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George Atisa

Alexis Racelis

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Article

Analysis of Urbanization and Climate Change Effects on Community Resilience in the Rio Grande Valley, South Texas

George Atisa ^{1,*} and Alexis E. Racelis ²

¹ Department of Public Affairs and Security Studies, The University of Texas Rio Grande Valley, 1201 W University Drive, Edinburg, TX 78539, USA

² School of Earth, Environmental, and Marine Sciences, The University of Texas Rio Grande Valley, 1201 W University Drive, Edinburg, TX 78539, USA; alexis.racelis@utrgv.edu

* Correspondence: george.atisa@utrgv.edu

Abstract: Disruptive development events have tested and will continue to test community resilience as people work to balance healthy living, economic growth, and environmental quality. Aspects of urbanization, if not designed and guided by healthy living strategies, convert natural areas into built environments, thus reducing the diversity of plant and animal species that are the foundation of resilience in communities. In this study, we attempted to answer the following question: What are the most effective ways to ensure that ongoing urbanization and climate change do not negatively affect ecological services and community resilience in the Rio Grande Valley (RGV)? The region is experiencing a high urban growth rate and is also one of the poorest regions in Texas. Thus, it has an inadequate capacity to prevent or mitigate climate change-related threats and take advantage of opportunities associated with urbanization. Using qualitative analysis, we consulted existing literature to identify relevant leverage points that can help foster regional resilience capacity. The findings show that there are very strong leverage points that can produce cumulative desired resilience outcomes, but these have not been incorporated into policy and natural systems in the RGV.



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Keywords: urbanization; resilience; health; leverage points; intervention

1. Introduction

Climate change-related threats have been described as transboundary and complex, and preventing them can be extremely challenging in urban areas [1,2]. The transboundary nature and complexity are the results of the unsustainable use and unequal sharing of natural resources, leading to the degradation of various ecosystems that support human and environmental health [3]. Major threats include extreme weather events such as floods, hurricanes, storms, droughts, fires, and heat waves. Climate change will continue to pose threats to urban infrastructure, quality of life, and economic outcomes [1,4]. Urbanizing regions, therefore, should incorporate resilient systems into the urbanization process to prevent or reduce the impacts of climate change.

The Rio Grande Valley (RGV), located in southern Texas along the U.S.–Mexico border and the Gulf of Mexico, is particularly susceptible to threats from climate change. The RGV is considered an agricultural hub of the state and one of the fastest-urbanizing regions in the U.S., where in a short period between the year 2000 and 2010, agricultural land was replaced by urban use at a rate of 46% and is characterized by a matrix of rural and urban environmental features [5–7]. Although urbanization is associated with strong indicators of economic growth, prosperity, and broader connections, ironically, the RGV happens to be one of the poorest in the state [5,7]. The average per capita income is approximately USD 13,500, which is 50% below the national average and ranks near the bottom nationally [5]. Approximately 40% of the population that is 25 years and older have no high school diploma, compared to the national average, which stands at 14% [5]. These conditions

present an inequitably low capacity to invest in more resilient infrastructure, mitigation, and slow adaptation to climate change effects [8].

Urbanization causes changes in land use where natural resources are cleared to pave the way for urban uses, placing great stress on biodiversity and the natural environment [9,10]. Significant population growth and corresponding economic, urbanization, and social and environmental changes have led to declining biodiversity and stressed ecosystem services, thus making the area less resilient and more vulnerable to hazards and other natural shocks [11–13]. The intentional design of a city and the regulations that govern settlements can, however, contribute to the quality of urban living conditions through reduced vulnerabilities [14]. The intentional design includes an understanding of ways to reduce the impacts of climate change, the development of resilient infrastructure, biodiversity protection, and regulated physical development and settlement patterns [15,16].

There are various pathways to achieving intentional design. One such pathway has been described as prioritizing the “right of local, community self-government” and the “rights of nature” over the current approach, where there is often disproportionate and exclusive control over resources and decision-making by the most powerful and wealthy people [17] (p 139). Another such way is the resilience approach advocated by [11], where city stakeholders act holistically, economically, and collaboratively to mitigate both expected and unexpected events. Analyzing European Union resilience policy-making, Ref [18] examined boundary spaces at the interface of science and policy to determine how to operationalize resilience efforts before they are translated into actual policies.

This study was designed to identify leverage points, potential interventions, and strategies to operationalize and implement resilience [19,20]. It also identifies the root causes of resilience failure as well as policies that enable existing systems and infrastructure to remain resilient in the face of climate change impacts. We used the public participation spectrum developed by the International Association of Public Participation (IAP2) to examine organizational and holistic strategies that were designed to operationalize resilience and tested in Canada and France, and adapted to conditions in the RGV [19,21]. Organizational and holistic strategies tie the concept of resilience to the core of the city and the people. These concepts concern the ability of the city and its residents to put preventive measures in place before, during, and after a disruptive event to minimize the negative impacts [19]. The modified spectrum serves as an awareness-raising tool as well as an empowerment tool.

While urbanization increases exposure and vulnerability to extreme events, the concept of resilience remains difficult to transform into tangible tools to mitigate the effects of climate change [12,19]. This study has two objectives: (i) to identify and analyze policy, economic and social tools that can be leveraged to foster resilience in the RGV and (ii) to identify and analyze opportunities that support the development of resilient infrastructure across all sectors in the region. These objectives will help to better understand how to leverage environmental opportunities and challenges, physical infrastructure, location, policy, and natural resources to reduce vulnerabilities associated with land use changes and current business models in the region. Vulnerabilities can be seen in the rising number of colonias in the region and the statewide freeze in the spring of 2021 that knocked out the electric grid and left millions of residents without power, some for days and others for weeks.

These events demonstrate that peri-urban regions such as the RGV that are transitioning from rural to urban suffer from “double exposure” to stress; first, they suffer from urbanization as a process due to the loss of natural resources such as forests and water, and second, they suffer from climate change, which is associated with severe and intense events [10,22]. The transitory nature of land use in the region, the state of existing and new infrastructure, and the economic marginalization of certain groups of people make it difficult to develop resilience approaches across various vulnerabilities [19]. For example, income levels, the quality of housing, settlements in urban centers, preurban areas, and

colonias in unincorporated settlements associated with lack of access to municipal services vary greatly [23].

These variations complicate the definition and application of resilience tools within such a small territory where infrastructure resources, needs, settlements, standards of living, and quality of life differ so drastically different. The operationalization of resilience in this environment requires more data on the drivers of these conditions and a better understanding of why people may want to stay or move away from the current development models, specific drivers of regional and local marginalization, and leverage points to address these difficulties. At the same time, there are no standard approaches to measuring the risks to the environment and natural resources associated with urbanization; developing resilience interventions for specific communities or activities is very difficult [15]. The detailed geographical, social, and economic resilience challenges associated with urbanization are difficult to address, as humans directly control plant diversity, zoning, and the nature of regulations that govern specific resilience outcomes [10]. For these reasons, we collected secondary data on several interventions that have been applied to other parts of the world to generate leverage points that can be used when addressing environmental, economic, and social challenges in the RGV. Various leverage points were developed to provide specific interventions for factors that can help the region mitigate extreme disruptions to its livelihood, natural systems, and infrastructure [24–26].

Urbanization involves the conversion of natural areas and underdeveloped as well as agricultural lands to residential, commercial, and industrial park areas [1,27]. Such conversion is greatly altering the environmental outlook of the RGV through the selection of areas that are settled and paved and those that remain green. Even areas that are left green are carefully reconstructed as people decide which trees and grasses should grow in them. Home ownership gives individuals the right to decide how to use their yards, which ultimately leads to fragmentation. In places such as the RGV that have weak regulatory and zoning rules, developing region-specific resilience frameworks is very difficult. At a deeper level, urbanization outcomes result from the balancing of activities related to green and hard infrastructure, where hard infrastructure is usually preferred [28].

“Resilience is a city’s, community’s or region’s ability to mitigate and prevent the risk of disruption, alleviating potential risks and responding to disruptions in ways that minimize loss or damage to lives, livelihoods, property, infrastructure, economic activities and the environment” [29]. Heinzlefa et al. define resilience as the “ability of populations, territories and infrastructure to develop the resources, skills and capacities needed to best experience a disruptive event in order to limit its negative impacts.” Resilience is also defined as the degree to which natural resources, systems, populations, territories, infrastructure, and institutions can tolerate a disturbance before acquiring or transforming into a new structure [30]. Therefore, as a concept, resilience is about understanding how natural resources, systems, populations, regions, settlements, infrastructure, and institutions respond to disasters [19].

As a strategy, resilience involves the operationalization of the concept into actionable interventions to produce desired and measurable outcomes. In this study, we analyze the transition from the concept to the interventions and, finally, to outcomes and identify the inputs required to produce the desired outcomes for the RGV region. The significance of this study is that we trace resilience from its formulation as a concept to its use as a strategy and finally to the nature and type of interventions that need to be developed and implemented. We also examine resilience as it applies to natural systems, populations in both rural and urban settings, infrastructure, and institutions to design a regional resilience framework that addresses all forms of vulnerability. The majority of the population in the region faces numerous barriers to basic development needs, such as access to education, health care, sufficient income, adequate housing, basic infrastructure, and utility services [25,31]. Therefore, modifying the IAP2 spectrum to gather experiences, policies, and initiatives that have worked elsewhere and present these as knowledge will go a long way toward

empowering communities to participate more effectively in future local resilience and sustainability initiatives.

2. Methods and Data

The RGV occupies the southeastern part of Texas and covers the Starr, Hidalgo, Willacy, and Cameron Counties, with a combined population of 1.4 million people in an area of approximately 4962 square miles. According to the 2020 U.S. Census Bureau, this population represents an increase of approximately 11% from 2010. The population is approximately 92% Hispanic/Latino and approximately 6% white, and the remainder are distributed almost evenly among Black, Native American, Asian and other ethnicities. The Hispanic/Latino population is the fastest-growing ethnic minority group in the U.S., and the RGV has the highest concentration of Hispanic/Latino residents in the country. Although this number is likely underreported, data from the office of the Texas Secretary of State put the number of people living in colonias at approximately 400,000. This means that more than 24% of the RGV population is presumably living under nonresilient structural conditions and thus is more vulnerable than other populations to any kind of disruptions. The location of the RGV in Texas and the major urban centers is shown in Figure 1.



Figure 1. Map of the RGV showing major cities and towns.

With intensified urban migration, urban settlements, housing, and homeowner characteristics often shape urban environmental conditions more than policies and regulations do [15]. Even in places with very strong regulations, more variables originating from the character, attitude, and priorities of businesses, homeowners, communities, and the nature of housing structures determine urban environmental changes. From a regulatory standpoint, land use, the way housing is designed, and land subdivisions are made can affect the character and priorities of businesses and homeowner attitudes [15]. Although environmental conditions and the general urban setup are tightly controlled by local governments, business and homeowner activities in an urban setting can have the greatest influence on ecological development and increased/reduced biodiversity, which ultimately determine resilience outcomes.

2.1. Qualitative Methodology

According to Rowe and Frewer, the IAP2 spectrum is a tool for designing public participation. We have modified this spectrum for use in the organization, understanding, collection of secondary data, and analysis process. This is because decisions about urbanization are rarely in the hands of the public, urbanization is an ongoing process, and it never stops and is at different stages in different urban settings [21]. The environmental impacts on different urban settings lead to very similar outcomes. IAP2 helped with a framework to consult the literature to generate information about various policy mechanisms designed to grow and manage urbanization. The study examined organizational and holistic strategies that were designed to operationalize resilience [10,32] and were tested in Canada and France. Using leverage and intervention point approaches [13,24,26], we identified various studies with empirical findings that show efforts and initiatives at different stages of the urbanization process that can prevent or minimize the impacts of climate change on community resilience.

We carried out a desktop review academic literature and relevant internet sources to identify organizational and holistic leverage points that could be used to develop a narrative on ecological resources, economic development, and desired climate change resilience outcomes. Literature for analysis was obtained from Science Direct, Google Scholar, Wiley, Emerald, Taylor and Francis, and Sage publications. In addition to the keywords that speak to the concept of resilience, these pieces of literature were selected based on the words used in the title, such as sustainability, urbanization, leverage points, intervention points, resilience, agriculture, and community. A total of 24 articles were examined, and 11 were selected for analysis. Using NVivo 11 qualitative analysis software, we identified leverage points and the ways they contribute to a specific realm of resilience. We examined specific initiatives, efforts, and interventions that other urbanizing regions have developed to improve resilience and considered whether these could provide lessons for the RGV. Resilience interventions take the forms of technical processes and social, ecological, and complex systems [33].

The ecological environment, urbanization patterns, infrastructure development, and settlements in the RGV present very complex systems when combined together in the name of resilience. We, therefore, conducted this analysis at two levels, the “organizational approach and holistic approach” [10,32], to help present clear interpretations of resilience within a system using the Donella Meadows leverage point framework: places to intervene in a system [13,33] (pp. 1). Meadows argues that “there are places within a complex system where a small shift in one thing can produce big changes in everything”. All that one has to do is apply intervention and push in the right direction [13].

Before the leverage points are employed, specific organizational and institutional tools must be in place to create a functioning system [15]. It is within that constructed system that leverage points can then be identified. We, therefore, took two approaches in selecting studies that were helpful for identifying systems from which to select leverage points for further examination. These leverage points were extrapolated to the organizational and institutional systems in the RGV to examine where they could produce large and desired resilience changes. One stream of literature selected focused on RGV, and the other was more global, investigating resilience in the context of sustainable development, resource use, housing and settlements, urbanization, infrastructure development, and climate change. These are presented in Table 1, column one. Data were obtained from 11 articles, the organizing engagement website that runs IAP2, and the World Bank website

Table 1. Using the literature to identify leverage points for urban resilience.

Reference Number	Study Title	Organizational Approach Leverage Points	Holistic Approach Leverage Points
[30]	Opportunities and challenges of urban agriculture for sustainable city development	Reducing food supply crisis	Rural–urban interface
[33]	Urban futures: Systemic or system changing interventions? A literature review using Meadows’ leverage points as analytical framework	Interventions at the right times in the right places	Agenda
[27]	Sustainable urbanization in Southeast Asia and beyond: Challenges of population growth, land use change, and environmental health	Awareness	Urban planning
[5]	Municipal annexation and the selective underbounding of colonias in Texas’ Lower Rio Grande Valley	Improved affordable housing	Improved incomes
[29]	Comprehensive evaluation of urban resilience based on the perspective of landscape pattern: A case study of Shenyang city	Resilience thinking	Improved infrastructure
[34]	Past results and future directions in urban community gardens research	Backyard gardens	Community gardens
[35]	The future of urban agriculture and biodiversity-ecosystem services: Challenges and next steps	Urban agriculture	Biodiversity conservation
[36]	Environmental change, urbanisation, and socio-ecological resilience in the Pacific: Community narratives from Port Vila, Vanuatu	Understanding communities	Land tenure security
[37]	Building the resilience of peri-urban communities to the impacts of climate change and urbanization	Civic engagement	Permanent infrastructure
[21]	Public participation methods: A framework for evaluation	Consultation and information gathering	Decision-making and implementation
[14]	The changing face of the Mary Valley: Considering the fairness, sustainability and resilience of the agricultural system in a peri-urban setting	Dealing with extreme events	Compounding impacts

The leverage points were then clustered into what Abson et al. call a realm of leverage points. While leverage points are places in a system where a small change can lead to a sizable outcome [13,25], it is the entire cluster taken together that defines the resilience outcome. Interventions can be either shallow if they are simple and have limited potential to trigger a large change in the outcomes, or deep, if they produce transformational changes [24,26]. There are two approaches to implementing interventions: organizational and holistic. The organizational approach refers to the capacity of organizations or institutions to leverage their presence or activities to influence resilience outcomes in the desired direction. The holistic approach involves taking advantage of the cumulative effects beyond organizational or institutional impacts to create conditions that foster regional, systems, and community resilience.

2.2. Organizational Leverage Points

Organizations are created to facilitate the achievement of specific targeted policy outcomes that should have impacts beyond the organization [15]. From the literature selected to generate leverage points, we found that some of the approaches for increasing resilience are providing affordable housing options for all communities, developing civic engagement platforms, improving access to food supply, and generating awareness and understanding among communities so that the right interventions can be applied. This can then lead to resilient thinking, the ability to deal with extreme events, and individuals' ability to start undertaking resilient activities such as backyard gardens and urban agriculture [34,35].

Holistic Leverage Points

The holistic approach makes resilience a public issue; therefore, when applied at the right places in the public sphere and then pushed in the right direction, it will create cumulative resilience effects across an entire region. For example, improved income, permanent (soft and hard) infrastructure, urban planning, and biodiversity conservation are all leverage points if applied adequately with support from local governments and can lead to even greater regional resilience [15]. Involving local governments, trust in social/business/environmental agencies, and finding salient shared values help to create decision-making tools and implementation decisions.

3. Findings

The literature shows the advancement of urban resilience in theory, but its actual application in policy, strategy, and conservation initiatives has not gone beyond supporting business as usual in urbanization processes [33]. "The type of interventions studied in the literature are partially driven by research methods and problem framings and that 'deep leverage points' related to changing the system's rules, values and paradigms are not given sufficient attention" [25]. The reality is that political efforts at higher levels within state and local institutions deliberately exclude colonias from funding and access to all types of economic and social opportunities that should automatically be available to low-income families. Such opportunities include increased funding for schools in poor neighborhoods, health care facilities, food access and transportation [5,31].

Urbanization and infrastructure (both hard and ecological) development in the RGV is still in flux and evolving. Depending on the specific location, there are large differences in the quality of life and infrastructure between the major urban centers of Edinburg, McAllen, and Brownsville and peri-urban areas that are home to settlements such as the colonias. Colonias are low-income settlements outside of municipalities where a lack of zoning enforcement leads to substandard housing conditions. Residents have limited access to basic needs, including well-paying jobs, food security, education, health facilities and water [31]. Colonia settlements are often excluded from consideration in projects to provide infrastructure and utility services as these were areas originally rural but are now in the hinterlands of cities owing to rapidly expanding urbanization [5]. As urbanization expands, colonias have also grown because of factors such as a rapidly increasing low-income

labor force, the need for affordable housing in the face of a lack of government-sponsored affordable housing in urban areas, lax regulatory frameworks, and a lack of representation in decision-making bodies.

The RGV is a place where human efforts, community lifestyle, institutional designs, cultural wealth and local governments can be leveraged to change the trajectory of the resilience of the region and mitigate climate change impacts. Improved access to affordable housing, better incomes, and a strong regulatory environment alongside strict zoning codes that encourage access to healthy food and outdoor leisure are currently lacking in the region and are among the reasons the RGV remains very vulnerable to climate change and weather-related disruptions [10,25]. Researchers have found that the region has “inadequate affordable housing and, lacks government sponsored housing options” leaving the residents in the hands of well-connected and profit-motivated land developers [5].

In Texas as a whole, counties have limited capacity to impose strong regulations to provide adequate services and zoning codes to prevent haphazard settlements, especially by residents who have moved to colonias because they cannot afford to live elsewhere. The median household income in the region is between USD 25,000 and USD 32,000 (in 2011, adjusted for inflation), which is far below the state’s median income of USD 51,000 [5]. With these inequalities and exclusions within this small but rapidly urbanizing region, there cannot be a single blueprint for resilience policies and strategies. The entire region lacks an integrated system upon which to develop beneficial networks among urban, rural, and business communities.

3.1. Ecological and Resilience Challenges

Investments aimed at building resilient and permanent infrastructure depend on civic engagement strategies, tenure in the ownership of land, regulatory public policies, and access to multiple funding options. In the RGV, “the transitory nature of many settlements often leads to erosion of social capital making it difficult to build ecological and urban resilience practices” [1,5,37]. Leveraging civic engagement tools is one way to build community and ecological and urban resilience, mitigate and adapt to climate change, and improve living conditions and social welfare [38]. The major question, although beyond the scope of this research, is what it would take to develop viable civic engagement platforms. First, the process of urbanization takes a very large toll on ecosystem services everywhere [5,37]. Urbanization leads to the “depletion of natural resources, reduced ecosystem services flow and loss in biodiversity” [39]. This process involves the clearance of natural resources resulting in a complete alteration of the landscape. Therefore, much more research is needed to establish ecological boundaries and policy-guided opportunities for the efforts and costs needed to mitigate and adapt to climate change in urban and peri-urban settings.

3.1.1. Intervention Points—Interventions at the Right Times in the Right Places

The next questions to be answered are when is the right time to intervene, what types of interventions should be used, and at what point/place in the urbanization process can the most durable resilience outcomes be produced? Identifying and developing leverage points to accurately frame and inform the right interventions to produce the desired outcomes, ref. [40] define the realm of leverage that we use in this study as the desired resilient outcome. Additionally, they argue that “leverage points are interdependent, rather than independent and their relationships are co-constructed such that ‘shallower’ leverage points influence ‘deeper’ leverage points and vice versa.” This explanation does not provide all the answers about very specific interventions but shows the range of what constitutes a leverage point and the overall realm of leverage. Abson et al. proposed three realms of leverage: reconnecting people to nature, restructuring institutions, and rethinking how knowledge is created and used in the pursuit of sustainability. Using local and international literature, as shown in Table 2, we propose four realms of leverage and several intervention

points that are relevant and applicable to fostering resilience in the RGV [24,38]. Examples of the realm of leverage points are provided in column 3.

3.1.2. Realm of Leverage Points

Leverage points are a way of engaging with the desired outcomes, defining various considerations, and identifying the means of reaching those desired endpoints [40]. The literature on leverage points divides them into shallow and deep categories [13,40], but we assume that while leverage points might not possess the same depths as those defined in the literature, their interactions should be considered as contributing to resilience based on their location in the system. For example, improved incomes, government-sponsored affordable housing options, food grown on balconies, and reduced dependence on ecological systems all contribute to resilience from different points in the system that cannot be classified as either shallow or deep [5].

In regard to resilience, the exact places and times to intervene must also be considered. The study examines two infrastructures—ecological and physical—and the key question is when, where, and at what point in the process does an intervention produce the most desired resilience outcomes? Does an intervention produce the most desired resilience outcomes at the ecological or physical infrastructure level? For example, in an urbanizing environment, there is an inverse relationship between the number of cars using the roads (physical) and emitting greenhouse gases that are responsible for climate change and the clearing of trees (ecological) that act as carbon sinks. These are important sticking points that additional research must help to reconcile. The salience of resilient initiatives and trust in social/business/environmental agencies that are on the frontline of creating networks and implementing policies are intervention points critical to desired resilient outcomes, but these were missing in the analyzed literature.

Table 2. Realm of leverage points for urban resilience in the RGV.

27. Meadows (1999)-Places to Intervene in a System	1. Abson et al. (2017)-Realm of Leverage Points in Increasing Constraining Order	Examples
Improved incomes, government-sponsored affordable housing options, self-help groups, food supply: <i>Backyard gardens, urban agriculture, producing food 'in the air' and 'on the water', on balconies, in rooftop gardens and in community gardens [35]</i>	Parameters	These refer to numbers such as income levels and distribution, affordable housing options and available housing units, the number and activities of self-help groups in the region, food supply sources, costs and quality
Engaged community, education/awareness, creative pursuit of goals dealing with extreme events, stakeholder collaboration, health understanding and accounting for complex socio-ecological relationships shared values	Feedback	Time needed for communities to make decisions, the speed or delays of information flow, strength of negative or positive feedback loops, time needed to recover from extreme events and the time needed to bring a majority of people from various communities to the conversation or decision table
Urban planning, rural–urban interface, permanent infrastructure, improved infrastructure, land use and zoning regulations, settlement patterns	Design	Balancing green infrastructure with hard infrastructure, ecological infrastructure, clear regulations that govern land use and settlements

Table 2. Cont.

27. Meadows (1999)-Places to Intervene in a System	1. Abson et al. (2017)-Realm of Leverage Points in Increasing Constraining Order	Examples
Resilience thinking, urban resilience, land tenure security, new urban agenda, equality, inclusion, biodiversity protection, compounding impacts; <i>Managing high dependence on ecosystems and fostering ecosystem's self-organizing ability.</i>	Intent	Changing priorities to start investing in programs and activities that foster resilience, equality and inclusion, biodiversity protection and sustainable use of natural resources

Adopted from Dorninger et al. (2020) [25], Fischer and Riechers (2019) [40] and Lin et al. (2015) [35].

3.2. Urban Resilience

Urbanization, in general, has brought about high dependence on hard infrastructure, which has made urban communities more vulnerable to all forms of disruptions [27]. Fenga et al. discuss another form of infrastructure, “ecological infrastructure,” a reference to a type of resilience that provides a buffer for hard infrastructure and therefore enables urban systems to minimize risks and losses, damage to property, livelihoods, and economic activities. Ecological infrastructure involves a combination of aspects of natural resource management, inclusion, leadership, social cohesion, diversity, and collective identity. It is an approach designed to restrict the scale of urban development to within the scope of its ecological capacity so that it can respond to risks as they arise, adapt to climate change, and foster the ability to recover and recommence development after a disaster [40].

The state of Texas and the RGV, in particular, are lacking almost all these aspects of ecological infrastructure. The presence of a high concentration of colonias in the RGV, the winter power grid freeze in 2021, and the lack of leadership on the policy front have had compounding effects on resilience outcomes in marginal and vulnerable regions. Support is provided for equality in regard to settlements and land use patterns, and the inclusion of all communities in mainstream economic activities and responding to extreme weather events is one measure of urban resilience [16]. At the state level, there are inadequate leadership, efforts, and investments targeting challenges faced by people living in colonias and other areas prone to climate change, flooding, fires, and other sustainable development challenges.

3.3. Operationalization of Desired Resilience Outcomes

We want to briefly introduce the operationalization of leverage points because each of the leverage points proposed in Table 2 merit further research. Therefore, many factors ranging from the selection of measurement and mathematical methods to weighting methods come into play when trying to operationalize or quantify resilience measurement [8]. Resilience can be operationalized using three specific metrics: economic (service), social (quality), and safety (functional) [8]. These metrics are both quantitative and qualitative in nature. Here, economic operationalization refers to investments in all systems (engineering and ecological) to ensure that there is minimal to no disruption and that when there is a disruption, the bounce-back time is as short as possible. Social operationalization refers to the quality or strength of the networks in responding together or simultaneously to minimize negative impacts. Safety operationalization means building systems that remain functional during and after an event.

Resilience in the RGV is impacted largely by informal settlements, inadequate access to basic needs and poor assets of the colonias. In addition, there is inadequate housing and only limited financing options for the residents of these settlements, and much of the region, in general, is described as economically marginalized. Therefore, translating

resilience-oriented policies into concrete implementation activities under these conditions and creating measurement units across various systems designed to pursue resilience goals in the region requires a thorough understanding of the complex socio-ecological relationships, the leveraging of local ecological and cultural assets, and investments in both ecological and technical infrastructures [18].

Figure 2 shows how local interventions can leverage location, the existing policies, funding, values, strengths, and vulnerabilities of communities to build a resilient society. Column 1 lines up how interventions and leverage points can be applied in column 2 to build resilience. In order to produce optimal resilient outcomes as shown in column 3, the figure presents proposals on where, when, and how to intervene.

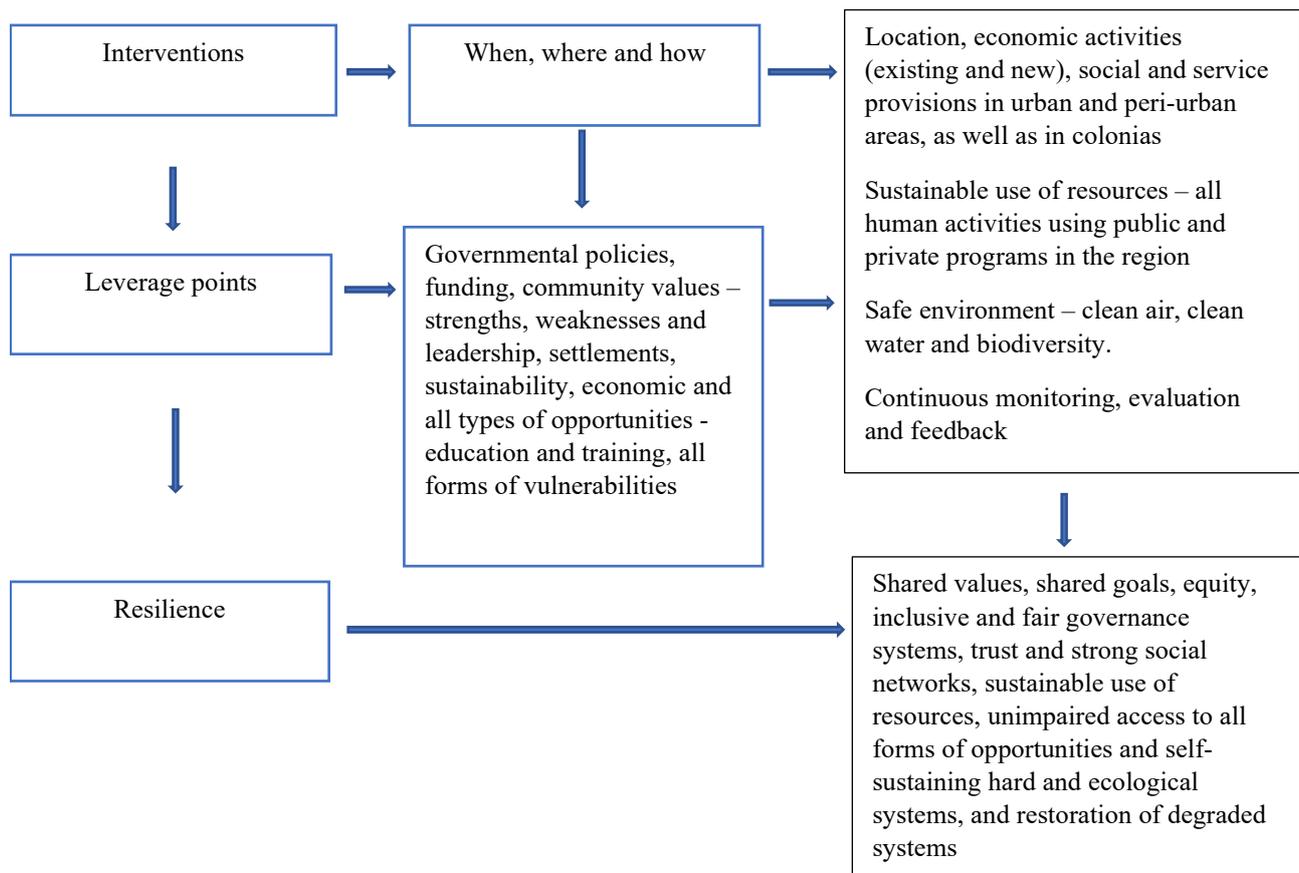


Figure 2. Interventions, leverage points and resilient outcomes.

The RGV region has been historically underserved, excluded, and marginalized in many respects, so interdependence across sectors is weak. Local governments are not well-funded, the private sector is not particularly vibrant, and there is no evidence of shared values across sectors. From an intervention viewpoint, operationalization concerns how to make systems self-reliant, meaning “the ability of people and places to pull themselves up by their bootstraps and reinvent themselves in the face of external disruptions” [14,20], (pp. 10). This is because economic growth does not necessarily reduce poverty and inequality if there is negligence in the provision of basic services. Lack of adequate access is in itself a barrier to community resilience and decent living standards [41].

Research has shown that “when government takes greater responsibility for risks in the community, it may feel under pressure to take increasingly more responsibility, thereby eroding community resilience” [20]. Therefore, compared to wealthier regions, in an economically marginalized region, it is not only difficult for the local government to take more responsibility but also much more difficult for different groups of communities to operationalize resilience initiatives. Engaging stakeholders beyond the region to identify

and fill the self-organizing capacity gaps may help to address these deficiencies, including improved access to economic and social service provisions, strengthened public sector programs, safer environmental conditions, and continuous monitoring and evaluation [3].

4. Discussion

Like other similar regions, the RGV continues to experience prolonged droughts and excessive heat warnings, intensified storms, and flooding. The entire region remains vulnerable to the impacts of climate-change-related disasters and many sustainable development challenges. An in-depth resilience study on the region has not been carried out; therefore, there is insufficient knowledge of regional and context-specific interventions. The areas and examples of intervention listed in Table 2 are not currently under consideration in the region; these are new approaches to building resilience and require further study, formulation, and adoption. Hecht and Sanders found that American cities and suburbs are an ecosystem in their own right. The idea that urbanization impairs the natural ability of the environment to provide ecosystem services such as clean air and water is not necessarily apparent to all stakeholders. Other critical factors were also missing in the analyzed literature, including salience and trust in social and environmental agencies. Urbanization will continue to expand, and, therefore, there must be a deliberate effort to prevent or minimize disastrous environmental outcomes. There is a need to discover and develop viable civic, institutional, and regional intervention places and platforms for resilience-oriented programs and policies in the RGV. Some researchers argue that aspects of power, scale, and equity are not given sufficient attention in the operationalization of resilience [9,26,37]. We argue that salience and trust are also key critical values for building resilience within communities.

In addition, in the examples in Table 2 that explain the range of leverage points, that is, parameters, feedback, design, and intent, the research has shown implementation gaps across communities, institutions, and leadership. Because of the ongoing transformations associated with both urbanization and land use changes, resilience initiatives in the RGV will likely function as moving targets until specific places to intervene, and the nature of such interventions are determined. Another challenge is that the tools that should always facilitate movement toward equality, inclusion, and resilience among communities in the RGV are the very tools that have been used to prevent such outcomes. Jepson provides an example of colonia residents trying to fight for fair access to water through elections in order to participate in the water control and improvement district (WCID) boards. The colonia residents lost, as this effort was viewed as a political threat to the power of the WCID boards. Instead, a legislative change was issued to deny colonia residents the right to vote and allow WCID governing boards to unilaterally exclude colonias from their districts.

Ultimately, “resilience as a concept provides a new framework and a way of thinking about uncertainty and vulnerability in spatial planning, urban landscape processes and use of natural resources. It is also an alternative paradigm for developing strategies and methods for coping with large-scale social, environmental, or economic changes” [27,29,42]. Urban resilience, therefore, means looking beyond safety-based thinking and access to livelihood needs around disasters and other environmental disruptions. Hard infrastructure and engineering safety features may be insufficient in light of more and intensified flooding, hurricanes, fires, pollution, and heat stress. Urban resilience should therefore involve investing in efforts to move toward self-organizing ecological systems that are able to maintain stability and balance in the face of severe disruptions.

5. Conclusions

Resilience barriers in the RGV originate from the ongoing transitions from agricultural lands to urbanization and insufficient access to basic needs such as affordable housing, education, employment, and adequate funding for public sector support programs by the community. Given that significant populations that live in colonias remain marginalized and excluded from mainstream economic, social, and political domains, and their situation

being exacerbated by unequal legal, social, and labor participation, it causes multiple vulnerabilities. Information gathered from the literature shows that no attention is being paid to investments in building resilience across all sectors in the region. The knowledge gathered on leverage points and resilient interventions provides stakeholders with opportunities to identify gaps and develop capacities to mitigate various vulnerabilities.

Although the leverage points and interventions generated in this study are from research conducted in other parts of the world, they can easily be modified to generate context- and region-specific technical, physical, ecological, and land use resilience outcomes. For complex policy initiatives targeting resource use, environmental protection, and climate change, successful outcomes would require federal, state, and local government leaders to support local capacities and leverage the locational values such as the socio-cultural, wealth to defray the perceived costs associated with building sustainable physical and ecological infrastructure. Specific region-wide interventions, as well as identifying places for intervention in a variety of systems related to economic, social, political, environmental, and settlement patterns, do not currently exist. Ultimately, ways to address resilience building alongside other regional challenges will require community empowerment and the development of relationships across all municipalities through well-managed governance platforms. These efforts will be strengthened by increased community participation and concern for the conservation of ecological, physical, and economic ecosystems that are designed to support equitable, sustainable, and socio-economic development outcomes.

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