterized by inclusivity, adaptability, transparency, accountability, cross-sectoral integration, and a long-term vision [20,21]. Numerous barriers related to good governance and effective engagement have been identified in implementing NbS. For instance, NbS requires socially embedded design processes that respond to local knowledge, needs, and governance structures [5,22]. Furthermore, there is an increasing focus on climate justice and procedural equity, ensuring that vulnerable populations (e.g. low-income, elderly, or minority groups) not only benefit from NbS but participate meaningfully in shaping them [23].

This study examines how participatory processes and governance structures can empower residents in designing adaptive, multifunctional public spaces in the Barrios Altos in the city of Lorca, Spain, as part of the NatUR-W (Nature-based Urban Regeneration through Water) EUI (European Urban Initiative) project (https://natur-w.eu/). The Barrios Altos is a heritage-rich district characterised by facing complex social challenges such as vulnerability to climate change, water scarcity and energy poverty. Barrios Altos is home to a predominantly low-income population, including a significant number of migrant families and gypsy communities. It suffers from community fragmentation, a lack of public spaces for social interaction and leisure and poor housing quality. The NatUR-W project aims to revitalize the district through the implementation of Nature-based Solutions. This initiative includes the creation of a new urban forest designed to provide green space that reboots urban biodiversity and mitigates the urban heat island effect. Additionally, the project's scope encompasses the installation of innovative green walls on public buildings to enhance energy efficiency and the conversion of a former prison into community centers to foster social cohesion and provide new services. The current study will try to answer the question: "How did inclusive engagement and collaborative governance shape the design of nature-based solutions, and what design-and-governance lessons should inform subsequent projects?"

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2. Materials and Methods

2.1. Study Area and Baseline Community Assessment

The study area is the Barrios Altos district of Lorca, Spain – a historic neighborhood characterized by a dense urban fabric, aging or derelict buildings, and socio-economic vulnerability. The area suffers from severe heat and water stress and has faced social challenges including post-earthquake recovery and persistent poverty *[24]*. By involving citizens early, the project aligned its objectives with the community's vision, a practice known to improve legitimacy and relevance of urban sustainability initiatives *[25]*. So, at the project (NatUR-W) outset, a baseline community assessment was conducted to identify local needs and priorities. This assessment combined household surveys and introductory community workshops to gather residents' input. Key priorities that emerged were: (1) expanding green infrastructure (e.g. trees, shade and parks) to mitigate heat and improve livability; (2) improving housing accessibility (e.g. safer and more accessible streets and homes - on the steep terrain – especially for elderly and disabled residents); and (3) economic diversification through better public spaces and cultural activities that could stimulate local businesses and provide opportunities for new jobs and training. These priorities, identified via participatory surveys and discussions, guided the subsequent co-design of the intervention.

Community-based assessments such as this are critical in grounding urban projects in local context, ensuring that interventions address residents' actual needs and values *[26]*. Therefore, this community-driven initial prioritization provided a foundational brief for the project's Nature-based Solutions (NbS) design and informed the participatory approach described below. Particular attention was given to the inclusion of social groups often marginalized in urban planning (e.g. women, elderly people, immigrants), so that their needs would be embedded from the outset in the co-design process. The importance of such approaches at early design stages is increasingly emphasized in international literature as critical for intervention legitimacy and community acceptance *[27,28]*.

2.2. Participatory Governance and Stakeholder Mapping

The participatory process in Lorca was designed in line with established principles of collaborative governance and climate justice. Participatory governance refers to the inclusion of diverse stakeholders in decision-making processes, aiming for more democratic and equitable outcomes. In climate adaptation and nature-based solution (NbS) planning, such approaches are widely advocated to enhance legitimacy, local ownership, and effectiveness of interventions [25,29]. Meaningful participation in urban climate governance can increase the sustainability of adaptation efforts and build capacity in the community [30]. In our project, participatory governance was both an ethical and methodological choice: it aimed to empower local residents to shape the NbS design, in line with calls for procedural equity (fairness) in urban resilience planning. To avoid tokenistic involvement or the "illusion of inclusion" [31], the engagement process addressed power imbalances and emphasized transparency, building trust, and tangible impact on decisions. The approach also drew from the IUCN Global Standard for NbS, particularly Criterion 5, which stipulates that NbS should be based on "inclusive, transparent, and empowering governance processes" [32]. This provided a guiding framework to ensure that the governance structures (such as stakeholder committees and workshops) facilitated genuine power-sharing and accountability.

In this context, a structured stakeholder mapping methodology was used to identify and analyze all relevant actors. Stakeholder mapping is recognized as a best-practice tool in participatory planning as it: (a) ensures that all groups who affect or are affected by a project are systematically considered, (b) helps anticipate potential conflicts, and (c) informs the design of appropriate engagement techniques [26,33]. Through this process, a broad spectrum of local stakeholders was identified, including municipal departments (urban planning, social services, parks), neighborhood associations, non-governmental organizations (e.g. cultural and environmental groups), local businesses, educational institutions, and resident representatives (with particular attention to

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women, youth, and other often underrepresented groups). Table 1 presents the main stakeholders' categories as identified at this stage.

Table 1. Stakeholder categories description.

Category	Description
Government Agencies and Authorities	Local, regional, and national bodies such as the city council, urban planning authorities, environmental agencies, and transportation departments.
Community & Residents	Individuals and families living within the area - directly affected by the project.
Environmental and Conservation Organizations	Local environmental groups, national conservation bodies, and international NGOs focused on ecological preservation
Local SMEs and Private Sector	Local businesses, developers, and real estate investors, contributing to or impacted by the project.
Experts and Academics	Researchers, scholars, and professionals with expertise in urban planning, environmental science, and sociology.
Educational Institutions and Teachers	Schools, universities, and teachers, engaged in education, awareness-raising, and knowledge transfer.
Funding Bodies and Financial Institutions	Banks, investment firms, grant agencies, and international economic organizations providing financial resources.
Media and Communication Channels	Newspapers, television, online platforms, and social media disseminating project-related information.
Regulatory and Compliance Bodies	National agencies (e.g., water authorities), ensuring adherence to laws, regulations, and standards.
General Public	Individuals and groups, indirectly affected by the project, including those outside the study area but interested in its outcomes.
Vulnerable Groups	Low-income households, elderly people, children and youth, persons with disabilities, immigrants, refugees, and minority groups.

Using a common influence-interest-impact matrix approach, each stakeholder or stakeholder group was assessed for their level of influence and impact (i.e. for their power to shape project's direction and outcome) and interest (degree of stake in the project). This analysis helped prioritize engagement strategies – for example, high-influence/high-interest actors were approached for intensive collaboration, whereas lower-influence or marginalized groups (who might otherwise be overlooked) were proactively included to ensure equity. This mapping exercise in Lorca paid special attention to vulnerable groups (e.g., low-income residents, immigrants, elderly tenants) in order to elevate their voices in the process. The outcome of the stakeholder analysis/mapping was a comprehensive list of individuals and organizations to involve, setting the stage for the collaborative activities that followed.

Following the stakeholder mapping, an inclusive Stakeholder Forum was held in early 2024 in Lorca to formally bring together the identified actors (i.e. to kick off the participatory planning). The forum's objective was to validate the stakeholder analysis, foster dialogue among sectors, and establish a governance structure for the project. A total of 31 stakeholders – including city officials, NGO representatives, local business owners, and residents – attended the initial forum meeting. Through facilitated activities, participants jointly mapped their influences and interests regarding the Barrios Altos regeneration, making the power dynamics explicit in a transparent setting. This exercise helped build a shared understanding of who the key players are and how they could contribute or might be impacted. By engaging stakeholders on an equal footing, the forum cultivated a sense of co-ownership from the beginning.

As a direct outcome, the Forum established a permanent Stakeholders' Board to guide the project throughout implementation. The Stakeholders' Board functions as a governance committee for the NbS intervention, institutionalizing the participatory approach. It includes representatives of the major stakeholder groups: municipal departments, neighborhood council, elderly and youth representatives, women's association, business owners, etc., aligning thus with the project's

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commitment to inclusive climate governance. Besides, embedding stakeholders in a formal governance body like this is expected to improve transparency and accountability in urban planning [34]. Furthermore, similar frameworks have proven successful in aligning stakeholder incentives and maintaining continuity across project phases [35]. The Lorca Stakeholder Board should meet regularly to review progress, make collective decisions on design adjustments, and plan community events. Decision-making in the board should be consensus-oriented, and meeting minutes should be recorded to document inputs from each sector.

This governance model resonates with the quadruple helix approach increasingly used in NbS projects, bringing together government, academia, civil society, and the private sector to co-create sustainable urban transformations [36]. Furthermore, our governance structure exemplifies an empowering governance process as envisioned by the IUCN NbS Standard [32], ensuring that local actors have continuous influence on the project's trajectory. Moreover, the multi-stakeholder board aims to serve as a platform for conflict resolution and knowledge exchange, thereby operationalizing collaborative governance on the ground (see Section 3.2).

2.3. Co-Design Workshops and Integration into NbS Design

In parallel with governance activities, a series of co-design workshops with residents were conducted with the primary objective of engaging residents in the planning design of the NbS interventions in Lorca's Historic District. Co-design (also called participatory design) is a collaborative approach that shifts urban development from the exclusive domain of professional planners to a shared space involving citizens and other stakeholders [37]. This participatory methodology enables communication between experts (e.g. designers, engineers, planners) and non-expert partners, allowing intervention and participation regardless of professional, social, or cultural background [38]. Such approaches have been shown to produce more contextually appropriate and accepted solutions in urban green infrastructure projects [23,39]. Two main workshops were held in the Barrio Altos neighborhood, at accessible community venues, to maximize local attendance.

The first workshop introduced the concept of NbS and the project vision to participants (approx. 30 residents, with an emphasis on including women, parents, and elderly who are primary users of the space), aiming to gather initial input on community priorities. Interactive presentations and examples of urban NbS (e.g., images of parks, green walls) were used to spark discussion. Participants were then engaged in brainstorming exercises about current problems and desired improvements in their neighborhood. Small-group (but also one-on-one) discussions and mapping activities enabled residents to voice needs and preferences for the NbA interventions. The facilitation team used conversational formats and visual prompts to encourage input from those less accustomed to speaking in public forums. This inclusive approach accords with inclusive co-design best practices, which emphasize creating a safe space for diverse groups to contribute [40].

The output of the first workshop was a raw list of community-identified needs and preferences for their neighborhood. Specifically, it revealed three interlinked sets of priorities, integrating environmental improvements with everyday social and cultural life:

- Residents emphasized accessibility and safety, pointing to the steep slopes of San Pedro Street, accidents caused by limited mobility options, and dangerous traffic on the nearby highway, all underscoring the need for railings, ramps, and wheelchair access, including around the Church as a key community site.
- Green infrastructure was welcomed but with caveats: vegetation should be carefully selected to avoid allergies, provide shade, and remain accessible, while also incorporating spaces for physical activity.
- Participants – particularly women – stressed family and community needs, calling for shaded play areas, craft and educational workshops, and childcare provision to enable participation in cultural or recreational activities.

Approximately one month later, a second workshop was organized to refine and prioritize design options, building directly on the feedback from the first workshop. This workshop focused

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specifically on the development of the new urban forest. The design team had prepared preliminary concepts—including site layout proposals and green infrastructure elements—that integrated many of the residents' earlier suggestions. These draft plans and visualizations were presented for community review and evaluation (see Figure 1).

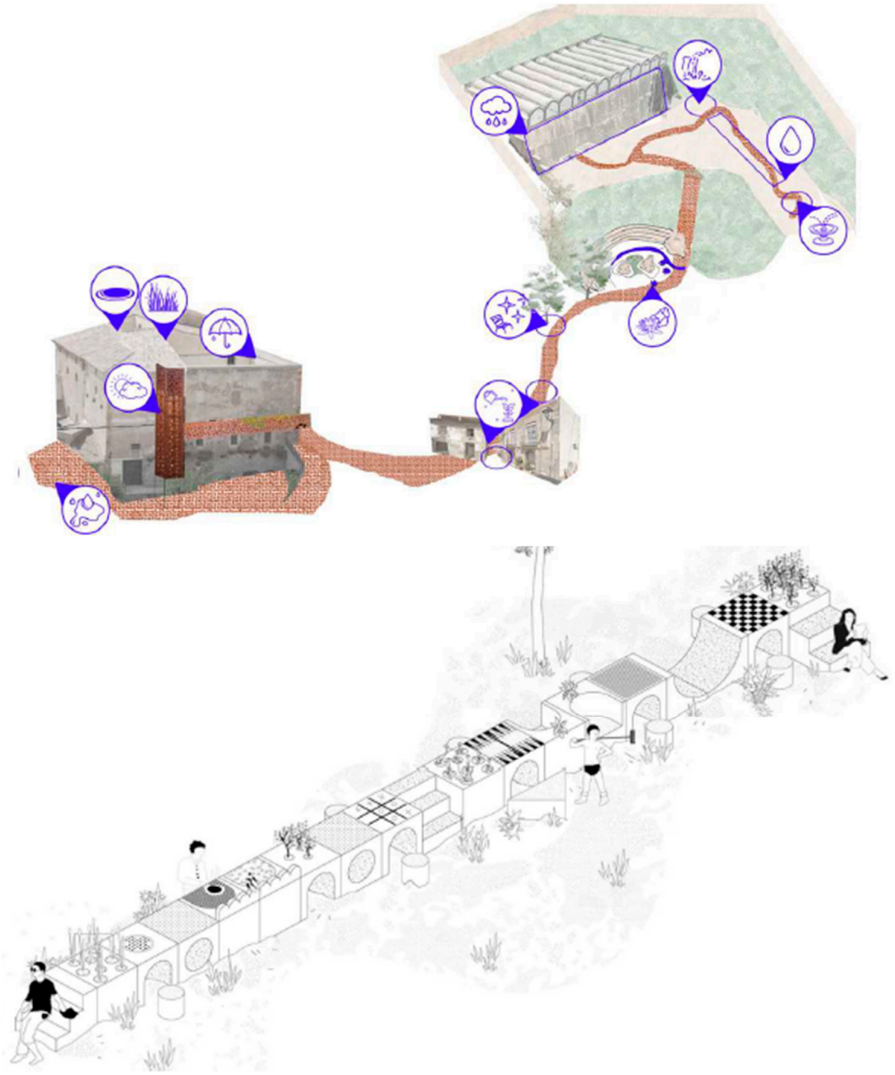

Figure 1. Visual presentation of the project's solutions during the second co-design workshop.

Participants, including many who attended the first session, were invited to critique and improve the designs. A set of structured activities (such as voting on alternatives and participating in focused discussions on specific features) ensured detailed and constructive feedback. In parallel, a dedicated activity was organized for children, who were provided with colorful pens and paper to create their own versions of the park, offering valuable insight into their perspectives and preferences. Participatory processes that include creative engagement tools for children—as adopted herein—are being recognized internationally as vital for inclusive urban design [41]. This dual-format approach proved highly effective, generating rich feedback from both adults and children. This iterative co-design process allowed residents to directly influence technical decisions – for example, the selection of tree species, and the design of pathways were adjusted in response to residents' comments. The workshops specifically highlighted and addressed the needs of vulnerable groups: for instance, women in the community had requested space for cultural activities (e.g. craft workshops or dance classes), so the design team incorporated a flexible-use plaza for such purposes.

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Elderly and mobility-impaired participants emphasized safe access, leading to the inclusion of gentler ramps and railings on steep sections of the park's paths.

2.4. Participatory Governance Plan and Innovative Tools

As the design phase progressed, the project also formalized a Participatory Governance Plan to sustain community engagement through implementation and beyond. This plan detailed how decisions would be made collaboratively among the city council, the community and the project partners and how the Stakeholder Board (see Section 2.2) would operate and delineate the roles of different actors (municipal departments, residents' representatives, NGOs, etc.) in decision-making. The main goals of this plan are: (a) to ensure stakeholder participation, (b) to foster collaboration and partnerships, (c) to ensure accountability and transparency, and (d) to facilitate replication and scalability. In this context, it established processes for continued citizen input, feedback management, and grievance mechanism, aligning with collaborative governance principles [42].

In addition, the project experimented with an innovative engagement tool: a dedicated NbS crowdfunding platform. This online platform aims to invite citizens and local businesses to contribute small donations or volunteer time towards the urban forest, and to suggest ideas or vote on certain features. Crowdfunding, in this context, may serve a dual purpose – as a minor funding supplement and as a broader outreach mechanism, engaging people who might not attend meetings. While not a traditional method in public space projects, crowdfunding has been noted as a way to increase public buy-in and awareness [43]. The platform will also help to amplify the project's visibility, by creating a sense of a "community campaign" around the urban forest.

The project also organized training workshops and webinars for local stakeholders (city technical staff, neighborhood volunteers) on topics like green infrastructure maintenance, participatory budgeting, and inclusive park programming. These capacity-building efforts are part of the governance framework to ensure that, once the physical intervention is complete, the local community and institutions are empowered to manage and program the new urban forest.

In summary, the participatory governance framework combines a formal multi-stakeholder committee (the Stakeholders' Board) with innovative engagement tools (crowdfunding and trainings) to embed co-management and local empowerment into the project's implementation and long-term stewardship. This approach reflects emerging best practices in NbS governance, which emphasize multi-level collaboration and community ownership of climate adaptation initiatives. Furthermore, by combining face-to-face deliberation with digital engagement, the project broadened its participatory reach, a strategy recommended in recent smart governance literature for urban planning [44].

2.5. Data Collection and Analysis

Multiple forms of data were collected throughout the engagement and design process, feeding into both the design decisions and the evaluation of the process. Table 2 provides an overview of the key data sources and their use in the project.

Qualitative data from meetings and workshops (e.g. minutes, flip-chart notes, design sketches annotated by participants, post-it, etc.) were analyzed using content analysis techniques. Quantitative data were also gathered: for instance, a short expert survey (n = 18 respondents) was administered to identify issues related to two key urban challenges: (a) the state of buildings, housing and open/green space and (b) the revitalization of the commercial activity to bring life back to the historic neighborhood. The survey results were summarized in simple descriptive statistics given the sample size. Additionally, environmental data (temperature records, tree canopy cover, etc.) and technical site analyses (soil tests, slope measurements for accessibility, etc.) were and will be collected by the design team and integrated with community input to: (a) monitor the impacts of the regeneration actions and (b) to test the feasibility of community-suggested solutions. The design team used GIS mapping and CAD modeling to iteratively test the placement and the details of NbS elements against

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the community-desired features. This integrative analysis led to the final set of design solutions that balanced community desires with engineering and budget constraints.

Table 2. Key community engagement activities and data sources in the Lorca NbS co-design process.

Activity / Data Source	Purpose and Description	Participants / Data Details
Expert's initial Survey (Spring 2022)	Gathered broader input by asking experts to identify issues related to key urban challenges.	18 survey responses from experts. Quantified preferences (e.g., % selecting priorities/solutions).
Stakeholder Forum (Jan 2024)	Mapped stakeholders' influence and interest; established Stakeholder Board and project vision.	31 participants (city officials, NGO leaders, residents, business owners).
Co-Design Workshop 1 (Feb 2024)	Brainstormed community needs and ideas for the whole neighborhood (with a focus on the urban forest); facilitated inclusive discussions and mappings.	~30 local residents (mixed ages and genders; included youth and elderly). Notes, sketches, and idea lists were recorded.
Co-Design Workshop 2 (Mar 2024)	Presented and refined draft NbS designs with community feedback; prioritized design options.	~20 residents (many returning from W1). Collected written feedback, votes on options, and discussion transcripts.
Stakeholder Board Meetings (2024–2025)	Ongoing participatory governance meetings to co-manage implementation, review designs, and plan maintenance/activities.	Board members (subset of forum). Meeting minutes documenting decisions and action items.
Technical Assessments / Indicators (parallel to above)	Site surveys, climate measurements (indicators), and engineering analysis to ensure NbS feasibility and to monitor NbS efficiency. These run in parallel and inform the design integration.	Data outputs included site maps, CAD designs, environmental metrics (e.g. projected cooling effect), which were cross-checked with community priorities.

In summary, the methodology of this project blended participatory techniques (forums, workshops, surveys) with standard urban design and engineering practices, under a unifying framework of participatory governance. This integrated methodology ensured that the resulting nature-based solutions were grounded in evidence, both scientific and community-derived, fulfilling the project's social and ecological objectives.

3. Results and Discussion

The NatUR-W pilot in Lorca's Barrios Altos yielded a set of co-created design solutions and governance mechanisms that address both the community's stated needs/preferences and the project's policy goals (environmental, socio-economic, etc). This section presents the main outcomes of the participatory process including the co-designed regeneration plans, the institutionalization of the participatory governance framework, and the observations on community engagement. It also discusses the significance of these results in light of broader literature on nature-based solutions (NbS) co-design and urban climate adaptation.

3.1. Co-Designed Interventions and Features

Through the participatory co-design workshops, residents and technical experts jointly developed a comprehensive plan for transforming the neighborhood of Barrios Altos in Lorca. The final design successfully integrates community-prioritized features such as safe play spaces for children, ample shaded areas, venues for cultural activities, and enhanced accessibility. For instance, in direct response to community input, the design includes child-friendly play zones (e.g. open play areas near seating for parental supervision) and a vine-covered pergola at the main entrance to provide summer shade. Likewise, residents' calls for spaces to support culture and education led to the incorporation of a small amphitheater for outdoor performances and the repurpose of the old

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prison into a multipurpose indoor space for workshops and classes. These additions address the community's desire for venues to host crafts, dance, and other group activities locally – a need emphasized particularly by women and youth during the engagement process.

The design also directly tackles safety and mobility issues identified by residents: it introduces gentler graded pathways, ramps and railings along steep sections of the park (e.g. near the main entrance and along San Pedro Street), greatly improving wheelchair access and general walkability in an area previously prone to accidents. Table 3 summarizes several key community preferences that emerged [45] and how the final design responded to them.

In sum, the community's top priorities of improved greenery and shade, accessibility, and social/cultural infrastructure (as initially identified in the baseline assessment; see Section 2.1) were comprehensively reflected in the final intervention plan, which encompasses: (a) six interconnected intervention areas, (b) heritage rehabilitation of the old prison and (c) green retrofits of social housing (dwellings). The six (6) areas, together with the old prison and the location of the dwellings that will be retrofitted are presented in Figure 2 and detailed below.

Area 1 - Upper slope (Urban Forest and green integration): The hillside above the neighborhood is transformed into a dense urban forest of drought-resistant native trees, supported by naturalized meadows and ecological corridors. This area also integrates the historic water reservoirs, now restored as both functional storage and heritage features. The forest provides biodiversity support, cooling, and a visual "green crown" for Barrios Altos.

Area 2 – Social Space and Urban Connection: This multi-level plaza was designed as the neighborhood's meeting point and connects the park with external roads. Terraced platforms and scenic viewpoints frame Lorca's historic skyline, while recreational play areas and shaded seating respond directly to residents' priorities for safe, family-friendly gathering spaces.

Table 3. Community-identified needs from co-design workshops and corresponding design responses in the Lorca urban forest design.

Community Needs or Preferences	Incorporated Design Response
Safe play areas for children and youth	The design successfully incorporates child-friendly play zones that allow for supervision by parents
Demand for ample shade in summer	Inclusion of a vine-covered pergola at the main entrance and the planting of additional shade trees along pathways
Spaces for cultural and educational activities (e.g. crafts, dance)	A small amphitheater has been included in the design, providing the community with a dedicated space for such events. One of the old storage rooms has been renovated and repurposed as a multipurpose space that can host workshops, classes, and other community-driven activities.
Safety measures on steep streets and terraces	Key areas, such as the main entrance, the newly designed access near the storage buildings, and the central gathering space, are all now fully accessible. The slope in the park's lower section was softened to make it more manageable, and handrails were installed throughout the park to improve safety and accessibility.
Use of allergy-friendly vegetation and specific preferences for vegetation and plant types	While not all requests could be fully implemented, efforts were made to incorporate as many community suggestions as possible while ensuring the species chosen are best suited for the park's environment.

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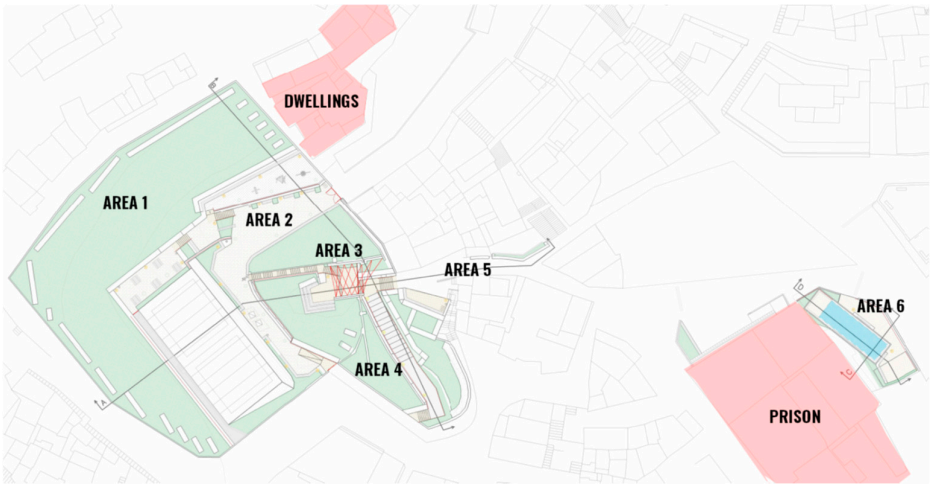

Figure 2. Masterplan of the Barrios Altos interventions, showing areas 1-6, the old prison retrofit and housing renovations within the integrated NBS.

Area 3 – Main Entrance: This gateway is marked by a vine-covered pergola and a small amphitheater, aiming to balance aesthetics with functionality. The pergola creates a shaded microclimate, while the amphitheater serves as a cultural venue and a meeting point – addressing thus community requests for spaces to host performances, workshops, and events.

Area 4 – Entrance Plaza: This area focuses on accessibility and mobility improvements. Steep, unsafe road sections are softened, renaturalized, and integrated into a new plaza that bridges the urban fabric with the park. The design includes permeable pavements, benches, and shaded rest points, ensuring universal access.

Area 5 – Visual Integration: Existing walls, once barriers, are transformed into active green surfaces with climbing plants and textured natural finishes. Scenic lighting and signage are also designed to further enhance the role of walls as identity (visual) markers for the park.

Area 6 – Plaza de la Roca (Rock Plaza): This area is the ecological and hydrological heart of the urban regeneration design. The Rock Plaza integrates a rainwater biofilter, underground reservoir, and wetlands vegetation, forming the base of a closed-loop water system. The plaza serves as a social landmark and gathering space, illustrating how NbS can simultaneously serve technical and cultural functions.

Notably, the co-design process managed to integrate community input without sacrificing technical feasibility. At each stage, residents' proposals were tested against engineering, budget, and environmental constraints, ensuring a realistic balance between aspirations and practicality. For instance, while many specific requests about tree and flower species could not all be accommodated, most were either adopted or replaced with ecologically suitable alternatives. Similarly, when financial limits ruled out costly amenities, simpler solutions were introduced to satisfy the same needs. Despite such adjustments, the final plan preserved the elements most valued by residents. Importantly, participants saw their feedback reflected in real time—for example, tree choices and pathway layouts were adapted during workshops—fostering transparency, trust, and a strong sense of ownership that is expected to support long-term community acceptance. This iterative process of balancing technical feasibility with community aspirations reflects core principles of co-creation in NbS, where mutual understanding and adaptive design are key to long-term legitimacy [20].

Beyond meeting social needs, the co-created design also provides significant environmental and climate resilience benefits. The new urban forest is explicitly planned as a model NbS for urban cooling and stormwater management in this historic neighborhood [45]. To address water scarcity and flood risks, an innovative holistic water-cycle integration was designed. According to this, rainwater is captured throughout the park, filtered in the Rock Plaza, and pumped uphill to irrigate vegetation across all areas. Greywater from the repurposed old prison's vertical gardens will also be

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treated and reused. This system aims to minimize potable water use, to address flood risks, and to create a replicable model of water-sensitive urban design. Figure 3 illustrates this holistic water-cycle integration in the Barrios Altos neighborhood. It should be noted that the community seems to support all the aforementioned NbS (green and blue infrastructure) once presented, recognizing their environmental role in the neighborhood.

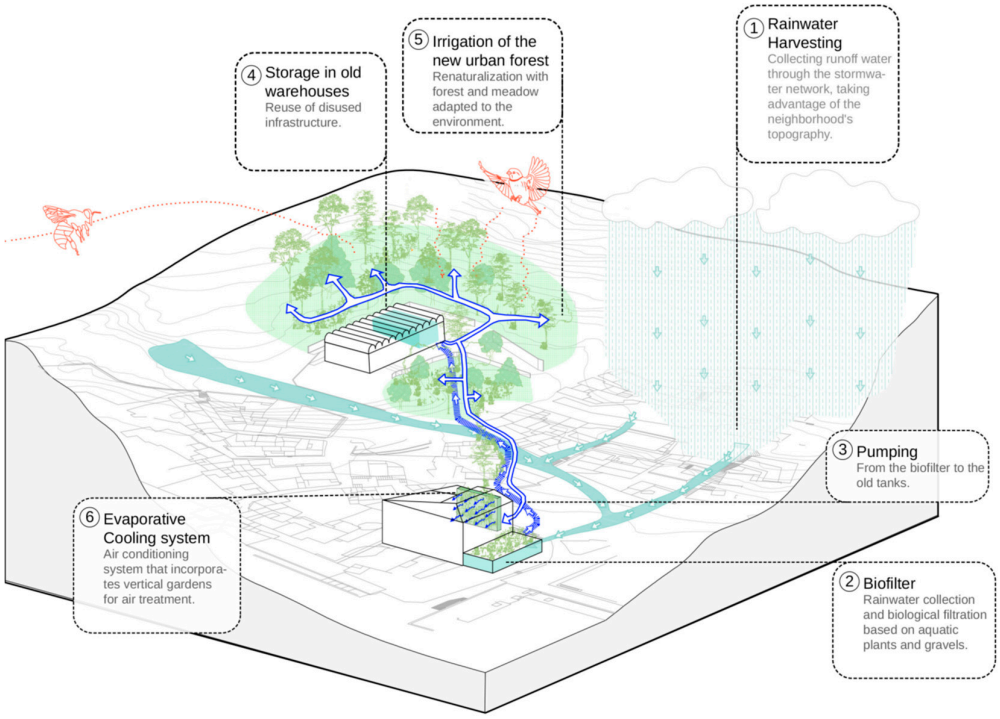

Figure 3. Holistic water-cycle integration in Barrios Altos neighborhood.

Regarding the social and cultural goals of the project, and in an effort to address both cultural identity and social well-being, as well as to link the regeneration effort to community heritage and everyday living conditions, there are two key interventions that complement the above-mentioned environmental design. The first is the restoration and adaptive reuse of the eighteenth-century Old Prison, which is being converted into a multipurpose cultural and educational hub. Vertical gardens will be installed in its courtyards to improve thermal comfort and provide evaporative cooling, demonstrating how nature-based solutions can be applied to heritage buildings while preserving their architectural value. The second focuses on public housing, where selected dwellings will undergo deep renovation, including the installation of green thermo-wall systems and climbing plants on sun-exposed façades. These improvements aim to reduce energy consumption, enhance thermal comfort for residents, and visually integrate the housing stock into the broader green network of Barrios Altos.

It should be noticed that as construction proceeds, the project aims to monitor various impact indicators (temperature reduction, soil moisture, biodiversity presence, park usage rates, etc.) to quantitatively evaluate the outcomes of the intervention. Those evaluation data will be valuable for demonstrating how co-designed NbS can deliver social (e.g. increased community cohesion and well-being) and environmental benefits (e.g. cooling, flood mitigation) in the study area.

3.2. Participatory Governance and Community Engagement Outcomes

In addition to co-design activities and to physical intervention, a key result of the NatUR-W project has been to establish a robust participatory governance framework in order to empower local stakeholders in decision-making. As detailed in Section 2.2, the project convened a multi-stakeholder

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forum early on, which evolved into a formal Stakeholders' Board representing all major interest groups (municipal departments, residents' association, local business, NGO's representatives, etc.). This Board is now actively functioning as a co-management committee for the project, and its diverse participants jointly formulated a shared project vision and identified their roles and influences in the neighborhood's regeneration. For this reason, the Board meets on a regular basis (monthly or bi-monthly) at City Council facilities to receive information on the project status and to review progress, to deliberate on decisions, such as design refinements and phasing, and to plan upcoming activities. Meetings are typically consensus-oriented, with minutes recorded to document input from each sector and to ensure transparency. As part of the process, study visits to the project's main points enabled participants to directly observe the interventions and gain a clearer sense of their potential, opportunities, and limitations.

By mid-2025, the Stakeholder Board had overseen several project milestones. In this period, stakeholders have shown high commitment: attendance has remained strong and consistent, and members have demonstrated a sense of shared responsibility for the project's success. So far, the functioning of the Stakeholders' Board illustrates several positive outcomes of participatory governance as stated in recent literature [18,42]. An important achievement was the clarification of roles and responsibilities among local actors. Board members from municipal services, neighborhood associations, and cultural organizations collectively defined how they would contribute to decision-making and how outcomes would be communicated to the wider community.

Another milestone was the early (October 2024) integration of sensitive heritage and topographic concerns into the NbS planning. Discussions highlighted the need to protect archaeological assets and to address steep slope constraints in Barrios Altos. These inputs directly influenced design adaptations, such as modifying pathways to ensure both accessibility and heritage preservation. The Board also enabled the broadening of the intervention's scope beyond purely environmental goals. Stakeholders emphasized the need for multifunctional spaces that could host cultural, educational, and recreational uses. These priorities were subsequently embedded in the final design of both the (repurposed) old prison and the new urban forest.

By integrating these concerns, the planning process gained legitimacy and minimized potential conflicts between ecological restoration and cultural heritage. At the same time, the governance framework broadened the scope of the intervention, ensuring that the final design also reflected the social and cultural aspirations of the neighborhood.

However, the positive impacts of the participatory approach extend beyond the formal committees to broader community engagement and social cohesion outcomes. The series of community workshops and forums has stimulated a new level of civic participation in Barrios Altos. The workshops effectively engaged a diverse spectrum of participants and maintained consistent levels of involvement over time, suggesting that participants perceived their contributions as valued and impactful. Meetings were held in the neighborhood's own community center (the Santa Maria neighborhood association hall) rather than in municipal offices – a strategy that aims to build trust and made easier for residents to attend by providing a safer and more inclusive environment for participation. The children's activity corner proved highly effective, offering the design team fresh perspectives and signaling to families that everyone's voice was valued in the process. Recognizing children as important users of public spaces also enriched the outcomes, since their imaginative ideas and playful outlook introduced possibilities that adults might overlook, while reinforcing the principle that participatory design should engage all generations.

Moreover, as mentioned in Section 2.4, the project introduced a digital crowdfunding platform as a complementary engagement and financing tool for the Barrios Altos urban forest. This tool was developed following a stepwise methodology defined in the project's crowdfunding plan: identifying the target audience, designing communication strategies, setting transparent funding goals, and integrating feedback mechanisms. Two NbS activities were selected as focal points for the campaigns: (a) a guided sightseeing tour showcasing Lorca's green spaces, cultural heritage, and the NatUR-W construction sites; and (b) a "sponsor a tree" initiative, where donors could name and label new

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vegetation in the urban forest. These actions were intentionally chosen to connect ecological goals with tangible community experiences, reinforcing the visibility of NbS while creating accessible entry points for citizens to participate.

The design of the crowdfunding strategy combined clear measurable economic (financial) goals with targeted outreach. So, while the financial target through this avenue was necessarily limited, the process had significant non-financial benefits. It increased visibility of the NbS intervention across Lorca, attracted younger citizens accustomed to digital interaction, and created a sense of collective ownership by allowing contributors to associate themselves with specific project elements. To ensure transparency and legitimacy, a local NGO with proven capacity and accountability was to be selected as hosting organization, while awareness-raising would take place through both in-person activities in Lorca and social media campaigns coordinated with municipal and academic partners.

3.3. Challenges, Limitations and Lessons Learned

Despite the largely positive results, our participatory process also encountered some challenges and limitations that are likely to provide valuable lessons for future initiatives. One challenge was the inherent tension between community desires and practical constraints. While several resident suggestions were integrated into the final design/plan, a few community requests could not be fully realized due to budget, technical, or ecological limitations – a common occurrence in co-design processes. For example, as noted earlier, participants had envisioned more elaborate play equipment and a greater variety of ornamental plants than the project could afford or maintain. These had to be scaled back, which risked some disappointment. The project team managed this by maintaining open communication about constraints and by finding creative compromises [45]. This highlights a broader lesson: managing public expectations is crucial in participatory projects [46]. It is important to be transparent from the outset that not every wish can be granted, and to educate participants about trade-offs. Otherwise, co-design can lead to frustration if community expectations far exceed what is feasible [23].

From an institutional perspective, an important limitation was the time and resources required for the participatory approach. Co-design workshops, stakeholder forums, and trainings made the process longer than a conventional top-down implementation. City officials had to adapt to slower decision-making, since building consensus took time. While this is a natural feature of deliberation, it sometimes conflicts with bureaucratic demands and funding deadlines [47]. Additionally, sustaining stakeholder interest over a multi-year project can be challenging; even committed individuals might lose momentum as the process moves from planning to implementation.

A further lesson comes from the interplay of expert knowledge and local knowledge. In the Lorca workshops, there were moments when technical experts had to convey to residents why certain ideas (like planting water-intensive vegetation) might be inadvisable. At times, technical jargon or complex data (for example, engineering assessments of slope stability) initially alienated some community members. The project learned to translate and communicate such information in more accessible ways – using visuals, analogies, and straightforward language – to ensure mutual understanding. It is advisable for similar projects to invest in capacity-building of participants (as NatUR-W did via educational/training sessions on NbS) so that stakeholder input is informed by a solid understanding of the issues at hand.

One of the more significant challenges in co-design processes is ensuring that the end results are implemented and maintained as intended. Often, citizens pour energy into planning workshops only to feel let down if authorities fail to follow through on the plans, a scenario noted in literature where institutional inertia can limit the transformative potential of co-design. In Lorca, this risk was reduced by having the municipality deeply involved from the start and by formalizing the Stakeholder Board's role in implementation oversight. Because the city officials who manage construction and maintenance were part of the co-design and are answerable to the Board, there is a built-in accountability to execute what was agreed.

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Finally, the NatUR-W project offers insight into the importance of scaling out and transferring lessons. The project was conceived as a demonstration of innovative participatory climate adaptation in a historic urban district, and the team is actively documenting the approach to inform other cities. A transferable lesson is the integration of cultural heritage and social justice goals into climate adaptation projects - a strategy increasingly recognized as essential for the long-term success of nature-based solutions [48]. By framing the urban forest as both an environmental project and a cultural regeneration action (revitalizing a long-neglected neighborhood and repurposing a historic prison building), the project garnered wider community interest and support. This cross-cutting approach made the initiative resonate on multiple levels, reinforcing what recent studies have identified as key to replicability and impact in socially vulnerable or heritage-rich areas [49,50].

4. Conclusions

The present study shows that nature-based solutions can function as effective socio-technical interventions when developed using an explicitly participatory methodology and grounded in collaborative governance. This process began with an initial community and stakeholder assessment. Two rounds of co-design were then carried out, focusing on identifying needs and testing options. Finally, a standing multi-stakeholder board was established to oversee decisions throughout the implementation process. Iterative feasibility checks and clear communication of trade-offs were coupled with this sequence, allowing community knowledge and technical assessment to inform each other and converge on an implementable set of interventions.

In summary, three contributions stand out for adapting this approach elsewhere. Firstly, in terms of practice, there is a clear, repeatable operational workflow that can be adapted by other cities with early municipal support and the capacity to operate and maintain the solution. Secondly, in terms of design, there is an innovative set of nature-based solution features/elements (green thermo-walls, biofilter, urban park design to tackle high slopes, etc.) that can be scaled and combined according to local constraints. Thirdly, in terms of governance and delivery, there is a compact set of procedures (e.g. regular decision checkpoints, transparent records, site walks), co-design formats (e.g. needs articulation and option testing, including under-represented groups) and low-barrier engagement tools (e.g. guided walks, sponsor-a-tree, light crowdfunding and targeted training), which are likely to turn participation into shared ownership and smooth the transition from planning to construction.

Future research should evaluate post-construction performance of the NbS interventions—linking environmental outcomes with socio-economic effects—and test whether benefits are shared fairly across all resident groups, including vulnerable populations. As engagement tools evolve, the effectiveness of crowdfunding and other low-barrier outreach mechanisms should be evaluated. Finally, comparative analyses with similar European contexts, particularly Mediterranean cities facing water stress and socio-spatial vulnerability, can clarify which elements of the workflow and governance design are transferable, and which require adaptation. Ultimately, reimagining public space at a human scale depends less on specific design solutions than on institutional arrangements that prioritize community involvement in design and delivery.

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Abbreviations

The following abbreviations are used in this manuscript:

EU	European Union
NatUR-W	Nature-based Urban Regeneration through Water
NbS	Nature-based Solutions
NGO	Non-Governmental Organization
IPCC	Intergovernmental Panel on Climate Change
SDG	Sustainable Development Goal

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