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Pathways to Greening Border Cities: A Policy Analysis for Green Infrastructure in Ambos Nogales

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Abstract: Green infrastructure (GI) has been proposed as a decentralized solution to complex urban water management issues. However, public policy remains a critical challenge for the wide adoption of GI, which is exacerbated in transboundary settings. We draw from public policy theory to analyze GI policies at the US–Mexico border. We examine the case of *Ambos* Nogales—two sister cities grappling with complex water management challenges. We examined existing policies and evaluated their impact on the implementation of GI at multiple levels (local, state, national, and binational). We also conducted interviews and a focus group with stakeholders. Our analysis unveils a set of barriers to the adoption of GI and a suite of opportunities for the enactment of GI policies. We outline five pathways for greening border cities, including (i) creating market-based GI incentives, (ii) adopting the net-zero urban water approach, (iii) engaging with existing institutions for greening efforts, (iv) planning for a GI network at the watershed scale, and (v) supporting local champions. By addressing shortcomings of policy and regulatory frameworks hindering local capacity, border cities will be more likely to adopt and widely implement GI solutions for more sustainable urban water management.

Keywords: green infrastructure; environmental policy; stakeholder engagement; transboundary water management; US-Mexico border; public policy; stormwater management

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1. Introduction

Green infrastructure (GI) is a decentralized water management approach increasingly considered a strategy to support gray infrastructure systems in cities and solve complex water-related problems—from reducing flood risk to augmenting water supply and reducing combined sewer overflows and polluted stormwater runoffs—all of which contribute to enhancing urban resilience [1]. Furthermore, a connected network of GI sites can help address habitat fragmentation and enhance landscape connectivity that directly affects wildlife and the conservation of biodiversity [2,3]. GI has also been linked to a wide range of ecosystem services related to the quality of life of urban residents [4,5]. A well-designed GI network can clean and cool the air through both shading and evapotranspiration, lessening the impact of the urban heat island effect [6]. These interventions are critical strategies to mitigate widespread environmental change, as cities continue to expand worldwide [7,8].

However, there are still significant challenges for the wide implementation of GI in cities, including significant regulatory barriers, contrasting urban planning and design practices, and other institutional hurdles that need to be addressed to harness the social and ecosystem services GI provides [9].

The pressure of climate change has prompted the development of public policies that promote GI as a strategy to mitigate its effects. Cities worldwide are increasingly investing in GI policies to advance climate adaptation goals—including tree-planting campaigns, rainwater harvesting programs, xeriscaping ordinances, and regulations that mandate in situ stormwater management for new development, to name a few [10–13]. In some cases, policies are launched after community-led efforts have advanced urban greening, following a bottom-up approach to policymaking [14–16]. However, regardless of the approach used to advance urban greening, community engagement has been identified as a critical factor for community buy-in that directly affects long-term maintenance and GI performance [15,16].

The global scale of climate change does not spare cities based on national boundaries. Border cities—or cities proximal to an international border—face an additional layer of complexity in adapting to climate change and in the planning, design, and implementation of GI policies. The factors that contribute to this complexity are several, but salient among them are the persistent peripherality of border regions, the institutional discontinuities created by borders, and the duality of borders as places of separation and connection amidst the increasing integration and metropolization of border regions worldwide [17–19].

International urban boundaries often bisect natural landscapes, ecosystems and urban infrastructure through border infrastructure (e.g., walls, roads, ports of entry) causing disruptions to their functions. Although the watershed scale has been identified as a suitable scale to address transboundary water management issues [20], a mismatch in water management approaches exacerbates the complexity of adopting an integrative watershed-scale approach [20,21]. Decentralized GI projects have the potential to support transboundary water management at the watershed level. Consequently, it is critical to examine and integrate the transboundary regulatory framework and institutional landscape of GI-related policies to achieve sustainable water management and enhance urban resilience in border cities.

This study strives to understand the role of policies, the institutional landscape in which these operate, and the regulatory framework for GI planning, design, and implementation in border cities. In particular, the paper seeks to identify elements of discontinuity in local regulatory frameworks and their implication for GI implementation at the transboundary level. We focus on the US–Mexico border cities of Nogales, Sonora and Nogales, Arizona, or *Ambos* ("both" in Spanish) Nogales, to evaluate GI-related regulatory instruments and analyze their effectiveness and shortcomings in widespread implementation. To conduct this study, we draw from public policy theory, a review of grey literature, interviews, and a focus group with stakeholders on both sides of the border. Our analysis unveils a set of barriers to the adoption of GI and a suite of opportunities for more supportive GI policies. We offer recommendations to fill existing gaps and bridge differences in water management approaches between the two sides of the border that can enhance urban resilience. Above all, we outline pathways for greening border cities, including strengthening local efforts spearheaded by binational champions, who are more equipped to engage with and understand the needs of their own communities.

Public Policy

Public policy refers to the broad range of instruments and resources developed by government actors to address problems or needs. Public policy instruments are the actual "tools of government"—the laws, guidelines, bans, and incentives that governments use to induce desired behaviors and outcomes [22,23]. Policy is defined as "a decision and subsequent suite of actions, developed and implemented to address a need, problem, or issue . . . influenced by various actors, issues, interests, and circumstances" [22] (p. 6). The

use of different policy instruments is dependent on political conditions and is influenced by a diverse set of actors and interests, circumstances, and issues [22]. In addition, policies are deeply affected by social and cultural characteristics [24], and different levels of government resources and the institutions that operate them [23,25]. Shortcomings include policies that can become outdated, or face weak implementation and enforcement, or have incomplete regulatory frameworks [22,25].

It is critical to evaluate the effects of policies and whether these are achieving their intended results. However, policy analysis and evaluation is usually labor intensive because documents can be very long and are often addressed to different sectors, directed to serve at multiple scales, and written by a diverse set of organizations [23]. Studies that evaluate policy instruments use a wide range of methodologies, including natural language-processing methods that automatically mine, scan, label, and classify policy instruments [23], or the regulatory impact analysis, which classifies policy instruments according to their level of coercion [22], or the "confluence of multi-layered government interventions" that may explain the spillover effect from innovation adoption [26] (p.14). To analyze the efficacy of policies and to know whether these aim at the appropriate targets and define the right incentives, researchers have used modeling and simulation, which allow for multiple trials and the exploration of related outcomes [27].

2. Materials and Methods

We followed a mixed-methods approach to examine the policies, regulatory framework, and institutional landscape for GI development in cities located along the US–Mexico border region. Methods include a case study of water management in Ambos Nogales and the role of GI as a decentralized solution. A case study analysis allows the scrutiny of multifaceted and complex interactions that can help increase our understanding of the effects of public policy on transboundary water management [28]. As part of the case study, we conducted a review of gray literature including policy and institutional documents, a regulatory impact analysis, a series of interviews with key stakeholders and a focus group. Data analysis allowed us to identify barriers and opportunities for GI adoption (Figure 1).

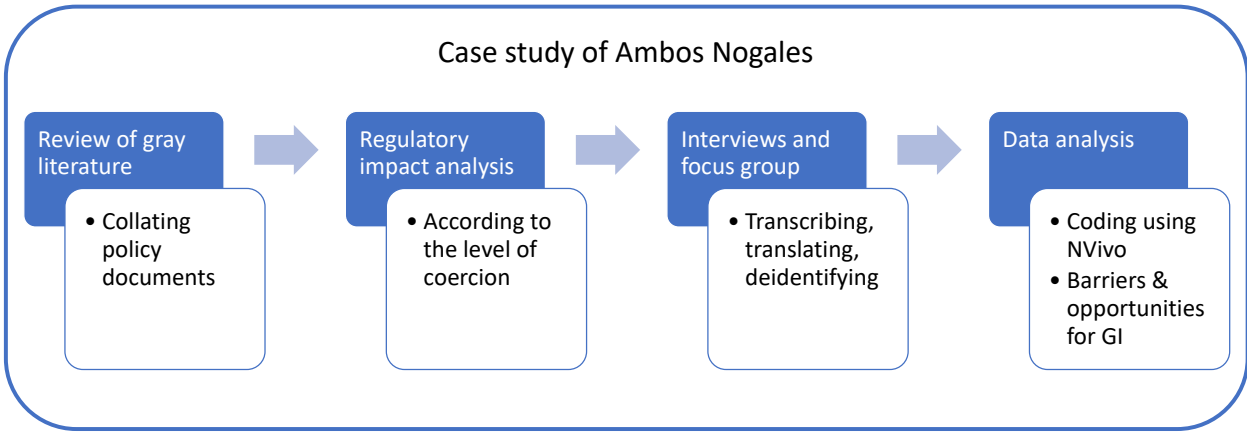

Figure 1. Methodology chart showing the steps of the research design (credit: Schwartz and Zuniga-Teran).

We began by collating policy and institutional documents (e.g., manuals, ordinances, building codes, meeting minutes, memos) as well as public-facing records (e.g., academic research articles, gray and white literature, journalistic articles) containing information about parameters, implementation strategies and impediments to GI in the Ambos Nogales region. Archival documents were drawn from institutions at multiple scales (municipal, state, federal, binational), and from a variety of nonprofit and commercial agencies, including some which operate binationally. Drawing on the networks and working experience of research team members was central to obtaining a comprehensive range of bilingual

archival documents. Our desk study (gray literature review) concentrated on the topics of urban development and institutional oversight while identifying key actors, relationships, and projects in the region's compound GI landscape.

To understand the regulatory framework for GI in Ambos Nogales, we followed the methodology of Anderson and Gough (2021) [22] for regulatory impact analysis. The first step of this methodology is to conduct a review of all existing policy instruments. The second step is to categorize each policy instrument according to its level of coercion following a policy continuum of coercion, which ranges from "moral suasion" (the least coercive) to "public ownership" (the most coercive) (Table 1). For our study, we added the level of coercion "0" to signify a policy or institutional gap. We further analyzed each policy instrument and identified barriers and challenges for implementation.

Table 1. The policy continuum for coercion [22].

Level of Coercion	Description	Examples of Policies
0—Policy/institutional gap	Category given to the absence of policy or institution to manage a policy	No institution oversees the prevention of a recurring problem.
1st. Moral suasion	" . . . exhorting or admonishing the target group to pursue or cease a particular action" (p. 6)	Advertising health campaigns that encourage avoiding the use of alcohol or tobacco.
2nd. Expenditures	" . . . seek to incentivize behavior change through financial means" (p. 6).	Rebates for energy efficiency retrofits (windows, appliances, solar panels).
3rd. Regulation	Norms that "impose heavy fines and penalties for violations" (p. 7).	Heavy fines for discharging toxic waste in rivers.
4th. Taxation	" . . . seek to discourage certain behaviors by imposing a financial burden on the targeted activity" (p. 7)	Tax on commodities such as alcohol or cigarettes.
5th. Public ownership	"the state will take on the ownership and administration of a particular activity in order to maintain complete control over it" (p. 7)	Production, distribution, and sale of electricity controlled by the municipality.

To contextualize insights from our policy analysis, we utilized qualitative methods including 23 key informant interviews with involved stakeholders and decision makers across Ambos Nogales, followed by a virtually facilitated focus group with developers and practitioners in Sonora, Mexico. We decided to focus on the Sonora side for the focus group to clarify concepts learned during the interviews and increase our understanding of the way development occurs on this, more populated, side of the border. Study participants were recruited via two consecutive rounds of snowball sampling; their affiliations are broadly described in Table 2 below.

The proportion of interview participants is aligned with population size; Nogales, Arizona has just under 20,000 residents [29], or about 14% of Nogales, Sonora's estimated population of 265,000 [30]. Therefore, a larger number of participants from the Sonora side of the border (n = 12; 52.17%) is representative of Nogales, Sonora's larger population. Semi-structured interviews ensured comparability of response data while allowing for the emergence of additional subjects and insights. Although we asked the same questions to all interviewees (Table 3), clarifying questions and unprompted topics arose with each unique conversation that enriched the qualitative dataset. Likewise, the focus group was guided by three future-facing questions, which produced deeper conversations about

shared experiences and imagined solutions. Due to travel restrictions during the COVID-19 pandemic, all phases were conducted online. Iterative phases of qualitative research constituted an adaptive methodology equipped to refine derived insights about perceptions of GI, identify policy mismatches and describe interlocking barriers/opportunities for cross-border collaboration and GI implementation in Ambos Nogales.

Table 2. Overview of Study Participants and timeline.

Timeline	Method	N	Geographical Affiliation	Professional Affiliations
September–December 2020	Key Informant Interviews	23	7—Arizona 4—Binational 12—Sonora	Municipal, state and federal government officials, NGOs, urban engineers, water utility companies, private developers, architects, academics, residents, and officials from binational institutions
9 April 2020	Focus Group	11	11—Sonora	Municipal government officials, architects, developers, urban planners/engineers, representatives from water utility company and urban planning department

Table 3. Interview and focus group questions and relation to research objectives [31].

Method	Questions	Relation to Research Objectives
Interviews	Do you know of any existing regulations or policies that govern/affect GI in Nogales?	This question allowed us to identify policies or institutional documents not included in the desk study (lit review).
	What could be done to facilitate GI in Nogales?	Participants suggested policy or practical interventions that they thought could affect GI, which led to opportunities in GI adoption.
	What motivations can you identify to implement GI in Nogales?	Motivations for GI among participants, allowed us to capture a range of understandings of GI, as well as how motivations correlate with professional affiliation.
	Are you aware of organizations or agencies (public or private) that currently do, or should, play a role in GI projects in Nogales?	Responses helped us identify institutional gaps for stormwater management.
	Any institutions on the other side of the border working on GI that you know of?	Responses were used to map out the network of stakeholders in GI planning and implementation.
	Do you participate in or are you aware of any cross border-collaborations around GI planning?	Understanding stakeholder experiences working within and around existing national structures allowed us to identify cross-border opportunities for GI.
	Can you think of anyone else we should talk to?	These recommendations informed snowball sampling until sampling saturation was reached.
Focus Group	How could GI concepts be incorporated into urban development in Nogales, Sonora?	Responses informed opportunities for GI adoption and implementation for different sectors.
	Who is needed at the negotiating table in order to create agreements or policy changes around GI?	Responses complemented the network of stakeholders.
	What factors could facilitate collaboration, planning or communication with actors on the other side of the border around GI?	Past experiences of cross-border collaborations and imagined solutions helped us identify opportunities to support GI across the border.

After transcribing, de-identifying and translating Spanish-language responses to English, we coded focus group and interview data using NVivo (a qualitative research

software developed by QSR International). NVivo's automatic coding processes allowed us to conduct content analysis and obtain an objective review of overall speech patterns. This research was reviewed for ethics on human subjects and approved by the University of Arizona's Institutional Review Board (UA # 2009017164) on 10 September 2020.

2.1. The Case of Ambos Nogales

2.1.1. Water Management and GI along the US-Mexico Border

The US–Mexico border is 1951 miles long and is the busiest and most asymmetrical border in the world [32]. Cities located along the US–Mexico border have experienced rapid urbanization fueled by industrialization, trade, and migration. This situation has resulted in recurrent urban flooding risk, water pollution, habitat destruction, and deep social inequalities leading to systemic vulnerabilities and heightening climate-related risks that affect both sides of the border.

An integrative water management approach at the watershed scale in these sister cities is critical but very problematic because there is a mismatch in water management approaches. A centralized water management authority is concentrated within the Mexican federal agency—*Comisión Nacional del Agua* (CONAGUA), while management in the US follows a more decentralized approach across federal, county, and municipal jurisdictions [33]. Therefore, GI becomes a feasible solution for transboundary water challenges.

The political boundary has a significant impact on the implementation of GI in cities located along the US–Mexico border. The border itself explains the asymmetries in development and level of urbanization experienced across the 14 sister cities. For example, Mexican border cities are often much larger than US cities because proximity to the US has attracted waves of people seeking job opportunities first created by the Bracero Program (1940s), and later by the emergence of *maquiladoras* in 1965, and the consolidation of export-oriented manufacturing enabled by the North American Trade Agreement (NAFTA) signed in 1994 [33]. Other asymmetries affecting GI policy development are financial and technical disparities as well as differences in urban governance and the way cities deal with flooding and land-use planning. Nevertheless, despite the institutional and structural asymmetries, the border offers potential solutions to complex problems, as there are opportunities for cross-border collaboration and funding sources at different levels [20].

2.1.2. Stormwater Management Challenges

The sister cities of Ambos Nogales offer an interesting case study to examine GI-related policies in transboundary settings. These cities are interconnected by history and geography and are grappling with severe water management challenges resulting from rapid urbanization and exacerbated by climate change. Seasonal rainfall and extreme wet-weather events present a suite of hazards, water quality concerns, and challenges to the residents, businesses, and policymakers on both sides of the border.

This binational conurbation lies completely within the boundaries of the Nogales Wash watershed, which is shared almost evenly by Mexico and the U.S. [34]. The Nogales Wash is a creek that flows north through the heart of Ambos Nogales. It is a tributary of the Santa Cruz River, a transboundary river whose headwaters start in the US, flows south into Mexico, and then turns around to flow north back into the U.S. (Figure 2). Increased areas of impervious surfaces due to rapid urban growth and encroachment of the floodplain by roadways and buildings have altered rainfall runoff and drainage patterns in the area. Because of the higher elevation of the Mexican city, water in the Nogales Wash flows northward into the U.S. side of the border. During dry weather conditions, flows in the Nogales Wash can reach a volume of 2–3 cubic feet per second (cfs) and consist mainly of a base flow supported by near surface groundwater/spring flow, along with untreated sewage discharge and potable water leaks from Nogales, Sonora [35]. These flows are transported through an urban network of natural and built channels and paved streets, and finally through a concretized conveyance system known as the International Outfall Interceptor (IOI), that runs along and under the bottom of the wash for 8.5 miles from

the border to the Nogales International Wastewater Treatment Plant (NIWTP) in Rio Rico, Arizona [36].

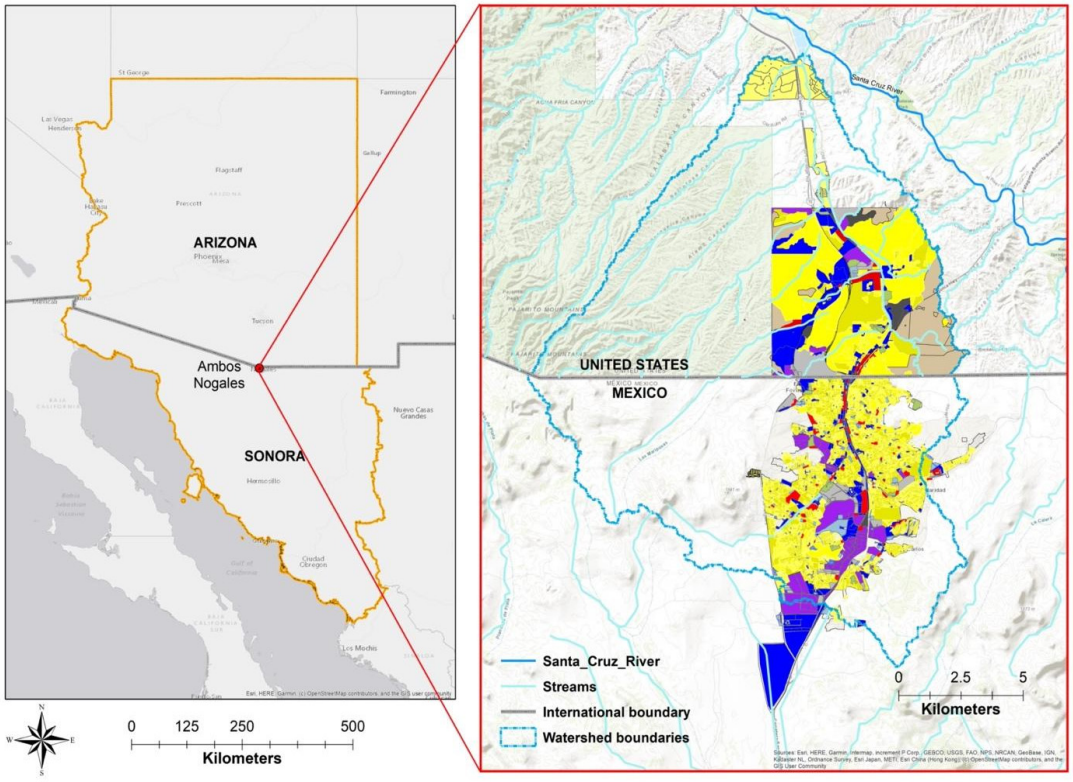

Figure 2. Map of Ambos Nogales and their relationship to the Santa Cruz River (credit: Lara-Valencia).

During periods of heavy rainfall—particularly during the summer monsoon season—transboundary flows overwhelm the capacity of the conveyance system. High-volume/high-velocity storm flows cause erosion of alluvial sediments and disturbed soils that enter the sewage conveyance network, producing combined sewer overflows (CSOs). CSOs contain untreated human and industrial waste, toxic materials, and debris as well as stormwater [37,38]. These flows are an enabling mechanism for the dispersion and transportation of pathogens, solvents, fuels, toxins, and other biological and chemical pollutants [38,39]. Monsoonal stormwater —laden with sewage, sediments, and garbage—washes into the lowlands in the form of flash floods, causing severe flooding, urban disruption, health hazards and damage to critical urban infrastructure [40] on both sides of the border. The result is two border communities under constant threat of illness, economic loss, unmet water quality standards, and even death.

The adverse impact of these processes will only continue to grow with increasing population and urbanization, while their underlying factors remain unaddressed. As shown by decades of water research in Ambos Nogales, a long-term solution to urban flooding and water quality issues requires an integrative, adaptive, and place-based approach linking land-use policy and water management, as well as cross-border knowledge exchange and cooperation [39,41–43].

2.1.3. GI Solutions in Ambos Nogales

GI solutions have been advocated as a sustainable and desirable strategy for stormwater control in Ambos Nogales [44–46], and other cities along the US–Mexico border [20,40]. In combination with conventional, or "gray" flood control mechanisms—concretized channels, piped drainage and active treatment systems —GI solutions are seen as an effective and comprehensive approach to protect the community on both sides of the border from flooding associated with seasonal and extreme rainfall events. An integrated GI network

can reduce the impact of intense stormwater runoff on critical binational infrastructure while decreasing the risk of stormwater-induced sanitary overflows [44,47]. GI solutions consider the hydrological dynamics underlying pre-development functioning of the Nogales watershed and focus on using natural processes to manage stormwater close to where precipitation falls, including retention/detention/infiltration infrastructure such as bio-swales, berms, streetside rain gardens, porous pavements, and others [45,48].

With the arrival of a new federal administration in Mexico in 2020, an aggressive "urban improvement" program was implemented nationally by the Ministry of Agrarian, Territorial, and Urban Development (SEDATU) [49]. Many of the early phase projects funded under this program were designed in partnership with prominent design practitioners and the National Autonomous University of Mexico (UNAM). This is the case with the redesign of the *Represo Colosio*, a detention pond in Nogales, Sonora (Figure 3). In 2021, the detention area of the Represo Colosio was transformed into a high-quality public space where stormwater runoff is detained and managed for the establishment of plant communities, and with defining terraced edges designed to mitigate the risk of drowning. The new GI site was designed with multifunctionality of public space and infrastructure in mind [50].

Figure 3. Represo Colosio detention basin in Nogales, Sonora (credit: Lara-Valencia).

Other GI projects in Nogales, Sonora have been implemented by the local government [51]. Additional GI interventions were developed between 2016 and 2017 in Nogales, Sonora, with funding support from the Border Environment Cooperation Commission (BECC) with specific goals: (1) sediment control in the DIF (*Desarrollo Integral de la Familia*) Park and (2) a demonstration project in the *Instituto Tecnológico de Nogales*. Both projects included a series of training and community engagement events [40]. Another GI project in Ambos Nogales is the *Secundaria* #3 (Middle School #3), in Nogales, Sonora, where academics and NGOs engaged with faculty and students to design and implement GI in their school campus (Figure 4).

The Mariposa Border Port of Entry, the main gateway for land trade in the Arizona–Sonora border, also includes GI strategies (Figure 5). Built in 2014, this 55-acre site was designed to collect runoff from buildings and paved areas, directing it to detention basins, rain gardens, and swales vegetated with native plants for infiltration [52]. A GI example in Nogales, Arizona is Las Lagunas de Anza, which is a privately owned site that was restored to provide out-of-doors historical and environmental education [53].

Figure 4. GI implementation at the Secundaria #3 in Nogales, Sonora (credit: Lara-Valencia).

Figure 5. GI projects at the Mariposa Port of Entry (credit: Zuniga-Teran).

Although there have been important GI projects implemented in Ambos Nogales, GI has not been established as a comprehensive urban planning tool for the two cities to address flooding issues and sewage spills [20]. A binational GI network can be a significant improvement to stormwater management in the border cities. Therefore, it becomes critical to understand the regulatory framework needed to scale up the greening for stormwater management in Ambos Nogales.

3. Results

3.1. Policy Barriers

Our multiphasic analysis provided a deepened understanding of the contours and complexities of interlocking policies affecting GI in Ambos Nogales. Across jurisdictions and binationally, five underlying barriers pervading legal structures were identified (Table 4).

Table 4. Summary of policy-related barriers for GI adoption and implementation.

	Underlying Barrier	Level of Coercion and Its Issue	Description of the Barrier
1.	Different water quality standards and monitoring regulations	3rd—Regulation. Unaligned regulations.	Mexico and the US have different standards for pollutants and water quality and disparate procedures/resources for its assessment.
2.	Institutional gap in stormwater management upstream	0—Institutional gap. No institution in charge.	The head of the Nogales watershed—Nogales, Sonora—lacks an institution/agency in charge of preventing flooding and managing stormwater in urban areas.
3.	Stormwater management is often reactive rather than proactive	0—Policy gap. Reactive approach.	Both sides of the border deal with flooding in a reactive manner—with major policies/programs designed to intervene only after damage is done.
4.	Existing regulations are underenforced	1st—Moral suasion. Policies are voluntary.	Many policies rely on the "goodwill" of developers and residents for compliance, and/or are overseen by under-empowered agencies with insufficient resources for enforcement.
5.	Multi-scalar authority and nested jurisdictions	5th—Public ownership. Centralized management impedes local action.	Discrepancies between conflicting/overlapping jurisdictional authorities weaken GI policies and impede harmonization; water management at the federal level impedes more responsive local efforts (between states or municipalities).

Binational policy solutions are hampered due to asymmetrical water quality and monitoring regulations across the border. This issue relates to the third level in the coercion continuum—regulation. Under the demands of the industrialized border economy, Sonora relies on its extensive manufacturing sector, complicating the enforcement of more stringent discharge standards on the maquiladoras and other corporations discharging waste-laden liquids into surface waters. Even if the region's overburdened, under-resourced monitoring systems were effective, discharge waters that comply with federal Mexican quality standards do not meet higher US requirements, though both groundwater and surface water are inextricably shared between the sister cities. One participant shared:

> *Though we know that those companies, maquiladoras for example, are complying with the Mexican regulations, we are trying with OOMAPAS (Organismo Operador Municipal de Agua Potable y Alcantarillado y Saneamiento—the water utility and sanitation authority in Nogales, Sonora) to go further and try and have them comply with the American standard. Not just looking at how to do it, but how to make them [maquiladoras] be part of the solution as well. Because right now, we can't legally do anything...you can't demand anything from them. Our role is more of negotiators or trying to convince them, rather than legal (enforcement). We don't have the power to interfere or to set fines.* (Participant Binational 3, 9/22/2020)

In addition to a mismatch in water quality standards, we found an important gap in the institutional landscape of Nogales, Sonora, as it has no floodplain management agency that can act to prevent future stormwater flooding, which represents a 0 in the coercion continuum (gap). The highest investments into flood risk mitigation strategies for the watershed have been made into large-scale gray infrastructure (e.g., lined canals or pipes which discharge stormwater rapidly). When these fail, county and municipal agencies rely on reactive harm reduction strategies which do little to address foundational shortcomings of the water management system upstream. Nogales, Sonora officials call the local *Protección Civil* (the Mexican disaster-response agency) to rescue victims and salvage property, while Santa Cruz County managers in Arizona rely on FEMA's intervention, though the area has not sustained "qualifying" storm damage for federal assistance since 1997. In both cities, the brunt of flood control funding is leveraged for emergency response while budgets for programs and infrastructures to help communities avoid disaster remain deficient. Despite broad recognition of GI benefits, institutions in Ambos Nogales remain legally and financially disempowered to employ GI and other preemptive, passive strategies in at-risk floodplains. Further, we found neither mandates nor incentives promoting GI retrofits in the floodplain after storm events.

We find that the regulatory framework for GI is weak on both sides of the border. Stakeholders in both cities expressed frustration at the need to rely on the "goodwill" of private developers to execute (effectively voluntary) GI policy requirements. This challenge relates to the first level of coercion—moral suasion. In Nogales, Arizona, the county-level floodplain management agency can delay proposed developments in recognized areas upon inspection and give citations for existing structures, though only during annual insurance renewal. Even if the floodplain authority withholds approval, ultimate enforcement is tenuous. As one official noted, "after that, if it becomes the issue of how much will is there in the higher-ups of the county to enforce anything—and from experience, it's not a lot" (Participant AZ 1, 09/29/20).

Likewise, the municipality in Sonora has few legal options for ensuring suitability of existing development in the dense urban zone. The local permitting system does not apply to standing structures and the city planning agency, the Municipal Institute of Research and Planning (*Instituto Municipal de Investigación y Planeación*—IMIP), serves a primarily consultative role on new legislation. Local authorities are unable to enforce the robust and advantageous environmental policies enacted at the state and national levels in Mexico in part because of their non-specific language and lack of "teeth"—or enforcement capabilities on the ground (Participant Binational 3, 9/22/2020, Participant SON 1, 10/15/2020; Participant SON 2, 1/11/2021; Participant SON 5, 12/1/2020).

Whether because of weak regulations or because of ineffective enforcement, much of the existing policy around GI and flood risk management in Ambos Nogales is upheld only when developers, corporations and residents voluntarily opt to comply (moral suasion). In addition, there are exchange programs for urban greening that enable developers and polluting corporations to exchange GI requirements in one area by planting trees somewhere else. These exchanges, particularly in the absence of required maintenance and follow up, ultimately reduce the effectiveness of GI policies on future development, particularly in disadvantaged areas (focus group, 4/9/2021; Participant SON 3, 11/3/2020; Participant SON 12, 12/17/2020).

3.2. Beyond Policy: De Facto Challenges to GI in Ambos Nogales

While revealing the inadequacy of targeted policy adjustments or institutional mirroring in resolving water management discrepancies in the context of the border, we found other factors—not related to policy—that are also important. Table 5 describes these de facto challenges that both influence and undermine policy and the regulatory framework, including resource gaps and overarching political and social barriers.

Table 5. Challenges for GI implementation (not related to policy) [31].

Scope	Challenge	Description
Binational	Lack of funding for GI	Neither public nor most private agencies have a GI allotment in their budgets.
	Lack of consideration of GI maintenance	Operation and maintenance (O&M) procedures are often overlooked in GI planning/budgeting, resulting in project failure and loss of local support.
	Water managers do not recognize their role in GI implementation	Water managers working at city, county and state offices, and private utilities on both sides of the border do not see their work as being related to GI.
	Limited local cross-border collaboration for GI	Despite Ambos Nogales' shared history of collaborative management and planning across the border are constrained by federal legal impositions, social/economic divides, and logistical barriers, exacerbated by recent restrictions related to the COVID-19 pandemic.
Nogales, Arizona	Lack of local GI design standards	There are no locally relevant, functional and approved GI design standards for regulators or developers to apply consistently.
	Lack of training and materials	There is a shortfall in education and capacity-building around GI tools and strategies, as well as necessary materials for implementation.
Nogales, Sonora	Rapid and high-density development	Unregulated land use and guidelines for affordable housing do not consider natural drainage systems and do not promote GI. In addition, guidelines are subject to economic pressures, industry incentives and a high demand for affordable housing.

We found a lack of construction guidelines in the Mexican side that identify natural drainage systems in plots and crucially preserve them from development which could significantly reduce flooding downstream (focus group 4/9/2021, Participant SON 9, 12/8/2020). The National Housing Fund for Workers (*Instituto del Fondo Nacional de la Vivienda para los Trabajadores*, INFONAVIT) guides urban development in the country, and this institution does not promote the implementation of GI sites or stormwater management (focus group 4/9/2021). Because developers need to comply with these guidelines if they aspire to get customers with INFONAVIT's mortgage loans, and there is no economic or regulatory incentive to adopt GI in new development, it is unlikely that GI will be adopted in future urbanization in Nogales (focus group 4/9/2021).

3.3. Opportunities for GI Adoption

Findings show that linking potential GI policies to functional examples in neighboring cities sparked increased interest and acceptance of policy suggestions. Arizona authorities expressed that they had lessons to learn from Sonora's more progressive GI regulatory frameworks, while leaders in both cities brought up models in practice, such as Tucson, Arizona's Rainwater Harvesting Rebate Program funded by a fee on resident water utility bills. A policy like Tucson's was proposed in our focus group: charging a modest monetary contribution on the water bill of Nogales residents to support GI and raise much-needed funds for its implementation (focus group, 4/9/2020). Overall, within the current political landscape, stakeholders identified project- and incentive-based policies (expenditures) as the most viable opportunities for creating change (focus group, 4/9/2020).

Surprisingly, some focus group participants from the private and civil planning sectors in Sonora advocated for stricter regulations on their own projects to address shared challenges. They expressed willingness to follow GI requirements, if their projects were economically feasible. The most popular targeted policies included changing guidelines for a specific site, converting unused urban space and/or creating economic/social incentives

for compliance with GI principles regardless of a legal imperative to do so (focus group, 4/9/2020).

Our findings highlight the importance of empowering local actors—both private developers and residents alike—to make applied changes in their neighborhoods (Participant AZ3, 10/52020; Participant AZ 4, 10/1/2020; Participant SON 4, 11/4/2020; Participant SON 6, 12/2/2020; Participant SON 10, 12/9/2020; Participant SON 11, 12/17/2020). The most progressive regulatory shift around GI in recent history anywhere in Ambos Nogales resulted from a civil lawsuit against the municipality of Nogales, Sonora, on the part of a community advocate and affiliated grassroots organization. A participant noted, "The city was being devastated so indiscriminately and the law was not being respected. In that sense, I decided as a citizen with legitimate interest to file a protection lawsuit in federal courts before a federal judge . . . I began to organize with some volunteers and citizens here in the city of Nogales to demand the authorities to respect Article 4 of the Constitution, which is to have a healthy environment" (Participant SON 6, 12/2/2020). The resulting 2020 *Reglamento del Árbol* mandates that developers replace each tree cut down with five more per specifications of the state's official native plant list. It established a city-wide tree count to inform reforestation, a citizen denunciation clause, and sanctions for violators. Unlike policies which put the onus of change on residents, it lays out a formal structure for developer accountability inspired by a civic bid to change the formal conversation around development regulations through political struggle.

Ultimately, without realistic enforcement capacity among municipal agencies, the recent Reglamento del Árbol, like other groundbreaking resident-led policy initiatives at both state and city levels (e.g., *Paleta Vegetal, Programa de Desarrollo Urbano*) remain largely unenforced and were described by some as "wishful thinking" (Participant SON 12, 12/17/2020). The adoption of the Reglamento del Árbol inspired some Nogales residents to contact local environmental NGOs—instead of municipal authorities—to report transgressions of de-vegetation in their communities. Youth leaders have been responding to these calls by documenting developer offenses, hosting neighborhood clean-up days and planting their own trees (Participant SON 11, 12/17/2020). The ripple effects of these aspirational policy demand demonstrate the potency of grassroots initiatives—including those once considered radical—in influencing the in/formal structures of urban development.

Results unveil the need for empowerment of local actors outside of and beyond policy through addressing practical barriers and supporting informal networks of practice (e.g., going around "red tape"—or bureaucratic restraints). A participant noted: "There have been politicians, there have been health initiatives, there's been everything. But every year the only crew doing something, like planting a fruit tree, guess who it is? It's the brown water harvesters that don't get the big money, right? They're changing the neighborhood...not making that many promises or extracting that much data...But every year there's at least another garden or another tree on the sidewalk, shared space in a water harvesting basin" (Participant AZ 4, 10/1/2020). Another participant reported: "There was no call for this. So, all the research was by sending proposals out to various agencies. It eventually got funded but there wasn't, you know, an RFP (Request for Proposal) out that said, 'would you like to spend 15 years studying watershed processes in this area?' There are just people that love Nogales, and I'm one of them" (Participant BIN 4, 4/8/2021). Several site-specific advantages and opportunities for progress outside of policy in Ambos Nogales came to light, as summarized in Table 6.

Table 6. Opportunities for GI adoption in Ambos Nogales [31].

Opportunity/Asset	Description
Enthusiasm for GI	Stakeholders across Ambos Nogales are energized and optimistic about GI potential, convening diverse motivations and opportunities for progress.
Local leaders	GI principles and projects have been progressed by a tight-knit group of binational leaders who leverage relationships and expertise to transcend institutional limitations and political boundaries.
Intracity collaboration	Through improved communication, there is room to improve intra-city collaborative relationships and transcend siloed work.
Cross-border collaboration	Leveraging binational, bilingual networks and facilitating cross-border training were identified as key opportunities.
Investments in equity	Within equity considerations among and across cities, there are opportunities for promoting equalized access to greenspace and its associated benefits.
Concern for community wellness	GI is widely recognized as an opportunity to bolster public health and livability of Nogales communities.
Bottom-up approaches informing policy	Projects spearheaded by local NGOs and residents have paved the way for official acceptance of, and evolving policy around, GI.

Though the alignment of projects in Nogales around the popular vernacular of GI (employed by authorities like the US Environmental Protection Agency, EPA) is relatively new, binational projects have long transformed sections of the landscape and solidified working relationships without government or commercial actors. Many of the actors we interviewed have helped bring community-level interventions to fruition and affirm GI as a mitigating strategy for Nogales' persistent water management issues. Legislation has been shown to follow demonstration projects; municipal officials told us that the implementation of functional and educational projects in neighborhoods, rights-of-way, schools, and public service buildings has been impactful to their thinking about the usefulness of GI (Participant AZ 1, 9/29/2020; Participant SON 4, 11/4/2020). Notably, grassroots projects prioritize interventions that can achieve significant results quickly and affordably, but also leave room for expansion or fortification via future investment. By lifting-up these initiatives and connecting diverse stakeholders across Ambos Nogales, this study added momentum to a growing impetus for local GI.

4. Discussion

In this study, we aim to understand the regulatory framework and institutional landscape that affects GI development in border cities. By examining the case of Ambos Nogales, conducting a regulatory impact analysis (looking at GI-related policies according to their level of coercion), and speaking with stakeholders across the border, we were able to identify important barriers to the wide adoption of GI as well as a suite of opportunities to move forward. Based on this analysis, we offer pathways to move forward with the greening of border cities.

Our analysis suggests that there are underlying policy-related barriers to GI implementation in Ambos Nogales that are related to the level of coercion. We find that a low level of coercion that hinders the effective implementation of important local GI policies (e.g., Reglamento del Árbol), and that higher-level coercion policies (third level—regulatory), such as water quality standards, differ between countries, making it unenforceable across the border. Some of the most coercive GI policies (fifth level—public ownership)

are driven by water management enforced at the federal level in Mexico and at the state level in the US, making it complicated to act locally.

Our results unveil mismatches in the binational regulatory framework and a reactive approach to urban flooding. For example, there are different water quality standards between the US and Mexico, which represents a significant barrier for an integrative management of water resources. However, this mismatch also provides opportunities for binational collaboration at the local level that may even involve the potential transfer of funding for decentralized GI projects on the Mexican side to address water quality issues on the US side. In addition, we find in the institutional landscape reactive approaches to flood management that hinder transboundary flood prevention efforts. We identify a key institutional gap on the Sonora side for flood prevention since there is no institution in charge of this water management aspect like the floodplain management authority in Santa Cruz County, AZ.

Overall, we find that the few existing GI-related policies have followed a bottom-up approach, especially on the Sonora side (the more progressive in terms of GI). Here, the local government was convinced of the need for GI after projects had been installed by local communities, sometimes with the help of NGOs, and their effects made evident. This finding aligns with Elder & Gerlak (2019) [14] who document do-it-yourself (DIY) GI interventions in Tucson and how these evolved into policy instruments over time. In addition to bottom-up approaches for policy development, we find a few large-scale GI projects already implemented on both sides of the border by governmental organizations, educational institutions, and the private sector, including Represo Colosio, Mariposa Port of Entry, Las Lagunas de Anza and more. However, GI has not been effectively incorporated into urban planning at the watershed scale, a critical step for wide implementation.

The transboundary setting adds a layer of complexity to the regulatory framework for GI because jurisdictions at different levels (state/county/municipal) are constrained in their ability to engage officially with analogous institutions on the other side of the border. Results show that there are significant discrepancies in codes, norms, and governance structures between the two cities across the border, presenting heightened challenges to streamlining policy. The complexities of multi-scalar and overlapping jurisdictional authority escalate the challenge of harmonizing watershed-scale policy to an insurmountable geopolitical scope. The two federal institutions in charge of water management on the US–Mexico border, the International Boundary Water Commission (IBWC) and its Mexican counterpart *Comisión Internacional de Límites y Aguas* (CILA) are charged with primary oversight of the border zone (defined as 100 km north and south of the international boundary, via offices on both sides). Meanwhile, the highest law of the land remains in a number of treaties between Mexico and the U.S., including multilateral trade agreements, which serve primarily to shore up economic arrangements and do little to ensure environmental oversight at the local level. This finding aligns well with Albrecht et al. (2018) [21], who find informal cooperation at the local level more feasible than the county, state, or country level in transboundary settings.

Beyond policy, we find that the regulatory framework for GI is deeply affected by several challenges at different scales. Findings suggest that funding for GI is one of the most critical factors affecting implementation. While IMIP in Nogales, Sonora has launched clear GI-related policies, the enforcement of such policies has not been effective. For the Reglamento del Árbol, for example, IMIP relies on the goodwill of developers—though without economic incentives to follow this policy, developers are not likely to consider it. Therefore, there is no clear pathway for its successful implementation. A higher level of coercion is needed for its effective implementation—from moral suasion to expenditures, or even regulation (e.g., rebate program, incentives, or even heavy fines). This finding aligns with Ferraro & Failler (2022) [25] and Firebanks-Quevedo et al. (2022) [23], who document governmental resources as fundamental for the enforcement of policy instruments. Policies without enforcement capacity can be considered aspirational or act as ineffective planning tools.

A critical challenge for flood prevention in the case of Nogales, Sonora is the lack of urban design and planning policies toward flood control. Affordable housing developers follow federal INFONAVIT policies, which do not direct development away from natural drainage areas (creeks) or mandate the protection of existing native vegetation. Consequently, developers usually wipe out the vegetated landscape and level off the land to extract the maximum number of lots from their parcel and the largest number of buildings to sell. We find that there is no existing urban planning approach to stormwater management on the Mexican side of the border. Furthermore, in the US, the stormwater management approach is to discharge runoff as fast as possible, without considering stormwater as a resource to harness in situ for landscape irrigation and aquifer replenishment in the long term. Without considering the topographic characteristics of the land and stormwater as a resource, future development is likely to disturb the urban water cycle even further, exacerbating flooding issues downstream.

In addition, housing regulations at the national level are hindering the adoption of GI in current and future urbanization processes. INFONAVIT is increasingly important to cities such as Nogales, Sonora, which struggle with housing shortages. However, the one-size-fits-all construction standards for low-income housing across the country fail to consider amenities which normally accompany new housing (e.g., schools, plazas, jobs, businesses). In terms of GI, INFONAVIT maintains only a minimum of 3% greenspace area per plot, leaving little room for DIY landscape adaptations [54]. This mandated percentage of greenspace is very small compared to international standards. The World Health Organization recommends at least 9% greenspace per plot [55].

By identifying major legal and regulatory restrictions for GI implementation in Ambos Nogales, we were able to locate opportunities for policy change. Primarily, policy-based opportunities involve reworking building codes and permitting, bolstering enforcement of existing regulations and localizing oversight of infrastructures. This involves moving some policies along the coercion gradient (e.g., from moral suasion to regulation). Stakeholders across the sample emphasized the importance of coupling new regulations with financial or tax incentives. As funding was confirmed as a major obstacle for overstretched city budgets and stringent private developers, bottom-line benefits make GI installation viable.

One important opportunity for GI policymaking includes prioritizing the establishment of requirements around adaptive retrofitting. Even in the event of a GI policy update, most of the urban space in Nogales, Sonora has already been built upon. Retrofit mandates (regulations) and/or formal incentives (expenditures) could help ensure that the largest and most impactful developers in both cities are obliged to alter standing construction to adapt to modern planning ideals, changing climate conditions, worsening drought, and in response to negative impacts on downstream neighbors.

5. Pathways toward Greening Border Cities

We offer five recommendations that can help with the integration of GI in urban planning at the watershed scale in border cities. These include (i) creating market-based GI incentives, (ii) adopting the net-zero urban water approach, (iii) engaging with existing institutions for greening efforts, (iv) planning for a GI network at the watershed scale, and (v) supporting local champions.

Market incentives can effectively engage developers of residential or commercial development on both sides of the border. We recommend the design of market incentives for GI for new development and for the retrofit of existing development, particularly on natural drainage areas. These incentives can take the form of tax breaks, or a reduction in development fees that can persuade developers to opt for respecting natural drainage areas from development in Mexico. NGOs and universities also have a valuable role to play in capacity building around the design of urban development that respects the natural drainage systems and incorporates GI across the landscape. We likewise recommend funding incentives tailored for these groups.

The net-zero urban water approach could provide a more integrative way to manage water in border cities. It brings together water managers and developers under a common vision centered at restoring the urban water cycle [56]. This approach necessarily engages water utilities, sanitation and wastewater treatment departments, flood control agencies, emergency agencies (FEMA, Protección Civil), local governments (urban planning departments), NGOs, and the private sector (developers) toward an integrated urban water management vision. By breaking institutional silos and working toward shared goals, stakeholders can solve complex water management issues. Learning from other cities can help clear the pathway forward. For example, following Tucson's experience, water utilities can charge a conservation fee in their water bill that can be used to fund GI projects implemented by another agency. This way, the utility can augment water supply in the long term (by infiltration into the aquifers), while reducing flooding risk. With the collaboration of local governments, flood control agencies can support greening efforts in public land (boulevards, roundabouts, chicanes), and the private sector can retrofit parking lots and other areas to incorporate GI projects, to name a few options. An integrative institutional approach can also bring more funding opportunities for GI project that benefits multiple agencies. For example, in Tucson, some GI programs are funded by a conservation fee charged in the water bill of all Tucson Water customers. This incentive model that collects funding on the supply side of water management helps flood control with stormwater management and with the enforcement of water quality standards, both of which are managed by different institutions.

Engaging established local organizations in GI efforts is a low-hanging fruit to incorporate GI at the watershed scale. Existing organizations usually own land throughout the city, in the form of school yards, churches, parking lots, courtyards, government buildings, parks, streets, etc. These sites can be places where GI demonstration projects can happen. This approach has been proven effective in Nogales and other cities [57,58] at the household level, and could be scaled up to the city level.

We highlight the need to develop a binational urban planning approach that promotes a GI network at the watershed scale, preserving natural drainage systems from development, which has been documented in earlier studies of sister cities in the US–Mexico border [20,40]. Because GI networks are spatially explicit structures reconnecting otherwise fragmented urban spaces, this approach has the potential of being a useful tool for planning and management of sister cities [59]. GI fits squarely within the advocated binational approach to integral stormwater management because of its emphasis on restoring and maintaining the horizontal and vertical interconnection of the urban hydrological system that are needed for a healthy watershed. These interconnections link components and processes sustaining a variety of regulating, provisioning, and cultural services important for urban resilience and sustainability [2,3]. In addition, a GI network has been identified as a strategy to address environmental justice issues around GI, providing greenspace access to people across the city [59,60].

Finally, supporting local champions who are already working with the community can be an effective way to implement more GI projects. There are engrained leaders who know the issues and have been working to make their communities safer. For example, Lara-Valencia et al. (2021) [61] find that residents in Nogales, Sonora are using plastic bottles to prevent soil erosion in hilly informal settlements. By building terraces, they are reducing not only soil erosion on their lots, but also sediment downstream. These local efforts can benefit from plant donations, the use of machinery, volunteers, and training to build capacity and integrate nature-based solutions in neighborhoods. GI site selection based on resident experiences may promote the engagement of local stakeholders in project success and sustainability. Overall, local efforts have been identified as critical for addressing climate change vulnerability in urban environments along the US–Mexico border [62].

6. Conclusions

In this study, we aim to understand the policies, regulatory framework, and institutional landscape for GI development in border cities. We examined the case of Ambos Nogales and conducted a regulatory impact analysis that included a desk study of GI-related policies, a classification of policies according to their level of coercion, as well as interviews and a focus group with stakeholders. Our analysis unveils significant barriers for the implementation of GI-related policies, as well as a suite of opportunities for more effective GI regulations and policies. We offer five potential pathways that can help move forward with flood management at the watershed scale. First, we recommend the creation of market incentives for new development that respects the natural drainage systems and incorporate GI projects into new and retrofit development. Second, adopting the net-zero urban water approach [56] can break institutional silos in water management that may enable collaboration and harness resources for GI projects across borders. Third, engaging with existing institutions can provide sites where GI demonstration projects can be implemented and later adopted by others. Fourth, directing urban planning toward a GI network at the watershed scale can help restore the urban water cycle and improve sustainable outcomes, regardless of institutional barriers. Finally, supporting local champions that are already leading GI projects at the local level can result in synergies for greening. For transboundary settings, cross-border collaboration at the local level is a valuable opportunity to advance greening efforts and enhance overall urban resilience and sustainability.

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