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Research article

Promoting green infrastructure in Mexico's northern border: The Border Environment Cooperation Commission's experience and lessons learned

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ABSTRACT

This paper describes the application of a comprehensive strategic approach for integrating Green Infrastructure (GI) in urban planning in Mexican communities along the U.S-Mexico border as a means to mitigate the environmental, economic, and social impacts of inadequate stormwater management. Population growth and extended urban footprints in the region's cities have decreased rainfall infiltration and significantly increased runoff, carrying sediments and other pollutants into binational watersheds thus contributing to the pollution of aquatic habitats and potable water sources.

As a strategy to mitigate these impacts, the Border Environment Cooperation Commission (BECC) developed a four year initiative with the long-term goal to support communities in building resiliency through the use of GI in public spaces such as parks, sidewalks, medians, and parking lots as a way to adapt to climate change, improve urban image, and strengthen native ecosystems. The Border Green Infrastructure Initiative was organized around training, strengthening municipal codes, developing pilot projects, restoring native vegetation, and the participation of residents, local government, and the private sector. The investment over the entire period was approximately USD$800,000. Outcomes were noteworthy. Approximately 900 professionals received various types of capacity building. Five cities and four Mexican border states were active participants in the program. Six pilot projects were implemented, three of which could capture a total volume of 4691 m^3 of water in one year. In two sites the annual sediment collected was 656 m^3. Finally, six technical tools were developed to assist communities in analysis and implementation.

This approach represents a paradigm shift from the conventional management of stormwater through gray infrastructure and is intended to influence public policy at the local level, in a replicable and scalable way, resulting in more livable cities, improved water quality, and stronger binational environmental health.

1. Introduction

Urban sprawl has been an issue as populations grow and are in need of housing. In the United States urban footprints grew almost three times faster between 1982 and 1997 than the population (O'Sullivan, 2007). In Mexico growth has also extended in an outward direction towards large amounts of vacant land (Arellano and Roca, 2010). Low transportation costs, less expensive land, and underpricing of new infrastructure are incentives typical of urban sprawl. To cope with this, many large Mexican border cities developed the concept of "municipal institute of planning", following the original design in Curitiba Brazil (Fukuda-Hayakawa, 2010). The development of more technical rigorous planning instruments allowed the inclusion of new techniques to improve traffic, mobility and better land use in general. Nevertheless, the rapid increase in nonpermeable surfaces combined with precipitation patterns of the Chihuahua and Sonora deserts (dominated by the North American Monsoon) have intensified stormwater damage to private and public infrastructure.

In North America and Europe many cities have now incorporated ecological and sustainability concepts into their planning processes that include green infrastructure (GI) elements (Lennon and Scott, 2014). Architects and civil engineers have established an important catalog of ideas and technologies for more sustainable stormwater management for residential and commercial development. At the community level,

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neighbors have developed techniques to collect and use rainwater reducing the volume and load to cities' stormwater infrastructure (Lancaster, 2013). Nevertheless, the increase of the effects of global climate change such as biodiversity loss, invasive species impact, flooding and dwindling water supply have refocused urban water management to include GI's role in optimizing eco-system services going forward (Ahern, 2007) (Pauleit et al., 2011) (Liu and Jensen, 2018).

The objective of this paper is to describe the experience of the Border Environment Cooperation Commission (BECC) in promoting GI along the U.S-Mexican border between 2014 and 2017; present and discuss the results and lessons learned from this 4 year effort; and propose a way forward to leverage these experiences into a national GI program for stormwater management (SWM) policy in Mexico. Although BECC's activities during this period promoted GI on both sides of the US-Mexico border, this paper will focus primarily on what was done and achieved on the Mexican side because GI is a relatively new approach in Mexican public policy circles and it is important to build on these initial efforts to promote the inclusion of GI in Mexico. Also, in the US, the U.S. Environmental Protection Agency (USEPA) has been promoting GI for over 10 years and there are already a number of successful initiatives in the US southern border states which served as an input for the Mexican context. The analysis and recommendations in this paper are applicable to other regions of Mexico more broadly, although the data presented here refers only to the northern border states of Baja California, Sonora, Chihuahua, Coahuila, Nuevo Leon, and Tamaulipas.

1.1. The border region and binational collaboration

The United States and Mexico are geographical neighbors with a high economic asymmetry, but a shared history and intense social, environmental, cultural, economic and security relations. These relations are particularly evident at the border which both divides and unites the two countries. On the one hand, some of the poorest communities in the United States are located in the border counties of California, Arizona, New Mexico, and Texas. Yet, migration from southern Mexico has continued, in search of employment and housing, to what are considered the “rich” Mexican border cities in the states of Baja California, Sonora, Chihuahua, Coahuila, and Tamaulipas. Prior to the U.S. 2009 recessions, the border region had one of the highest population growth rates in Mexico. Since 1965, at least 3839 *maquiladoras* (manufacturing plants) have been established in the area, generating approximately 980,000 jobs (Kiy and Wirth, 1998). The accelerated growth in these Mexican cities aggravated the need for infrastructure in a region where the budgets allocated for these basic services were insufficient.

Over 15 million people reside along the U.S.-Mexico border and share an environment with natural resources that include watershed and air basins which transcend political boundaries. Pollution impacts both sides of the border and requires a coordinated response at the local, state, and federal levels. In recognition of this, the La Paz Agreement was signed by the Governments of the U.S. and Mexico in 1983 to improve and protect the environment and public health along a defined region of 100 km north and south of the border (Fig. 1). This served as the foundation for binational cooperation needed to address the interwoven environmental issues between the two countries (USEPA and SEMARNAT, 2016). It also served as a later basis for the creation of the Border Environment Cooperation Commission (BECC) and the North American Development Bank (NADB).

The BECC and NADB were created in 1994 as a side agreement to the North American Free Trade Agreement (NAFTA). Their mission is to work jointly to provide financing, as well as technical assistance and capacity building, to support the development and implementation of environmental infrastructure projects that help preserve, protect and enhance the environment of the border region, in order to advance the well-being of the people of the United States and Mexico. Their jurisdiction is 100 km north and 300 km south of the U.S.-Mexico Border thus serving 10 states, 13.9 million residents in the U.S. and 26.1 million residents in Mexico. In the last 20 years, this binational environmental cooperation has strengthened the operations of water utilities and cities in addressing basic infrastructure needed to address issues of untreated wastewater, poor air quality, and solid waste management with the participation of Mexico's National Water Commission (CONAGUA) and Mexico's Ministry of the Environment (SEMARNAT) and the USEPA. Projects developed under this framework have been effective on both sides of the U.S.-Mexico border and in facilitating regional collaboration among 14 sets of greatly interdependent sister cities along the border, where the vast majority of border residents live (USEPA and SEMARNAT, 2016).

1.2. Shared watersheds and stormwater management

The regional climate in the U.S.-Mexico border region is characterized by drought conditions alternating with heavy rain episodes of short duration and high intensity. Like other regions in the world, this area has experienced the cumulative impacts of severe weather events, with a significant increase in extreme hydrometeorological events as well as higher costs to address the associated damages, particularly under the high ratios of impervious urban landscapes in the largest 11 sister cities complexes (Figs. 2–4).

The decrease in rainwater infiltration as a result of urban development and paving can cause an average stormwater runoff increase of up to 45 percent (USEPA, 2003). This represents an infrastructure maintenance challenge; the lack of adequate SWM causes significant damages to private property and public infrastructure as a result of flooding and sediment transport and accumulation. Regionally, these runoffs transport into binational water bodies a number of pollutants (oil, garbage, fecal matter, sediments, etc.) that cannot be abated through traditional infrastructure. The funds allocated by Mexico's Natural Disaster Agency (FONDEN) to the border, in connection to disasters such as heavy rains and floods, has consistently increased since 2002; by 2014 it amounted to approximately $35 billion pesos (Fig. 5).

These occurrences are not atypical and happen on a regular basis along the U.S. Mexico border region. Excess runoff flows into shared water bodies where rivers either cross the international boundary (e.g. the Colorado and Tijuana Rivers) or serve as the boundary (e.g. the Rio Grande). These watersheds are sources of water supply for many communities. However, unlike other environmental efforts coordinated by USEPA and SEMARNAT, a consistent and coordinated strategy to improve water quality related to stormwater runoff does not exist.

Between 1994and 2017, significant efforts had been made by both governments through the BECC and NADB to eliminate pollution from untreated wastewater discharge through the facilitation and funding of 59 wastewater treatment plants with a capacity of 450 million gallons per day and benefitting 8.5 million residents in both countries (Border Environment Cooperation Commission, 2017). Prior to this successful bilateral cooperation, this wastewater pollution was flowing into shared water bodies. Having addressed the basic needs of treating wastewater in the border region, attention could now be dedicated to other areas impacting water quality in shared watersheds, specifically contamination by stormwater runoff.

Decreased rainfall infiltration, significantly increased runoff, and contamination of aquatic habitats and potable water sources into binational watersheds is expected to only worsen with climate change through intensification of precipitation events, runoff and flooding. Thus, most diagnostic assessments on vulnerability and resilience establish the need for more public spending on stormwater management. With this in mind, and understanding the benefits of using a range of complementary strategies and technologies in the GI field, BECC decided to seriously explore the potential of Green Infrastructure and,

Fig. 1. Map of the U.S. Mexico Border region as defined in the La Paz Agreement. Source: U.S. EPA 2017.

in 2014, the year of its 20th Anniversary, launched the *Border Green Infrastructure Initiative,* the first of its kind in Mexico.

1.3. Green Infrastructure

The term Green Infrastructure (GI) has been used with a range of meanings, associated with the scale at which it is applied. The broadest sense is used by Benedict and McMahon (2006, p. 3), who define it as "an interconnected green space network (including natural areas and features, public and private conservation lands, working lands with conservation values, and other protected open space) that is planned and managed for its natural resource values and for the associated benefits it confers to human populations." Tzoulas et al. (2007, p. 167) also use this broad understanding of GI as "urban and peri-urban green space systems" and (Tzoulas et al., 2007, p. 169) "… all natural, semi-natural and artificial networks of multi-functional ecological systems within, around and between urban areas, at all spatial scales". From a landscape ecology and urban planning perspective, Ahern (2007, p. 267) defines GI as "an emergent planning and design concept that is principally structured by a hybrid hydrological/drainage network, complementing and linking relict green areas with built infrastructure that provides ecological functions." Watershed Management Group (2012, p. 3) focusing more on the urban ecosystem services it provides, defines GI as "… constructed features that use living, natural systems to provide environmental services, such as capturing, cleaning, and infiltrating stormwater; creating wildlife habitat; shading and cooling streets and buildings; and calming traffic." Lancaster (2015, p. 1) defines GI as "living infrastructure … [which] strives to align principles and ecological-systems understanding … [working] *with* and [demonstrating] natural processes within our built environment." On its part (USEPA, 2009), defined GI as "an array of products, technologies, and practices that use natural systems –or engineered systems that mimic natural processes—to enhance overall environmental quality and provide utility services." With this agency's focus on water quality preservation, it has emphasized the stormwater retention and infiltration services provided by GI, even though it recognizes other valuable co-benefits such as improved air quality, reduced energy consumption, urban heat island mitigation, and aesthetic benefits to communities, among others (USEPA, 2009).

Water quality is improved as the soil, mulch and root systems from the green spaces remove contaminants that runoff water collects (Xiao and McPherson, 2011). Rainwater infiltration has the advantage of recharging the groundwater aquifers (Bedan and Clausen, 2009). This also decreases evaporation and improves soil humidity and structure, nutrients, and microorganism development (Watershed Management Group, 2012). Additional vegetation, specifically trees, absorbs

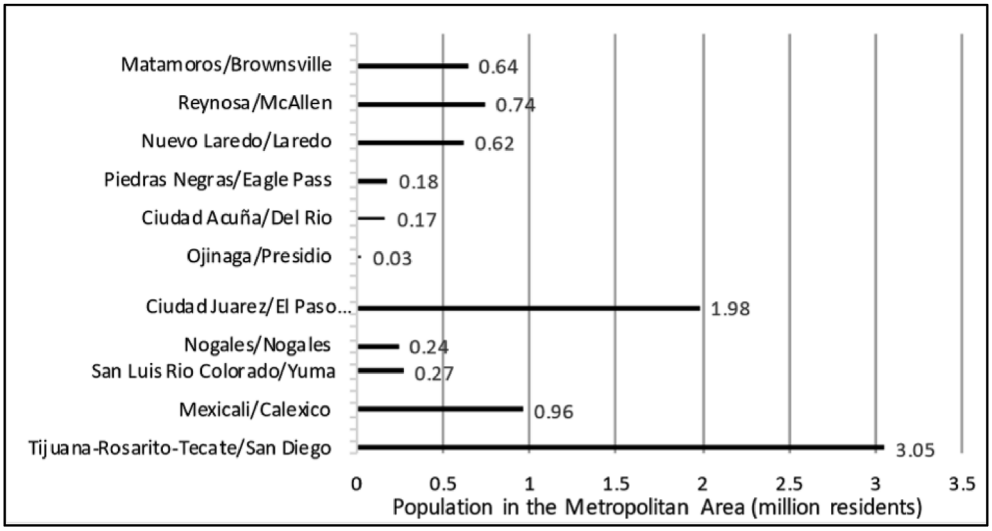

Fig. 2. Population of pairs of U.S.-Mexico border sister cities. Source: Texas Commission on Environmental Quality (2011).

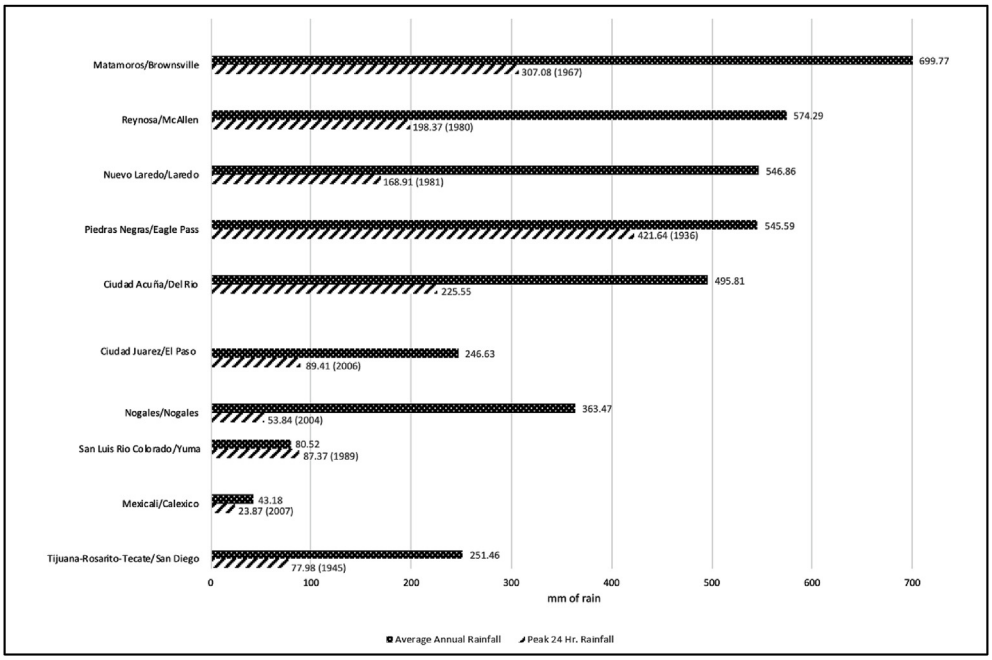

Fig. 3. Precipitation by pairs of sister cities on the U.S.-Mexico Border. Sources: Authors' synthesis with climatological data from Texas A&M (n.d.), Western Regional Climate Center (n.d.-a), Western Regional Climate Center (n.d.-b), Texas State Historical Association (n.d.), and CILA (2006).

suspended particles (Nowak and Heisler, 2010) and removes air pollutants such as nitrogen oxides and volatile organic compounds (Akbari, 2005). Reduced temperatures from the thermic control vegetation has results in less air conditioning use and consequently energy demand (Akbari, 2005). Finally, native vegetation interaction with animal species such as birds, mammals, amphibians, reptiles, and insects, gradually restores food chains and increases biodiversity (Alvey, 2006).

"Green infrastructure is a cost-effective, resilient approach to managing wet weather impacts that provides many community benefits. … [G]reen infrastructure reduces and treats stormwater at its source while delivering environmental, social, and economic benefits" (Matthews et al., 2015) (USEPA, n.d.-b). As described later in this paper, this emphasis on stormwater management, which is also captured in the concepts of Water-Sensitive Urban Design, Low-Impact Development and Sustainable Urban Drainage Systems, would be the one that served as the basis for the BGII.

Management of stormwater in densely populated cities has been traditionally undertaken through "gray infrastructure" involving underground pipes, concrete channels, pumps, and detention ponds to manage peak flows, reducing flooding and contact with the public by collecting and moving the polluted water away from risk areas. Green Infrastructure promotes the use of vegetation, soil, and natural processes to slow the velocity of water flow and recover the capacity of

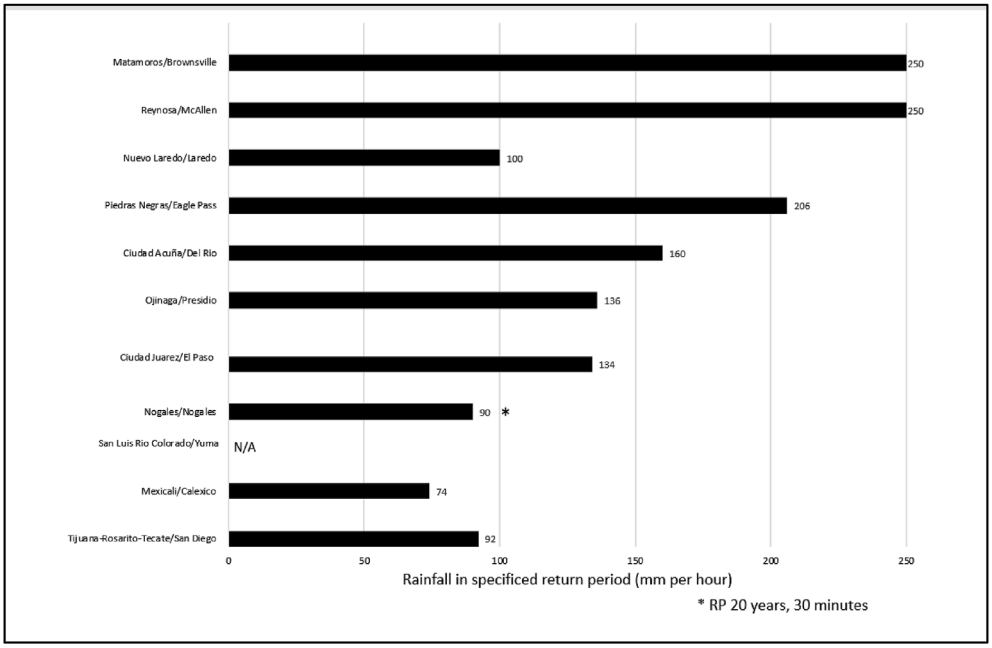

Fig. 4. Precipitation for Return Period 10 years, 5 min, by pairs of sister cities on the U.S.-Mexico Border. Sources: Authors' synthesis with climatological data from Texas A&M (n.d.), Western Regional Climate Center (n.d.-a), Western Regional Climate Center (n.d.-b), Texas State Historical Association (n.d.), and CILA (2006).

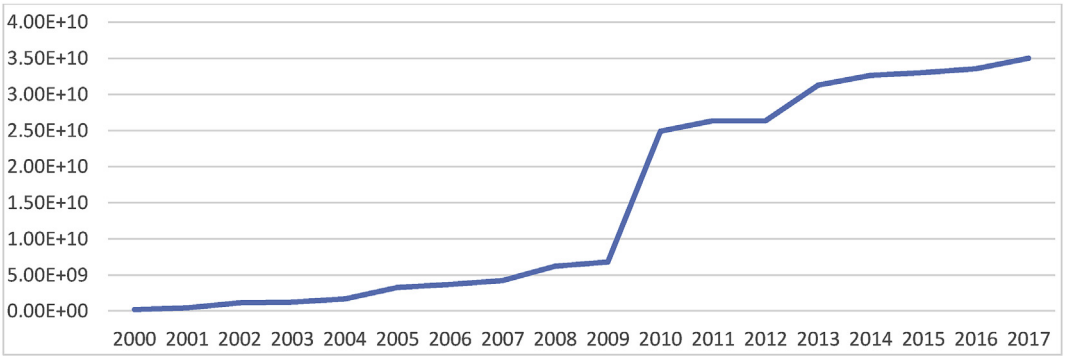

Fig. 5. Accumulated Federal Hydrometeorological Disaster Reconstruction Funds for Border Mexican States. Source: Authors' synthesis with data from Mexico's Natural Disaster Fund (FONDEN Mexico's Natural Disaster Agency, 2017).

native ecosystems to reproduce the natural water cycle, thus reducing the risk of flooding. Strategies include: structural interventions along roadways to increase vegetation in medians and sidewalks, creation of green corridors, restoration of rivers/canals, green roofs, and permeable pavements (Watershed Management Group, 2012).

All of these strategies have a common goal of slowing water flow and increasing infiltration by capturing rainwater where it falls in the city and utilizing it as a resource for (preferably native) vegetation by dispersing it in green spaces along medians and sidewalks with rain gardens. These actions help to: a) reduce runoffs associated to flood risk, b) lessen the vulnerability to droughts by recharging the aquifers and reducing the use of potable water for irrigation, c) protect water quality through absorption of heavy metals and other contaminants d) reduce sediment entrainment and silting in reservoirs and other water and wastewater infrastructure, e) improve air quality through additional green spaces, f) involve the community in actions that are affected by large infrastructure projects and increase awareness and conservation of natural resources and biodiversity (Watershed Management Group, 2012).

Green Infrastructure is now recognized as a strategy that reduces the amount of investments required for traditional gray stormwater infrastructure projects and advances the integration of the social fabric by recovering public areas and environmental services (USEPA, n.d.-a), (European Commission Environment, 2016), (Kettunen, 2011). This is particularly important in view of the ever-limited resources available to municipalities for building and maintaining urban infrastructure and the urgent need to move towards greater resilience as a climate change adaptation strategy.

1.4. BECC's Border Green Infrastructure Initiative

1.4.1. Beginnings

Awareness of GI at the organization began when BECC General Manager was invited as a commentator to a panel in a Regional Green Infrastructure Forum organized in Tijuana, Baja California, by El Colegio de la Frontera Norte and the Universidad Autónoma de Baja California in November 2013. The General Management was so impressed with the concept of GI and its successful implementation in arid environments that they wanted to reproduce this type of forum more specifically focused for the practitioner level and expand to include all of the border cities, states and relevant decision-makers to learn about Green Infrastructure. Thus, in early 2014 BECC decided to begin the planning of its First Border Green Infrastructure Forum (BGIF), which took place in Ciudad Juárez, Mexico, in September 2014.

The first BGIF covered three dimensions of GI: 1) the technical aspects, 2) air quality and health benefits, and 3) associated economic development. The Forum aimed to showcase to local decision-makers and professionals ready-to-apply GI strategies and technologies that could be implemented in border communities in the short and medium term, bringing speakers with hands-on experience in success stories relevant to the border region. The main audience were professionals in fields related to infrastructure design, development and maintenance, public officials from all three levels of government, as well as academics, non-profit organizations and the general public.

The 2014 conference included speakers with extensive experience in the application of GI in cities such as Tucson, Phoenix, and Philadelphia. All of these cities had found a positive benefit-cost ratio and had experience moving GI policies through the city council and agency processes. Additionally, three researchers were included that studied health effects and air pollution removal facilitated by green spaces. Air pollution related to particulate matter is also a challenge for many border communities. Participants surpassed 300 from all ten border states from both countries. A large component of the investment in the Forum were participant travel and lodging costs, funded by EPA's Border 2020 program. To further facilitate participation, the event was web-streamed live and all conference presentations and videos were uploaded into a website that is still available today (http://www.becc.org/page/border-green-infrastructure-forum-ivmaterials).

The principal themes that served as the model for future conferences and foundation for the BGII were the following:

- Engineers needed to speak to engineers. This element was fundamental as it lent credibility to the technical aspects of GI design.
- Public health was a priority for many cities. Understanding the role of green spaces in contributing to a cleaner environment that would improve public health was important.
- Appropriate municipal ordinances based on design guideless were a requirement to ensure consistency across the competitive bid process and a fair regulatory environment.
- An understanding of the potential cost savings and/or economic development that could be achieved with GI would convince elected officials of requiring GI in new subdivision development, new roads, and rehabilitation of existing roads.
- Utilizing Tucson, Arizona as a relevant case study was important as it provided a relatable, geographically and hydrologically, recent example of the application of GI. The success of Tucson was based on support from an important local non-profit organization, Watershed Management Group (WMG), being championed by a city council member, accepted by the engineering community, and the development of relevant municipal ordinances and design guidelines. The process utilized to gain acceptance as an established practice could serve as a blueprint for other communities.

The model utilized by BECC for introducing GI to Mexican border communities consisted of advancing five strategic areas that served as building blocks for municipalities and states to develop and implement a paradigm shift in the design and implementation of urban infrastructure for enhanced stormwater management.

1.4.2. Chronology

The success of the first Forum led BECC to begin the design of a more full blown strategy at the end of 2014 and beginning of 2015. It was decided that applications of GI in road pavement projects for municipalities in Mexico would yield the most benefit since poor drainage design reduced pavement life due to stagnating water. Also, Mexican communities tended to have fewer green spaces; thus GI in roadways presented a unique opportunity to introduce additional green spaces along medians, sidewalks, and linear parks without additional potable water irrigation, as well as lower construction costs, since less concrete was required for sidewalks and medians.

The strategic lines of action would ultimately be: Capacity Building, Technical Tools, Legal Framework, Pilot Projects and Strategic Partnerships, which are described below:

- **Capacity Building**: Build awareness and knowledge through forums, webcasts, and an interactive website. Develop hands-on experience with professionals through training.
- **Development of Technical Tools.** Develop guidelines to incorporate best practices and encourage innovation in construction techniques for roadways, sidewalks, mediums, parks, parking lots that promote transform public spaces into water recharge and recreation areas with native vegetation.
- **Legal Framework.** Provide a legal framework, including state laws and municipal regulations, that provide for GI in the housing and commercial sectors, new roads, and rehabilitation of existing urban roadways.
- **Pilot Projects**: Increase awareness amongst stakeholders through the implementation and maintenance of beautiful and effective demonstration sites, which will allow residents to experience firsthand GI and its benefits.
- **Strategic Partnerships:** Create political will through identifying champions in key positions of influence at the federal, state, and local levels as well as through professional organizations and academia.

The Second BGIF took place in May 2015, in Tucson, Arizona, with 14 panelists and over 300 participants from all 10 border states. This Forum included site visits in Tucson to successful neighborhood, institutional and city-level GI projects and initiated a collaboration with the local organization WMG, as well as the presentation of BECC-funded preliminary analyses of how the Mexican Federal, State and Municipal legal framework could integrate GI into urban planning and stormwater regulations. Momentum was building among local and state government participants, who were encouraged and inspired by what they had heard and seen during the Forums. BECC agreed to fund what would be the first hands-on training and pilot project intervention in a 100-m median in the City of San Luis Río Colorado, Sonora. A series of BECC-funded hands-on training workshops in many other border states followed in 2015 and 2016. Other types of workshops also took place, such as a 10-session course on GI's potential to stimulate tourism, offered in Ciudad Juarez, Chihuahua, in 2015, with attendees from local government, academia and private sector developers.

By 2016, BECC was actively working in all strategic lines of the BGII. On the Capacity Building front, in addition to continuing with an annual BGIF and training workshops, BECC began sending Mexican planning professionals, along with some of its own staff, to Rainwater Harvesting Certification courses offered by WMG, in Tucson, AZ. On the Legal Framework Analysis front, BECC contracted a Mexican law firm to draft legal instruments that would allow three border municipalities (Nogales, Tijuana and Ciudad Juárez) to incorporate GI concepts into their legal framework. BECC served as a liaison with the municipalities to incorporate feedback to the legal drafts, as well as to assist the municipalities in moving the proposed regulations through their administrative and city council processes. Also a great number of activities related to technical toolset and pilot projects took place, with funding allocated to hydrological modeling and runoff water quality improvement studies on both sides of the border as well as pilot GI projects in Mexican border cities. These studies and projects were funded by through technical assistance and USEPA's Border 2020 funds.

In 2017, the last year of BECC's BGII program and the executive management which championed it, two BGIF's were held, one in Hermosillo, Sonora in May and the other in Brownsville, Texas in October. Rainwater Harvesting workshops and certifications continued, and several pilot projects and legal and technical studies initiated in 2016 concluded. In the same year, two of the largest studies were contracted including the inclusion of GI design in a city-wide paving project Hermosillo, Sonora and a binational stormwater management masterplan for Douglas, Arizona and Agua Prieta, Sonora which explored the use of both gray and GI. This represented the first time the BECC had been able to move beyond the pilot study phase and integrate GI into its normal activities. Finally, in 2017 BECC contracted the Planning Institute of Hermosillo to develop a manual with guidelines for GI design adapted to the Mexican planning context. This was the first of its kind in Mexico and was envisioned to assist filling a technical gap and assist local communities in updating their city planning efforts and design standards for construction or rehabilitation of roads (IMPLAN de Hermosillo, 2016).

As was mentioned, the fifth strategic pillar of the BGII was the Development of Strategic Partnerships. In terms of federal partners, EPA and SEMARNAT were natural partners of BECC since both environmental agencies sat on the organization's Board of Directors. EPA already had a Green Infrastructure Program, so needed little convincing to support the BGII through its Border 2020 funds, managed by EPA and SEMARNAT through BECC. Mexico's National Water Commission (CONAGUA) was the next important partner to establish.

Overall, the federal relationship with Mexican authorities served to educate them on the topic, and earnest interest was seen but ultimately there was no clear understanding on which agency could have authority on this topic. More interest was found at the state and local levels.

At the State and City levels, effective partnerships were developed with the states of Sonora and Coahuila, and the cities of Hermosillo, Nogales, and Ciudad Juárez.

1.5. Inputs, outputs, and outcomes (results)

The primary input for this initiative consisted of four BECC staff members (a 2 full-time equivalent), two outsourced expert advisors that functioned as an extension of staff on an as-needed basis, and funding from both BECC's operating budget and EPA's Border 2020 program.

Tables 1–5 summarize the outputs of the BGII. There were 5 BGI forums, in the states of Chihuahua, Arizona, Coahuila, Sonora and Texas, with a total attendance of 711 participants in person, in addition to 241 via webinar; 8 workshops, of which 5 were hands-on training, in Sonora, Coahuila, Chihuahua and Nuevo León, serving 290 participants; and 10 staff from Sonora, Chihuahua, Nuevo León and Tamaulipas local planning institutes or state government were sent to Water Harvesting certification courses in Tucson, AZ (Table 1). This *Capacity Building* component had an investment of close to 240,000 USD during the 4 years (Fig. 6) of the BGII.

In terms of the *Development of Technical Tools*, approximately 630,000 USD were invested to produce and/or print manuals on GI for the Mexican context; develop modeling tools for GI; test various porous pavement materials; develop a stormwater master plan for Douglas, AZ-Agua Prieta, Sonora with green and gray infrastructure recommendations; and produce a GI master plan for Hermosillo, Sonora along with the inclusion of GI in current paving projects (Table 2).

The *Legal Framework* component of the BGII included an analysis of the existing regulatory framework of 6 major Mexican border cities (Tijuana, Nogales, Ciudad Juárez, Ojinaga, Piedras Negras and Nuevo Laredo) and the opportunities of integrating GI, as well as the development of seven specific new codes that integrate GI for Tijuana,

Table 1
Capacity building outputs of BGII 2014–2017.

Activity	Output Achieved
Forums	Conference I: October 2014 in Ciudad Juarez, Chihuahua; 231 participants and 84 via webinar
5 Forums	Conference II: May 2015 in Tucson, Arizona; 200 participants and 113 via webinar
711 participants	Conference III: September 2016 in Arteaga, Coahuila; 150 participants and 44 via webinar
241 via webinar	Conference IV West: May 2017 in Hermosillo, Sonora; 90 participants
	Conference IV East: October 2017 in Brownsville, Texas; 40 participants
Hands-on-training workshops	September 2015 for San Luis Rio Colorado, Sonora; 45 participants
5 workshops	November 2015 for the State of Coahuila; 73 participants
290 participants	December 2015 for the State of Coahuila; 40 participants
	November 2016 for the State of Sonora; 60 participants
	November 2017 for the state of Nuevo Leon; 72 participants
Other workshops	September through November 2015 for Ciudad Juarez; GI and Tourism Seminar; 95 participants
3 workshops	September 2016; Nuevo Leon Construction sector; 38 participants
170 participants	September 26, 2016 for state of Nuevo Leon officials; 37 participants
Certification on water harvesting in the US for Local Planning	Mar 2016 BECC: 2 staff members and 1 external consultant trained and certified
Institute Staff	Oct 2016 Hermosillo, Sonora Municipal Planning Institute: 2 staff members trained and certified
10 Local Planning staff members, and 3 BECC staff/consultants	Oct 2016 Nogales, Sonora Municipal Planning Institute: 2 staff members trained and certified
	Oct 2016 Ciudad Juarez, Chihuahua Municipal Planning Institute: 2 staff members trained
	Mar 2017 Nuevo Leon State government officials: 2 staff members trained
	Mar 2017 Matamoros, Tamaulipas Municipal Planning Institute: 2 staff members trained
Website	2014–2017 A dynamic website with videos and presentation materials to disseminate materials and
Completed in-house	products as they are being generated.

Nogales and Ciudad Juárez (Table 3). This part of the BGII received an approximate investment of 65,000 USD.

Finally, it was important to develop pilot projects that would demonstrate to local communities and decision-makers how GI works and its true benefits. With an investment of 145,000 USD, 6 pilot projects were built in San Luis Río Colorado and Nogales, Sonora; Ciudad Juárez, Chihuahua; and Saltillo and Ramos Arizpe, Coahuila, in most cases with the involvement of local communities and/or municipal staff who also received basic training (Table 4).

The investment in the strategic lines of action, on a yearly basis is synthesized in Figs. 7 and 8. One can observe a clear and general upwardly trend in the investment throughout the period, the role of capacity building annually, and culmination of the program with the development of technical tools and pilot projects.

1.5.1. Outcomes

Much was produced and contracted during the 4 years of the BGII, as described above, but of interest is also what the outcomes of those actions and investments were as well as how the actions have fared since the end of the BGII. In addition to a wealth of press coverage of GI conferences, workshops and demonstration projects throughout the region and an active conversation having been developed among many stakeholder groups in the region, there were important outcomes in terms of champions and developments in various states and cities.

1.5.2. Champions

One notable impact of the Forums was the emergence of champions among decision-makers who were first exposed to the concept and the new stormwater management paradigm of GI. The passive, regenerative nature and multi-functionality and co-benefits of GI were too hard to ignore. In her comments at the First Regional Green Infrastructure Forum in Tijuana 2013), BECC General Manager had identified the importance of the existence of a champion of the concept to promote it in various contexts, and she ultimately became a champion herself by beginning the BGII. Likewise, at BECC's first BGIF, the Secretary of the Environment for the State of Coahuila and the Directors of Hermosillo's and Nogales' Planning Institutes themselves became champions, strongly promoting the development of GI concepts, projects, regulations and technical tools in their own areas of influence during the 2014–2017 period. Academics as well as local government and non-profit organization staff also promoted the concept, so that the objective of the Forums of familiarizing different stakeholder groups with GI was ultimately effective. One academic, who had participated in several BGII activities and later became the Executive Director of the State Central Water Utility of Chihuahua, included an important GI component in the Ciudad Juárez stormwater infrastructure design in 2018 and became a champion for the state.

1.5.3. Developments in states and various cities

BECC worked closely with all Mexican border state governments during the BGII, and the ones which responded most successfully from the beginning were the States of Sonora, Coahuila, and subsequently Chihuahua. These were states where champions had emerged but also further supported the effort by engaging the municipalities within their

Table 2
Technical tools outputs of BGII 2014–2017.

Activity	Output Achieved
Technical Design GI Guidelines Manual	2017 Green Infrastructure Technical Design Guidelines Manual for border municipalities in Mexico
Watershed Management Group GI Spanish version Manual	2015 Printing of 500 copies
Hydrological modeling and opportunities for Green Infrastructure in the “Tapioca” micro-watershed in Ciudad Juarez, Chihuahua.	2015 Developed practical methodology to characterize urban watersheds
Assessment of flood mitigation alternatives, including gray and green infrastructure for the Douglas, Arizona-Agua Prieta, Sonora region	2017 Develop hydrologic model for transboundary washes for storm events and propose location of LID and GI to mitigate urban runoff
Modeling tool for GI stormwater detention requirement in the Lower Rio Grande Valley	2017 A planning/designing tool to reduce flooding and promote the compliance of runoff discharges into surface water bodies
Analysis of ideal bioswale porous material for south Texas stormwater management	2017 From the 5 options tested, pumice was the best locally available porous material for rainwater infiltration (other materials include manufactured sand, recycled glass sand and conventional sand)

Table 3
Legal framework outputs of BGII 2014–2017.

Activity	Output Achieved
Incorporation of GI concepts onto legal framework in Nogales, Sonora	2017 Three (3) legal instruments proposal with the incorporation of GI
Incorporation of GI concepts onto legal framework in Tijuana, Baja California	2017 Three (3) legal instruments proposal with the incorporation of GI
Incorporation of GI concepts onto legal framework in Ciudad Juarez, Chihuahua	2017 One (1) legal instrument modification proposal with GI concepts

respective jurisdictions.

1.5.4. Sonora

In May of 2017, the state of Sonora modified two of its state laws to include GI concepts: the State of Sonora's Law Ecological Equilibrium and Environmental Protection, and the State of Sonora's Law on Land-use Planning and Urban Development (*Ley del Equilibrio Ecológico y la Protección al Ambiente del Estado de Sonora and Ley de Ordenamiento Territorial y Desarrollo Urbano del Estado de Sonora*, respectively) (Gobierno del Estado de Sonora, 2017). In the former, economic and tax incentives were defined for actions leading to water saving, sustainable use and pollution prevention, which include GI. Under the latter, GI guidelines were defined as mandatory in urban development as a measure to generate urban resilience in the context of Climate Change.

At the city level, in February 2018, Nogales published its Urban Development Program (Gobierno del Estado de Sonora, 2018a), which included several references to the Green Infrastructure Technical Design Guidelines Manual funded by BECC. This Program is the basis of other laws, regulations and ordinances, such as the land-use planning, the building and the GI codes. The new municipal codes have not yet been completed due to resource restrictions, with exception of the native plant palette, which will be part of the future GI code.

In Hermosillo, the City government and the Planning Institute developed and published the GI Technical Norm and the native plant palette in September 2018. This technical norm establishes the requirements, criteria, guidelines and technical characteristics for the implementation of GI in public and private development within the City of Hermosillo. It provides guidance to incorporate GI techniques for the development of streets, medians, sidewalks, public parks and green areas, as well as private residential development. The Program for Stormwater Management and GI design is expected to be concluded by early 2019. The construction of the first section of the Metropolitan Park, with GI components, began in mid-2018. It also created an ongoing Adopt-a-Median program where the private sector can provide funds to upgrade medians and sidewalks to include GI with native vegetation (Gobierno del Estado de Sonora, 2018b).

Three pilot projects were funded through BECC in this state:

1) Green infrastructure project for sediment control in DIF Park in Nogales, Sonora.

A 5,000 m^2 rain park was built with 937 m^3 infiltration capacity. The project involved 25 volunteers and 70 plant elements were planted. With an annual rainfall of 334 mm, the volume of sediment intercepted from street runoff was 1.74 m^3. These results are very valuable for a city that has many flooding problems and a high sediment load. Through this project, over 500 people were familiarized and/or trained in GI. Eighty eight professionals took a GI 2-day training course and 15 professionals received a two-day training in native plants and nursery management. Staff from the City Government, the Municipal Planning Institute and a local non-profit organization was heavily involved and the local Architecture and Engineer Colleges participated to a lesser degree. This large local involvement increased community capacity to identify GI solutions for reducing sediment and flooding impacts downstream. Stakeholders from Nogales, who had benefitted from this experience were instrumental in drafting the 2017 state-level laws that included GI.

Table 5
Partnerships outputs of BGII 2014–2017.

Activity	Output Achieved
Outreach to federal/state/local partners	EPA CONAGUA, SEDATU Mexican Border State Goverments Local Planning Institutes

2) Green infrastructure demonstration project in the Instituto Tecnológico de Nogales and capacity building events.

A passive rainwater harvesting project was built with up to 1965 m^3 of annual rainwater harvesting capacity and the participation of 50 students and staff volunteers. The volume of sediment and trash that did not reach natural watercourses or accumulate in the streets was measured at 654 m^3. Over 220 people received basic GI instruction. In addition three more rainwater harvesting demonstration sites were developed: an active GI system in the Planning Institute building, a rain garden at the Nogales Municipal High School, and an erosion control project at a sports field. The blueprints for all projects are of public domain.

3) Median in San Luis Río Colorado

This was the first physical intervention of BECC within the BGII. It consisted of 100 m of median retrofitting to serve as stormwater capture system along an important avenue in the city. The intervention took place on September 11, 2015, with the participation of over 80 people, the mayor and other important city officials. It received much press coverage. However, the effort was ultimately abandoned. We speculate that while it generated some excitement, it was an isolated effort and not part of an overall approach to adopting GI city-wide. Here the mayor fully supported and engaged in the effort, but with the change in

Table 4
Pilot project outputs of BGII 2014–2017.

Activity	Output Achieved
Border 2020 Program	2017 Green infrastructure project for sediment control in DIF park in Nogales, Sonora 2016 Green infrastructure demonstrative project in Tecnológico de Nogales and capacity building events 2017 Green Infrastructure in Public Areas of Valle del Sol in Ciudad Juárez, Chihuahua.
Technical Assistance Program	2015,100 linear meters of median in front of the Technological of San Luis Rio Colorado, Sonora 2015 Four infiltration water harvesting basins implemented in a public linear park in Saltillo, Coahuila 2015 GI project in public park in Ramos Arizpe, Coahuila

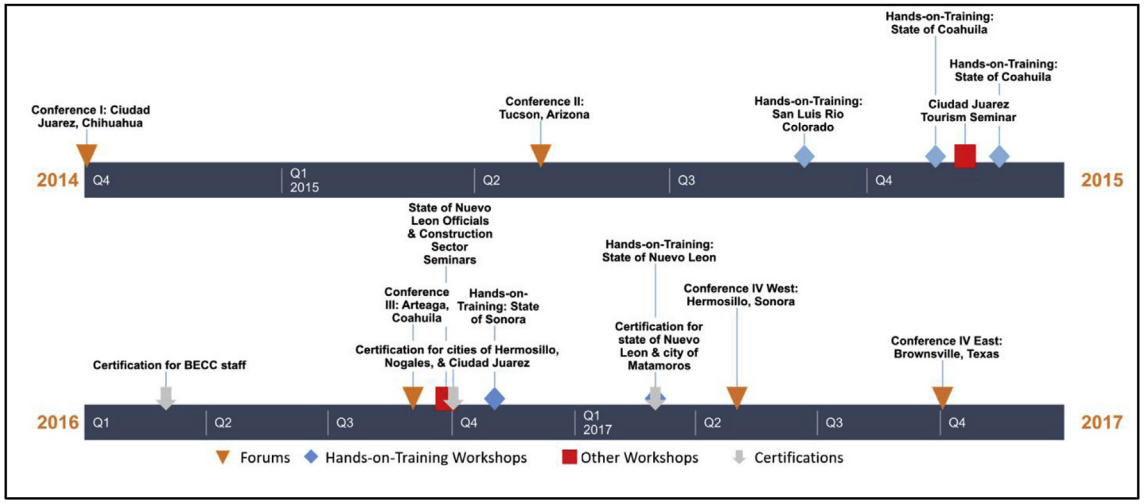

Fig. 6. Capacity building timeline of BGII 2014–2017.

administration after municipal elections and the lack of a champion to further conduct follow-up through its municipal code process, the effort was discontinued.

1.5.5. Coahuila

The state of Coahuila promoted the training of Parks staff from most municipalities in GI techniques and facilitated the introduction of GI in various state and municipal parks to maximize rainwater capture and infiltration on site.

1.5.6. Chihuahua

In 2018, the State Central Water Utility of Chihuahua contracted the design of stormwater management infrastructure for Ciudad Juárez, Mexico, which included 16% of the funds for green infrastructure design. To dedicate this amount of stormwater infrastructure investment in GI was quite innovative in the Mexican context and an impressive outcome of the BGII. At the city level, the urban development commission of the Ciudad Juárez City Council held a series of taskforce meetings in 2018, with representatives from government, academia, and non-profit organizations, to identify how to include GI guidelines in the codes and regulations for urban development for that city. The meetings were discontinued due to local elections, but the concept of GI has a broader permeability among local stakeholders. By late 2018, the state and city project to revamp the Chamizal Park in Ciudad Juárez has included several GI proposals formulated by a wide range of stakeholders.

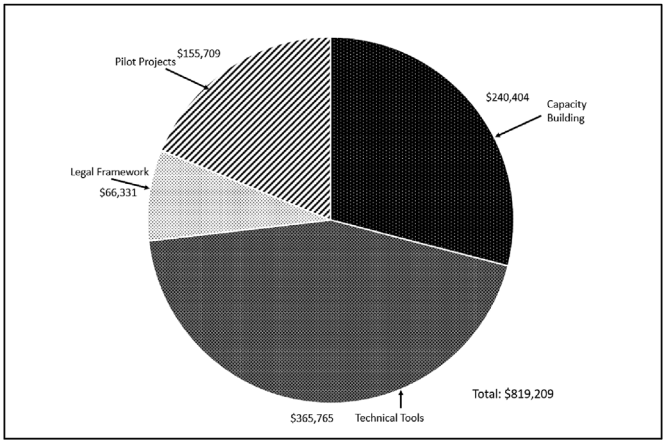

Fig. 8. Total BGII Investment by strategic line of action.

Ciudad Juárez was also the recipient of Border2020 funds for the pilot project Green Infrastructure in Public Areas of Valle del Sol in Ciudad Juárez, Chihuahua. In 2016, a park in the "Valle del Sol" sector of the city was retrofitted with rainwater harvesting features, which

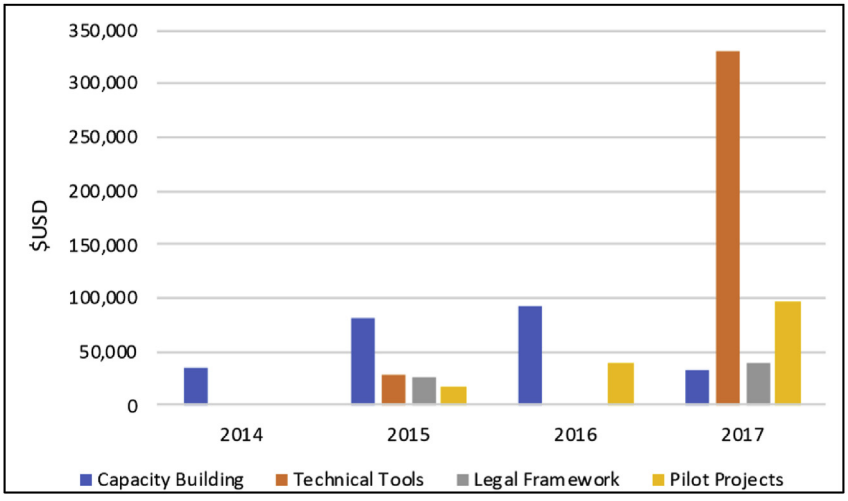

Fig. 7. Yearly BGII investment by strategic line of action.

collected stormwater runoff from two adjoining streets. The park was reforested with 96 native plant elements (trees, bushes and flowers). During the first year, 1789 m^3 of stormwater were harvested and flooding along the adjoining street sections was eliminated. In addition, social use of the park was increased, children's reading workshops, neighborhood swap meets, walks and exercises were developed, and citizen participation in space conservation was increased.

1.5.7. Tamaulipas

As a result of municipal staff participation in Rainwater Harvesting training and certification courses, the Municipality created the Directorate of Sustainable Planning and Green Infrastructure.

The BGII was not equally successful in all states and cities along the US-Mexico border. Baja California and Nuevo León did not adopt or implement any major GI initiative, either on the ground or within the legal framework during the 2014–2017 period. This was likely due to a series of factors. The absence of a local champion was a critical element; changes in administration affected the level of impact the BGII had on decision-makers; sometimes, some decision-makers were simply less interested in the topic; and it is also true that four years of BGII efforts do not represent enough time to effect change in all cases.

In terms of the regulatory framework, Mexico's national-level General Law of Urban Sustainable Development changed in 2016 and established that by December 2017 all states had to complete the appropriate modifications to their respective legislation. This meant that cities were constrained to pass their new GI-friendly Urban Development codes and regulations until their states completed their own state-level modifications to comply with the General Law. This affected Ciudad Juárez, for example, where GI had been integrated into the new proposed Urban Sustainable Development code, but could not be officially approved until the state published its own new Urban Development law (which had not yet happened by 2018). In the case of the city of Tijuana, changes in local and state government in 2016, caused a break in the political process leading up to legal modifications, which was not overcome by the next year when BECC's BGII ended.

1.6. General lessons learned

From the four-year BECC experience, and the knowledge generated through the specific efforts in various cities and states, we have derived a set of lessons learned for the integration of GI into public policy and practice, described below.

1.6.1. Institutional change

It usually takes at least two to three budget cycles to integrate new concepts or practices into governmental agencies. Any organization seeking to promote new paradigms and investments must keep this in mind. The presence of a strong and high-level champion in an agency can accelerate this process.

It is essential to very concretely and specifically identify the way in which GI fits into the mandate of each agency. In the case of EPA and BECC, improved stormwater management and improved surface water quality were the motivators. For CONAGUA, the maintenance of urban flood protection and binational hydraulic infrastructure seemed more important. For SEDATU, the interest in GI seemed more associated to urban parks and urban greening. Thus, the marketing of GI to each government agency needs to be concretely and specifically articulated to their specific mandates.

States and cities also provide an opportunity to implement a change in paradigm as they experience with more immediacy the repercussions of flooding, lack of green spaces, among others. In Mexico, cities rely heavily on states for funding of municipal infrastructure therefore state involvement was very effective in assisting in a paradigm shift. Additionally, the creation of tools needed to facilitate this change is important, especially the legal framework and design guidelines needed to update state laws and municipal construction codes.

Sometimes it is important that a new concept arrive to an agency from different sources. BECC was relatively unsuccessful at "selling" GI to SEDATU, or getting SEDATU on board the BGII. Yet the German International Cooperation Agency (GIZ) was later able to interest the agency in the concept, presumably because it had a better suited relationship with SEDATU and approached the topic from a vantage point –urban development—that was more clearly in line with the agency's mandate than BECC's approach.

1.6.2. Promotion of a paradigm shift in stormwater management

BECC was uniquely positioned to promote GI among federal, state and local government partners along the Mexican border. It had a two-decade long relationship with many of these agencies and governments. It had a history of providing financial assistance for environmental infrastructure. It represented a high-status binational organization that commanded respect and attention, a wide network of partners on both sides of the US-Mexico border, an extensive experience involving a wide range of stakeholders and access to funds to build capacity, develop legal and technical tools, and implement pilot projects. All of these characteristics made BECC ideal to promote the paradigm-shifting concept of GI.

The four-pronged approach used by BECC to promote the GI concept proved effective and powerful. Capacity-building, the development of technical tools, legal framework analysis, pilot projects and the development of partnerships complemented each other and were far-reaching. Because different stakeholders adopted the GI concept with varying levels of enthusiasm (depending on the political, administrative, social and environmental specificities of each site), the broad range of partners, at the federal, state and local levels, gave the BGII robustness. In some instances the champions came from the local level and brought changes to the state level, such as in Sonora. In other cases, a state champion permeated the effect towards the municipalities, like in Coahuila. So reaching out to partners in all levels represented an effective strategy to maximize response rates.

1.6.3. Implementation

In addition to awareness-raising among developers and decision-makers, the integration of GI into the federal, state and local *legal framework* is crucial for its adoption by local authorities and developers, and also for the channeling of financial resources for its implementation. In Mexico, the areas of regulations most related to GI implementation are urban development, water and stormwater management and environmental legal frameworks. Local, state and federal laws may need modifications. Technical guidelines proved essential for the integration of GI into the legal framework. Without them it is not possible to set new standards to be observed.

Training for GI implementation is critical for appropriate design and correct-functioning of the interventions. We observed cases where well-intentioned efforts were invested in building GI interventions, but the lack of experience and training led to design mistakes which jeopardized the performance and functionality of the water harvesting basins. The design and construction of road-side water harvesting features is not "rocket-science", but it does involve specific skills and experience in surface and subsurface water movement, sediment transport and erosion processes, among others. Poorly functioning GI interventions will give bad reputation to a technology that is new for people, thus it is of utmost importance to avoid poorly functioning GI interventions.

Along the same lines, *continued maintenance* is indispensable for the successful operation of GI. This can definitely not be taken for granted. For aesthetic and operational purposes, there are basic maintenance tasks that need to be conducted on a regular basis. In the case of Mexican cities which can have deficient solid waste management, it is very common for a significant amount of trash to accumulate in rainwater harvesting basins. This trash needs to be removed regularly. High sediment load in cities like Nogales and Ciudad Juarez require wide

inlets for the water-harvesting basins that will not clog with excess sediment. Alternatively a regular removal of accumulated wind and water-borne sediment is necessary. In terms of vegetation, native plants require less maintenance than non-native vegetation, but some weeding, pruning and mulch management must be carried out. In addition, Parks Department staff needs to be trained to identify and preserve native vegetation. In several sites (both in Mexico and the U.S.) park staff have cut native plants from water harvesting projects in the belief that they were undesirable weeds.

Addressing these issues requires continued communication, *follow-up* and training with municipal decision-making and operational staff. This is particularly true for Mexican cities which tend to have relatively high staff turn-over due to short local government administrative terms. Also, *decision-maker buy-in* of the concept is essential to maintain funding resources for implementation and maintenance of GI. This was evident in two contrasting cases. In Hermosillo, the mayor was convinced of GI and maintained institutional support for its implementation even when the Planning Institute leadership (the original champion in that city) changed, whereas the San Luis Rio Colorado GI efforts dwindled because of lack of commitment and interest of its newly elected mayor. Finally *involvement and ownership by the local communities* is also essential in keeping local public agencies accountable for maintenance in GI. It is not easy to maintain community interest in keeping GI interventions clean and functional, but continued training and regular meetings may help with this.

1.7. The way forward

There has been gaining momentum in Mexico on the use of GI for stormwater management. We would like to highlight a couple of those more recent initiatives in Mexico that have expanded upon BECC's efforts.

The German International Cooperation Agency (GIZ), through its Climate Protection and Urban Development Program, is working with Mexico on the development of public policy for the implementation of GI in Mexican cities. The main partners have been SEMARNAT, SEDATU[1] and Mexico's National Autonomous University (UNAM). They have engaged in several activities, including the production of a catalog of ongoing efforts related to GI in Mexico and the creation of a GI website which will serve as a platform for hosting useful materials and exchanging GI experience among local communities. In March of 2018, GIZ, SEMARNAT and SEDATUconvened an International Conference on GI and Climate Change. More than 70 attendees included participants from international organizations, academics form Mexico and Latin America, Mexican Federal agencies and the representation of several Mexican cities, as well as private and non-profit sectors. After the event, GIZ, SEDATU and SEMARNAT published the *Roadmap for the Implementation of Green Infrastructure as a Climate Change Mitigation and Adaptation Strategy in Mexican Cities* (Quiroz Benitez, 2018), which includes a detailed strategy of 22 actions along four thematic lines: water, mobility, public space and biodiversity. The thematic line of water is in line with the focus on adequate stormwater management that BECC had been promoting. BECC's BGII efforts have been integrated into the GIZ initiative, both through the participation of the city of Hermosillo –a champion created through the BECC BGII–, presenting its Adopt-a-Median program, in the event, and the inclusion of the 2017 Green Infrastructure Technical Design Guidelines Manual for Border Municipalities, funded by the BGII, in the resources section of the Roadmap document.

In November of 2018, the World Resources Institute (WRI) Ross Center, located in Mexico City, launched a call for applications for a GI Program for Mexican Cities (WRI Ross Center, 2018). The program included funding and technical assistance for the development of a project-specific business plan including project scope definition, funding sources identification, financial modeling, and a critical path schedule for implementation. The business plan would ultimately be promoted among investors for potential funding. In April 2019 WRI selected five projects for assistance that include green infrastructure for stormwater management in public spaces in Puebla, Hermosillo, Cancún, Mérida, and Mexico City (WRI Ross Center, 2019).

[1] Mexico's Federal Urban, Territorial and Agrarian Development Secretariat.

2. Conclusions

Cities in Mexico have experienced significant urban sprawl causing an increase in urban runoff due to higher rations of impermeable surfaces, which results in flooding. In four years (2014–2017) and with a modest investment of less than one million USD over the entire period, BECC was able to widely disseminate the concept of GI among state and local stakeholder groups in the Mexican border region and make inroads in a paradigm shift for stormwater management. The focus on pavement and other flooding-related infrastructure projects in BECC's project portfolio led the BGII to focus mostly on GI as a stormwater management strategy, even though it also publicized and communicated the important social and public health co-benefits of GI.

BECC's Border Green Infrastructure Initiative worked along five main strategic lines of action including capacity building through conferences, website, and hands-on training; technical tools to update planning and design standards; legal framework necessary to update state law and municipal codes; pilot projects to visualize results and gain public support; and partnerships with decision makers and advocates. The outputs and outcomes were impressive and continue to flourish in cities like Hermosillo, Nogales, and Ciudad Juarez and states of Chihuahua, Sonora, Tamaulipas, and Coahuila where champions were created through BGII and continue to make progress. Financial support goes a long way to getting new ideas adopted in an agency (through capacity building, technical input development, pilot project implementation), but is not the sole basis of success.

One shortcoming was the lack of a national stormwater permitting process which could incentivize the adoption of GI, as in the United States. However, the new partnerships between SEDATU, SEMARNAT, GIZ and WRI could change this. Other barriers identified were the lack of champions and state or local government changes of administration since continuity is important and several years are necessary to develop the framework and establish the practice. The future of GI promotion in the Mexican border region, and Mexico more broadly, can take elements from the BECC, GIZ, and WRI experiences as well as other local efforts and initiatives. It is encouraging that GIZ, SEMARNAT, SEDATU and WRI have been able to convene a wide range of stakeholders and are integrating experiences on the Mexico-US Border that were initiated by BECC. Hopefully they will be able to further leverage the work done during the BGII.

References

Ahern, J., 2007. Green infrastructure for cities: the spatial dimension. In: Novotny, V.B.P. (Ed.), Cities of the Future: towards Integrated Sustainable Water and Landscape Management. IWA Publishing, London. https://doi.org/10.1016/0017-9310(88)90092-0.

Akbari, H., 2005. Energy Saving Potentials and Air Quality Benefits of Urban Heat Island Mitigation. Retrieved from. https://escholarship.org/uc/item/4qs5f42s.

Alvey, A.A., 2006. Promoting and preserving biodiversity in the urban forest. Urban For. Urban Green. 5 (4), 195–201.

Arellano, B., Roca, J., 2010. Some considerations about the urban sprawl process in Spain and Mexico. In: 50th Anniversary European Congress of the Regional Science Association International, (Jönköping).

Bedan, E.S., Clausen, J.C., 2009. Stormwater runoff quality and quantity from traditional and Low impact development watershed. J. Am. Water Resour. Assoc. 45 (4), 998–1008.

Benedict, M.A., McMahon, E.T., 2006. Green Infrastructure: Linking Landscapes and Communities. Island Press, Washington, DC. https://doi.org/10.1007/s10980-006-9045-7.

Border Environment Cooperation Commission, 2017. U . S . -Mexico Border Water Infrastructure Program Accomplishments. Retrieved from. http://www.becc.org/

uploads/content/images/BEIF-Pipeline-2.pdf.
CILA, 2006. Comisión Internacional de Limites y Aguas entre México y los Estados Unidos Informe Anual 2006. Retrieved from. http://www.sre.gob.mx/cilanorte/images/stories/pdf/2006.pdf.
European Commission Environment, 2016. Green Infrastructure. Retrieved October 12, 2018, from. http://ec.europa.eu/environment/nature/ecosystems/index_en.htm.
FONDEN (Mexico's Natural Disaster Agency), 2017. Recursos autorizados por declaratoria de desastre (Authorized funds for natural disasters). Retrieved June 23, 2018, from. http://www.proteccioncivil.gob.mx/en/ProteccionCivil/Recursos_.
Fukuda-Hayakawa, I., 2010. Planeación urbana en Curitiba. *Quivera*, vol. 12 Revista de Estudios Territoriales.
Gobierno del Estado de Sonora, 2017. Boletín Oficial Tomo CXCIX Número 38 Secc III. Retrieved from. http://www.boletinoficial.sonora.gob.mx/boletin/images/boletinesPdf/2017/mayo/2017CXCIX38III.pdf.
Gobierno del Estado de Sonora, 2018a. Boletín Oficial Tomo CCI Número 16 Secc. VI. Retrieved from. http://www.boletinoficial.sonora.gob.mx/boletin/images/boletinesPdf/2018/febrero/2018CCI16VI.pdf.
Gobierno del Estado de Sonora, 2018b. Boletín Oficial Tomo CCII Número 26 Secc. II. Retrieved from. http://www.boletinoficial.sonora.gob.mx/boletin/images/boletinesPdf/2018/09/2018CCII26II.pdf.
Instituto Municipal de Planeacion Urbana de Hermosillo, 2016. Manual de Lineamientos de Diseño de Infraestructura Verde para Municipios Mexicanos. Hermosillo, Sonora.
Kettunen, M., 2011. Water, Ecosystem Services and Nature: Putting the Green into Green Economy. Retrieved October 12, 2018, from. http://www.worldwaterweek.org/documents/WWW_PDF/2011/Tuesday/T5/Water-and-Green-Frowth-Examing-the-Links/Water-ecosystem-services-and-nature.pdf.
Kiy, R., Wirth, J.D., 1998. Environmental Management on North America's Borders. Environmental History Series, vol. 14.
Lancaster, B., 2013. Rainwater Harvesting for Drylands and beyond, second ed. Rain Source Press, Tucson, Arizona.
Lancaster, B., 2015. An Evoloving Checklist of Strategies to Build Successful Green Infrastructure. Retrieved May 28, 2018, from. https://www.harvestingrainwater.com/2015/05/25/an-evolving-checklist-of-green-infrastructure-capacities-to-develop-and-potential-strategies-to-implement-in-our-communities/.
Lennon, M., Scott, M., 2014. Delivering ecosystems services via spatial planning: reviewing the possibilities and implications of a green infrastructure approach. Town Plan. Rev. 85 (5), 563–587. https://doi.org/10.3828/tpr.2014.35.
Liu, L., Jensen, M.B., 2018. Green infrastructure for sustainable urban water management: practices of five forerunner cities. Cities 74, 126–133. November 2017. https://doi.org/10.1016/j.cities.2017.11.013.
Matthews, T., Lo, A.Y., Byrne, J.A., 2015. Reconceptualizing green infrastructure for climate change adaptation: barriers to adoption and drivers for uptake by spatial planners. Landsc. Urban Plan. 138, 155–163. https://doi.org/10.1016/j.landurbplan.2015.02.010.
Nowak, D.J., Heisler, G.M., 2010. Air Quality Effects of Urban Trees and Parks. Retrieved from. https://www.nrpa.org/globalassets/research/nowak-heisler-research-paper.pdf.
O'Sullivan, A., 2007. Urban Economics, sixth ed. McGraw-Hill Irwin, New York.
Pauleit, S., Liu, L., Ahern, J., Kazmierczak, A., 2011. Urban ecology:patterns, processes, and applications. In: Handbook of Urban Ecology. Oxford University Press, Oxford, pp. 272–285.
Quiroz Benitez, D.E., 2018. Implementación de Infraestructura Verde como Estrategia Para la Mitigación y Adaptación al Cambio Climático en Ciudades Mexicanas Hoja de Ruta. In: GIZ, S., SEDATU (Eds.), *Foro Internacional Infraestructura Verde Y Cambio Climático*. Mexico City: SEDATU SEMARNAT, and GIZ.
Texas A&M Texas State Climatologist. n.d.. http://climatexas.tamu.edu/products/texas-normals/index.html Retrieved July 1, 2015, from.
Texas Commission on Environmental Quality, 2011. Binational Population Data in Sister Cities along the Rio Grande. Retrieved January 5, 2015, from. https://www.tceq.texas.gov/border/population.html.
Texas State Historical Association and Texas, County Almanac. n.d.. https://texasalmanac.com/texas-towns/search Retrieved July 1, 2015, from.
Tzoulas, K., Korpela, K., Venn, S., Yli-Pelkonen, V., Kaźmierczak, A., Niemela, J., James, P., 2007. Promoting ecosystem and human health in urban areas using Green Infrastructure: a literature review. Landsc. Urban Plan. https://doi.org/10.1016/j.landurbplan.2007.02.001.
USEPA Green Infrastructure Funding Opportunities. n.d.-a. https://www.epa.gov/green-infrastructure/green-infrastructure-funding-opportunities#FundingSource Retrieved May 31, 2018, from.
USEPA What is Green Infrastructure? n.d.-b. https://www.epa.gov/green-infrastructure/what-green-infrastructure Retrieved October 12, 2018, from.
USEPA, 2003. Protecting Water Quality from Urban Runoff. Retrieved from. https://www3.epa.gov/npdes/pubs/nps_urban-facts_final.pdf.
USEPA, 2009. Green Infrastructure: Glossary of Commonly Used Terms. Retrieved October 12, 2018, from. https://ofmpub.epa.gov/sor_internet/registry/termreg/searchandretrieve/glossariesandkeywordlists/search.do?details=&glossaryName=Green Infrastructure_Glossary.
USEPA and SEMARNAT, 2016. Border 2020: US-MEXICO ENVIRONMENTAL PROGRAM State of the Border Region Indicators Interim Report.
Watershed Management Group, 2012. In: MacAdam, J. (Ed.), Green Infrastructure for Southwestern Neighborhoods. Watershed Managment Group, Tucson.
Western Regional Climate Center Arizona Climate Summaries. n.d.-a. https://wrcc.dri.edu/summary/climsmaz.html Retrieved July 1, 2015, from.
Western Regional Climate Center California Climate Summaries. n.d.-b. https://wrcc.dri.edu/summary/climsmca.html Retrieved July 1, 2015, from.
World Resources Insitute Ross Center, 2018. RELEASE: WRI Mexico, Citi Foundation Launch ' TheCityFix Labs Mexico ' to Promote Investment in Green Infrastructure in Mexican Cities. Retrieved from. http://wrirosscities.org/news/release-wri-mexico-citi-foundation-launch-thecityfix-labs-mexico-promote-investment-green.
World Resources Insitute Ross Center, 2019. RELEASE: 7 Sustainable Infrastructure Winners Announced for TheCityFix Labs México. Retrieved from. http://wrirosscities.org/news/release-7-sustainable-infrastructure-winners-announced-thecityfix-labs-mexico.
Xiao, Q., McPherson, E.G., 2011. Performance of engineered soil and trees in a parking lot bioswale. Urban Water J. 241–253.