The University of Chicago

From Lots to Lush: Repurposing San Antonio’s Underutilized Spaces to Combat Water Scarcity, Food Deserts, and Urban Heat

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A thesis submitted for partial fulfillment of the requirements for a Bachelor of Arts degree in Environmental and Urban Studies

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Abstract

San Antonio, Texas, faces increasing environmental and social challenges driven by rapid population growth and worsening climate conditions. Most pressing among these challenges are food insecurity, water scarcity, and urban heat, which disproportionately affect the city's low-income and underserved communities. This thesis explores the potential of transforming vacant lots and green spaces into multifunctional sites that address these interconnected issues. By integrating urban agriculture, bioretention basins, and vegetative cooling, these spaces can provide sustainable solutions to enhance food security, bolster the local water supply, and mitigate urban heat island effects. To support this proposal, the study analyzes historical trends in aquifer water levels and infiltration metrics, spatial data on food deserts, and heat vulnerability indices across San Antonio to identify priority intervention areas. Benchmarks for evaluating the impact of these interventions are aligned with the city's Climate Action & Adaptation Plan (CAAP) and water conservation goals, focusing on groundwater recharge, food accessibility improvements, and urban cooling. This study utilizes data from case studies in West Texas, Dallas, and San Antonio to project the results of these proposed interventions. This research demonstrates how targeted land use shifts can focus urban agriculture, urban greening, and water infiltration projects to strengthen San Antonio's climate resilience and social equity in the face of a growing population. The findings underscore the urgency of implementing integrated solutions that repurpose underutilized urban spaces, providing a scalable and comprehensive framework for cities facing similar challenges in our rapidly changing climate.

Introduction

Within the last two years, San Antonio, Texas, has reigned as the largest population gainer by a city in the United States (U.S Census), broke its record for days over 100℉ (SA Climate Ready), and hit its water supply's lowest point since 1990 (Edwards Aquifer Authority). The city is increasingly vulnerable to environmental and social challenges, all exacerbated by its rapid population growth and climate change. As the city expands, it faces intensifying food insecurity, water scarcity, and urban heat effects, all of which disproportionately impact the city's low-income and underserved communities. These challenges are interconnected, compounding one another as San Antonio's food and water systems struggle to meet rising demands. Addressing these issues requires an integrated approach that maximizes the potential of underutilized urban spaces to support sustainable food production, water conservation, and temperature regulation; vacant lots and existing green spaces are uniquely positioned to support these initiatives. As the city's population grows, large-scale urban development will prioritize commercial and residential projects, leaving smaller vacant lots unsuitable and unused. Furthermore, existing park and green spaces are strictly protected from residential development and thereby also useful for long-term mitigation projects. By repurposing vacant lots and taking advantage of the stability of existing green spaces, San Antonio can implement targeted solutions to enhance community resilience and address resource challenges without competing with the housing demands of its growing population. This thesis examines how transforming San Antonio's vacant lots and green spaces can serve as a multifaceted solution to these interconnected challenges.

To effectively identify and address problem areas in San Antonio, this study will focus on three key indicators: heat vulnerability to assess urban heat and cooling impacts, groundwater levels and zones to evaluate water scarcity and recharge capability, and the prevalence and distribution of food deserts to gauge food insecurity. This thesis proposes a land-based framework that strengthens San Antonio's resilience to climate impacts through the adaptive reuse of vacant lots and parks for urban agriculture, groundwater recharge, and vegetative cooling projects.

Drawing on case studies and empirical data from Dallas, San Antonio, and smaller municipalities in West Texas, this research will examine and predict the potential impacts of such land use strategies in delivering measurable benefits across these interconnected challenges. By leveraging the ecological and social benefits associated with these spaces, this study aims to provide San Antonio with actionable solutions that enhance urban resilience and address resource scarcities in a holistic, community-focused way. This thesis underscores how comprehensive land-use transformations reflect the untapped potential of San Antonio's vacant lots and green spaces to meet the city's evolving needs, illuminating the value these spaces hold in mitigating worsening environmental problems amid the city's population boom.

Background and Context

San Antonio, characterized by hot summers, mild winters, and unpredictable precipitation, is located in south-central Texas at the intersection of three distinct ecological regions: the Edwards Plateau, the Blackland Prairie, and the South Texas Plains (SAWS 2017). This transitional geography contributes to the city's unique topography and complex hydrology, particularly its relationship with the Edwards Aquifer, a karst limestone formation that serves as the city's primary water source (SAWS 2017). This geographic positioning results in high variability in annual rainfall, which averages 30 inches per year but can fluctuate between 10 and 50 inches depending on weather patterns (SAWS 2017).

The city experiences prolonged droughts interspersed with periods of intense rainfall that can lead to flash flooding, complicating efforts to maintain a stable water supply. While heavy rain events, such as tropical storms and stalled cold fronts, can replenish local water sources, these occurrences are unpredictable and thereby require long-existing solutions. Furthermore, evaporation rates are high, particularly in the scorching summer months when daily temperatures exceed 90°F more than 80% of the time (SAWS 2017). Climate projections suggest that the region may experience hotter, drier conditions in the coming decades, further stressing water resources and increasing the urgency for adaptive, decentralized sustainability strategies (COSA 2016). These geographic and climatic conditions form the basis for San Antonio's evolving relationship with water and land use, directly informing this project's focus on urban agriculture, infiltration, and climate resilience.

Edwards Aquifer, Groundwater Recharge

The Edwards Aquifer accounts for 90% of San Antonio's water supply, serving as more than just the primary water supply for San Antonio and its surrounding communities (SAWS 2017). This vast underground limestone aquifer is highly permeable, allowing for the rapid movement and storage of water, but its structure also makes it vulnerable to over-extraction and contamination. The aquifer is divided into three primary zones: the Drainage Area, the Recharge Zone, and the Artesian Zone, each playing a critical role in the movement and availability of groundwater.

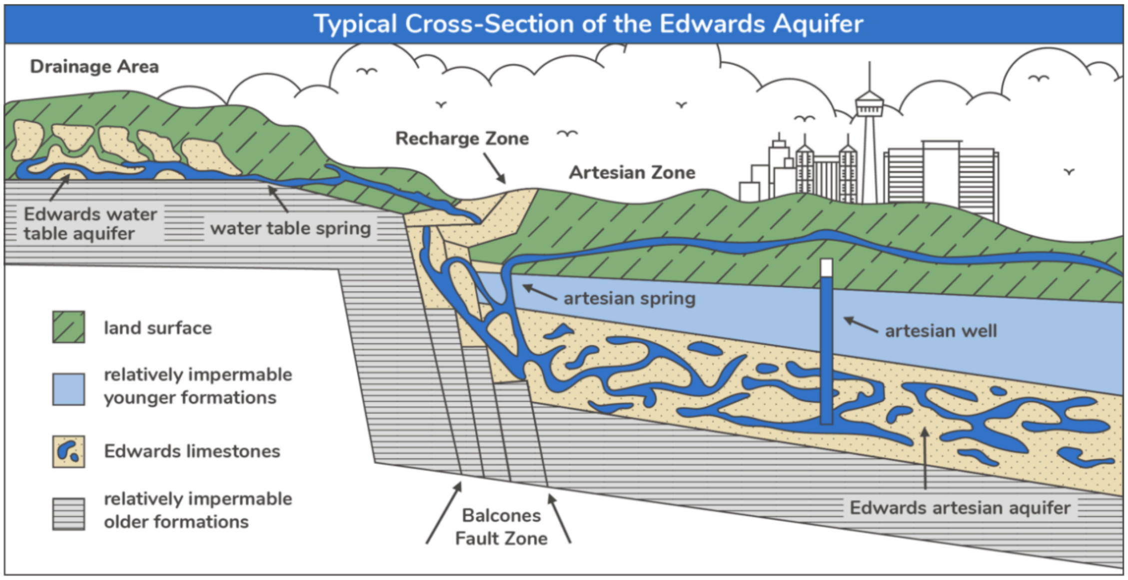

Figure 1. Underground cross-section of the Edwards Aquifer, depicting geological and hydrological characteristics. Courtesy of the Edwards Aquifer Authority (EAA).

The drainage area, located on the higher elevations of the Edwards Plateau, serves as the initial collection point for rainfall and surface water. As water moves downward, it reaches the recharge zone, a crucial region where precipitation and streamflow infiltrate through fractures, sinkholes, and porous limestone to replenish the aquifer. This zone is highly sensitive to pollution and urban development, as contaminants from surface runoff can directly enter the groundwater supply. Below the recharge zone lies the artesian zone, where water is confined between layers of relatively impermeable rock formations. Due to the pressure from this confinement, water in the Edwards Artesian Aquifer can rise naturally to the surface through artesian springs and wells, supplying water to rivers, ecosystems, and municipal sources. The Balcones Fault Zone, a significant geological feature in the region, further influences groundwater flow, creating a complex hydrological system. Most of San Antonio is contained within the artesian zone, with its northern border crossing into the recharge and drainage areas.

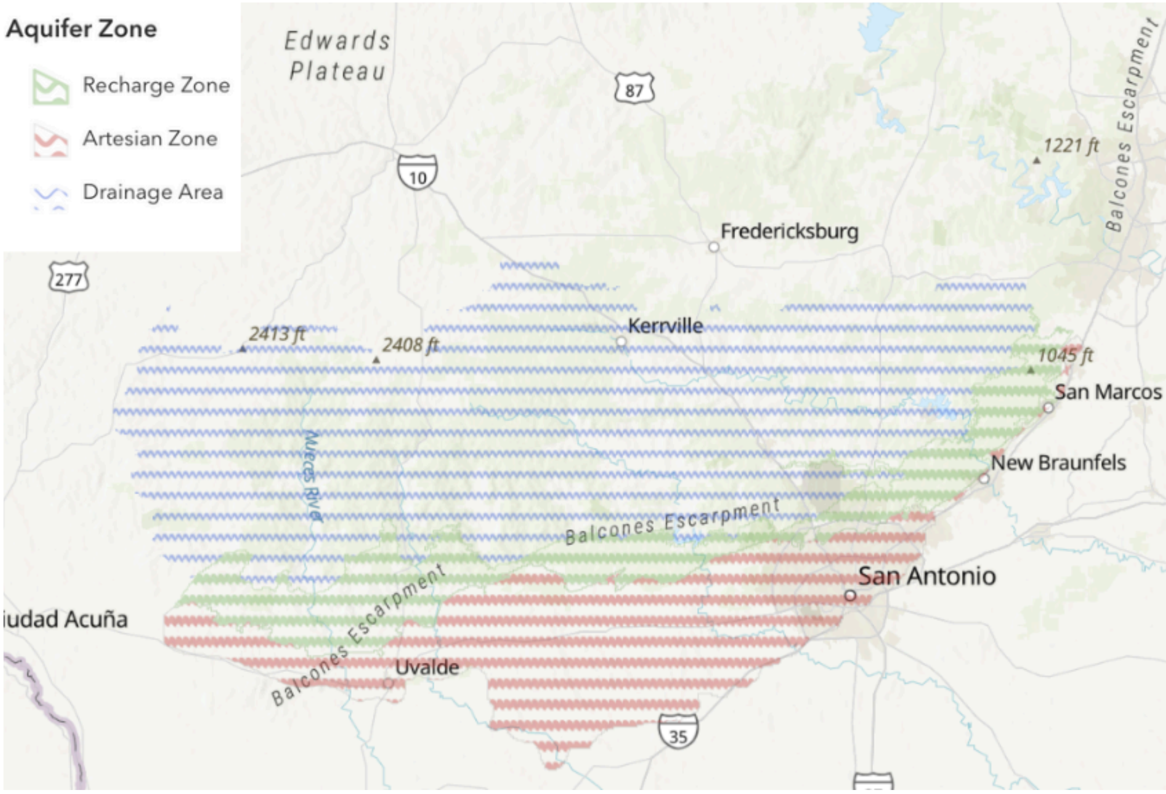

Figure 2. ESRI GIS Map depicting the spatial boundaries of each aquifer zone within the Edwards Aquifer. Data made available by the EAA.

Groundwater recharge is a vital natural process in which surface water slowly infiltrates through the soil, replenishing underground aquifers that serve as essential sources of drinking water and ecological stability. In regions like San Antonio, which rely heavily on the Edwards Aquifer, sustaining recharge is crucial to maintaining both water availability and long-term resource resilience (San Antonio River Authority). However, the expansion of impervious surfaces (roads, rooftops, and parking lots) has significantly reduced the landscape's ability to absorb water, thereby diminishing recharge rates and increasing surface runoff. This runoff often carries pollutants including oils, nutrients, heavy metals, and sediments, which can contaminate nearby waterways and reduce water quality (Birch 2018). Fortunately, as stormwater moves through natural substrates like soil and vegetation, it undergoes important ecological filtration, where physical, chemical, and biological processes remove contaminants before the water enters the aquifer (Schroeder 2022). This filtering function not only protects the aquifer's integrity but also supports healthy ecosystems throughout the water system, replenishing out water supplies with clean, usable water.

The Edwards Aquifer is a highly productive yet fragile resource. Its reliance on natural recharge means that prolonged droughts and over-pumping can significantly lower water levels, threatening both human consumption and ecosystem stability. The following graph was derived from the Edwards Aquifer Authority, detailing its historic water levels since January 1st, 1990. Since 2020, the aquifer has seen continuously diminishing peak volumes and hit its lowest point since 1990 in August of 2023 (Fig. 3).

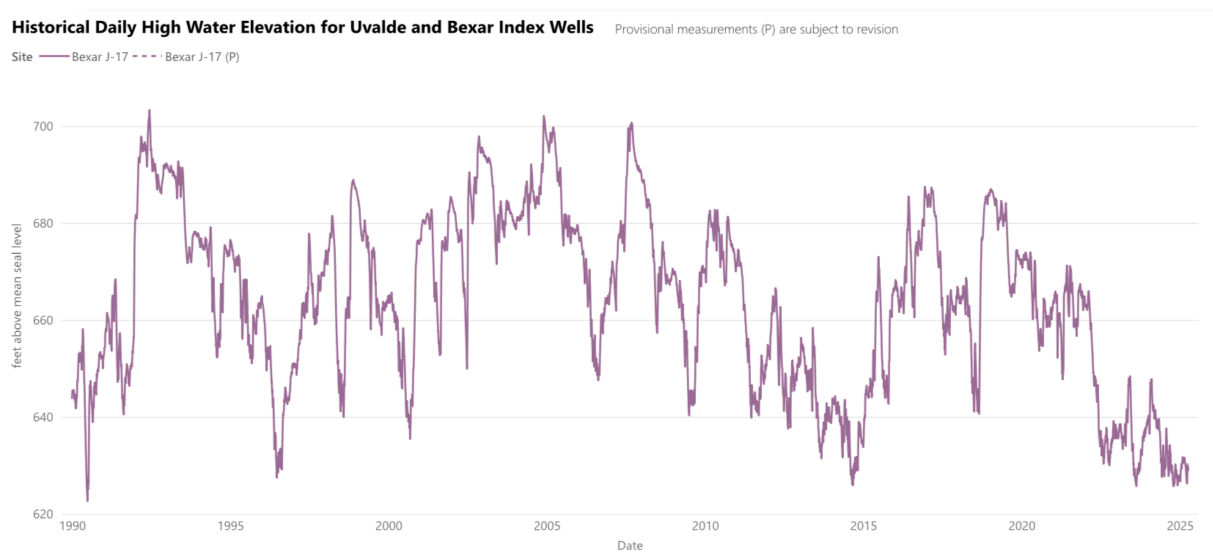

Figure 3. Graph depicting water levels in the J-17 well of the Edwards Aquifer, Bexar County and San Antonio's water supply well. Courtesy of the EAA.

Given that San Antonio depends on this aquifer for nearly all of its drinking water, managing recharge and groundwater extraction is a critical issue for the city's long-term water security. Initiatives such as aquifer storage and recovery (ASR), conservation programs, and recharge zone protections have been implemented to ensure sustainable use. Ongoing drought conditions and aquifer decline, exacerbated by climate change, urban expansion, and increasing water demands, underscore the need for more targeted and intensive water management strategies that balance human needs with ecological preservation. This project prioritizes groundwater recharge as a viable method of supplementing San Antonio's water supply. Infiltration that occurs within the recharge and drainage zones helps directly replenish the Edwards Aquifer, which supports both ecological systems and long-term water reserves. Meanwhile, infiltration within the artesian zone can contribute more immediately to the city's pressurized well water supply, improving short-term water availability.

Severe Urban Heat, Access to Food

Agriculture played a crucial role in San Antonio's early economy, with surrounding farmlands supplying fresh produce to local markets as railroad infrastructure expanded (City of San Antonio). However, the city's transition from an agrarian to an urban-industrial economy led to a sharp decline in agricultural land, resulting in increased reliance on imported food and a weakened local food system (Guerry 2023). This shift not only diminished the city's self-sufficiency but also exacerbated spatial inequalities in food access, as low-income neighborhoods became increasingly disconnected from fresh food sources. Then emerged food deserts, defined as low-income census tracts where residents live more than a mile from the nearest grocery store (USDA). The absence of a comprehensive public transit system and the unaffordability of personal vehicles for many residents in these areas further intensify this issue, reinforcing the structural barriers to food accessibility.

Simultaneously, San Antonio faces growing challenges from the Urban Heat Island (UHI) effect, wherein densely built environments with minimal vegetation experience significantly higher temperatures than surrounding rural areas. This phenomenon is particularly acute in neighborhoods with limited green space, high impervious surface coverage, and widespread socioeconomic hardship: all conditions that often overlap with and worsen the city's food deserts (Texas Trees Foundation 2017). As the climate warms, these areas are disproportionately affected by rising temperatures and worsening heatwaves, which have been linked to increased risks of respiratory and cardiovascular illness (Brown 2023).

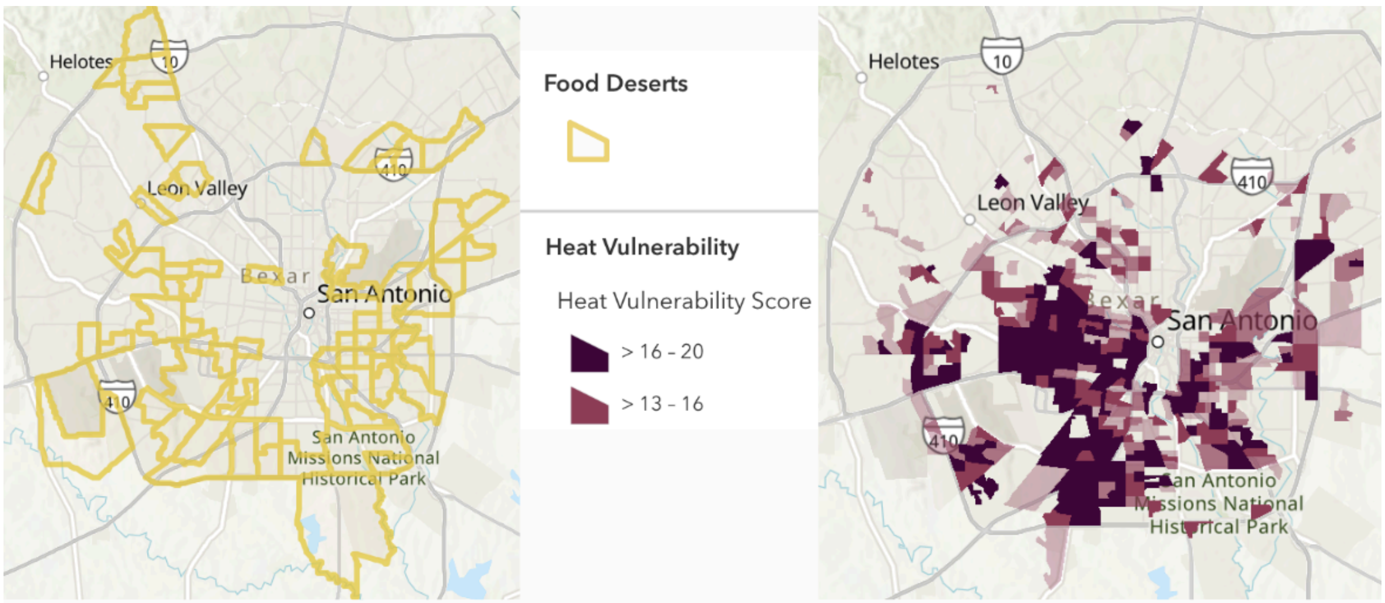

Figure 4. Maps depicting Food Deserts (left) and Heat Vulnerability (right) in San Antonio. Data made available by the USDA Food Desert Atlas and University of Texas San Antonio.

The map above overlays food desert boundaries with San Antonio's heat vulnerability index, which combines satellite-based land surface temperature data from the United States Geological Survey (USGS) with indicators of social and economic vulnerability, including poverty rates, housing conditions, and access to cooling infrastructure (Brown 2023). This combined spatial representation reveals a significant concentration of residents who are vulnerable to both severe heat and food insecurity, particularly in the city's south and west sides. Individuals in these overlapping zones are not only more likely to face chronic food insecurity, but must also navigate long, unshaded walks in extreme heat to access groceries, thus intensifying the physical burden and health risks they face. The compounding nature of these inequities underscores the urgency for multifaceted interventions that address food access, environmental justice, and public health in tandem.

Environmental Justice

Environmental justice refers to the fair treatment and meaningful involvement of all people in the development, implementation, and enforcement of environmental policies and practices (Clark 2021). It demands equitable access to environmental benefits and protection from environmental harms, as well as inclusive decision-making processes that give voice to historically marginalized communities. In San Antonio, environmental justice has long been a contested issue, particularly for low-income and majority-Latino neighborhoods on the city's west and south sides. These communities have historically been burdened by disproportionate exposure to environmental risks such as flooding, industrial pollution, and underinvestment in infrastructure while being excluded from urban planning processes (Miller 2014).

The legacy of these injustices can be seen in spatial disparities in food and water access and exposure to severe heat. This project directly engages with these concerns by prioritizing adaptive land reuse in areas most affected by environmental and infrastructural neglect, particularly food deserts and heat-vulnerable neighborhoods. By allocating urban agriculture interventions in underserved zones, cooling the most vulnerable residents, and replacing inefficient drainage infrastructure, the framework seeks to operationalize environmental justice through equitable land use, resource distribution, and climate resilience planning. In doing so, it attempts not only to address environmental needs, but also to redress historical spatial inequities in San Antonio's urban fabric.

Planning Policy

In response to environmental challenges, San Antonio has adopted policies focused on improving urban sustainability and attempting to bolster resilience. Initiatives such as the SA Parks System Plan aim to guide the expansion and improvement of parks and recreational facilities, enhancing the city's green spaces. San Antonio's Climate Action & Adaptation Plan (CAAP) serves as a guiding framework for addressing the city's climate challenges, including urban heat, water scarcity, and general sustainability (City of San Antonio). While the plan emphasizes emissions reductions, expanding green infrastructure, and increasing community resilience, it often prioritizes economic arguments over equity concerns, which can undermine efforts to address the needs of low-income communities disproportionately affected by food deserts, water shortages, and urban heat.

Recent advocacy efforts in San Antonio have emphasized the importance of food security, climate resilience, and the preservation of green spaces. Collaborative projects between institutions like the University of Texas at San Antonio and the Southwest Research Institute have focused on studying and mitigating the Urban Heat Island effect, particularly in vulnerable neighborhoods. These initiatives reflect a growing commitment to integrating environmental considerations into urban planning and community development.

Literature Review

San Antonio faces a unique convergence of environmental pressures driven by rapid urbanization, increasing climate stresses, and a booming population. As the city expands, it is increasingly impacted by food insecurity, water scarcity, and the urban heat island (UHI) effect, with these issues compounding one another, especially in low-income areas. Kamata et al. (2024)

underscore the importance of nature-based solutions to address these environmental concerns holistically, particularly in urban centers where the effects of climate change are amplified. Green spaces and vacant lots emerge as untapped resources with the potential to mitigate these challenges, providing ecosystem services that can improve air quality, reduce heat, and support local food and water systems (Burkholder 2012). Daher et. al (2019) proposes an integrated approach to these problems through a water-energy-food (WEF) nexus that illuminates the interconnectedness of these problems. This thesis will build on these insights, proposing instead a water-heat-food nexus approach for transforming San Antonio’s underutilized urban spaces into multifunctional resources that address these issues in a way that serves both ecological and social needs.

1. *Water Scarcity and Management in San Antonio*

Water scarcity in San Antonio is a growing issue, driven by both the natural aridity of the region and the demands of a rapidly increasing urban population. As Hudock (2019) illustrates, current water conservation efforts in San Antonio may fall short of meeting future demands, suggesting solutions like rainwater harvesting and more robust groundwater recharge systems to address the city's increasing water requirements. Kamata et al. (2024) further support this by emphasizing that green infrastructure, such as rain gardens and bioswales, can effectively capture rainwater and reduce runoff, offering valuable strategies for reducing groundwater depletion by improving water retention in urban areas. Silva Junior et al. (2024) examines different water retention and wastewater treatment projects in smaller communities in West Texas, such as Colorado City. One system, the Pond-in-Pond system, enhances water retention by incorporating a deep anaerobic pit within a larger traditional pond, reducing evaporation and allowing stored water to infiltrate permeable soils, thereby contributing to groundwater recharge. This system focuses primarily on wastewater; another system, infiltration basins, focus on groundwater recharge through stormwater capture (Masetti 2016). Their multifunctional design can also improve water quality (Birch 2005) and enhance biodiversity (Monberg 2018), making them particularly valuable for ecologically stressed environments. Furthermore, their potential to mitigate runoff during heavy rainfalls aligns with San Antonio's climate adaptation goals, reducing the risk of flooding in urban areas while conserving water for future use (COSA).

He et al. (2021) underscore the importance of implementing localized and low-impact solutions to urban water challenges. Their study suggests that strategies such as improved water-use efficiency and small-scale water retention projects could help mitigate water scarcity in cities like San Antonio, particularly when integrated with broader climate adaptation and land-use planning initiatives such as urban agriculture. Their assessment of environmental trade-offs associated with large-scale interventions supports the case for smaller, less invasive solutions like rainwater harvesting, pond-in-pond, and infiltration systems; this thesis will utilize infiltration basins as the intervention project for groundwater recharge, as San Antonio's unpredictable rain patterns and rapid evaporation require maximum infiltration and no ponding during rain events. Additionally, they can exist as usable green infrastructure, expand habitat for wildlife, and provide shade for people through their variable design. Daher et al. (2019) argue that addressing water scarcity in cities like San Antonio requires solutions that intersect with food production and environmental conservation. By capturing runoff during rainfall and maximizing its recharge into the aquifer, infiltration basins provide a sustainable water source for drinking water and irrigation, supporting livelihoods in semi-arid regions like San Antonio.

This portion of the literature supports the idea that San Antonio can combat water scarcity by rethinking land use in a way that conserves water and bolsters local food security.

Building on these studies, this thesis will integrate infiltration basins into an urban land reuse framework, showcasing that solutions for water scarcity can provide additional ecological and social benefits. By transforming vacant lots and parks with integrated infiltration systems, these spaces can be repurposed to serve as important water conservation zones that address multiple environmental needs simultaneously.

2. *Food Insecurity and Urban Agriculture*

Food deserts in San Antonio create significant barriers to food access, especially in low-income communities. Middlemass et al. (2021) highlight the breadth of food insecurity in urban settings and its psychological toll on residents, stressing that limited access to nutritious food exacerbates health disparities and lessens community resilience. This body of research emphasizes the urgent need for solutions that bring fresh food to underserved areas and improve local food security, particularly in neighborhoods with limited access to grocery stores and high levels of economic hardship.

Urban agriculture offers a promising avenue for addressing food insecurity by transforming vacant lots into productive green spaces. Mkwambisi et al. (2011) show that urban agriculture can provide both food and income in resource-scarce communities, with participants earning revenue by selling surplus produce in local markets and engaging in value-added activities like processing and packaging. In San Antonio, integrating urban agriculture into vacant lots could foster not only food production but also contribute to community cohesion and local economic development as residents actively participate in sustainable food practices. Specht et al. (2014) add that urban agriculture enhances social interactions and environmental awareness, positioning it as a transformative tool for addressing food insecurity while promoting social sustainability.

Payen et al. (2022) highlight the significant productivity potential of outdoor urban agriculture, estimating that underutilized urban spaces globally could supply up to 10% of local food demands. They demonstrate that urban farms in underutilized spaces, when properly managed, can achieve crop yields comparable to traditional farming while reducing the environmental footprint associated with long food supply chains.

A study by Fan et al. (2023) highlights that by integrating technologies like the film fully-mulched ridge-furrow (FMRF) system, urban agriculture projects in water-scarce regions like San Antonio can significantly improve water retention and crop yields. The FMRF system's ability to capture and store rainwater in the soil enhances water availability for crops, making it a viable strategy for transforming vacant urban spaces into productive agricultural hubs, even in semi-arid cities like San Antonio. This aligns with the potential of urban agriculture to address food insecurity while optimizing limited resources.

Similarly, Gómez et al. (2019) demonstrates how controlled environment agriculture (CEA) focuses on optimizing indoor plant production through advanced lighting technologies that enhance crop yield and quality. They also note that CEA can further reduce water use by controlling irrigation systems more precisely, which is essential for sustainable food production in a water-strained region. However, CEA isn't very applicable to this framework due to its high costs, energy usage, and need for indoor/constructed spaces. Specht et al. (2014) also introduce the concept of Zero-Acreage Farming (ZFarming), which refers to food production systems integrated directly into buildings, such as rooftop gardens, greenhouses, and vertical farms. This approach offers a sustainable solution to urban land scarcity by using existing structures to produce food while also contributing to stormwater management, air purification, and urban cooling. While ZFarming holds significant environmental and social promise, key barriers to widespread adoption that include high startup costs, technical complexity, and regulatory challenges (Specht et al., 2014) make this technology similarly unfeasible for this project.

Guerry et al. (2023) examine the role of food forests and urban farms in San Antonio, highlighting their potential to enhance local food security, ecosystem services, and climate resilience. The study emphasizes that urban food forests, while producing less food by weight than urban farms, have added ecosystem benefits such as flood mitigation, biodiversity, habitat enhancement, urban cooling, carbon storage, and accessible green space (Guerry 2023).

By leveraging vacant lots and other neglected spaces, cities can maximize local food production and improve access to nutritious food in underserved areas. While studies have focused on various methods of urban agriculture, this project will utilize FMRF farming on urban farms to minimize water usage while maximizing output, as opposed to other more water or construction intensive methods. Building on these findings, this thesis will advocate for urban agriculture as a critical component of San Antonio's response to food insecurity in low-access areas by utilizing both urban farms and food forests.

3. *Urban Heat Island Effect and Green Space Mitigation*

San Antonio's urban density and lack of green spaces contribute to the UHI effect, making it particularly vulnerable to rising temperatures and exacerbating the challenges posed by climate change. Zhao (2018) discusses how San Antonio's local climate zones differ in terms of temperature and suggests that targeted green infrastructure can effectively cool high-density urban areas. By maximizing vegetation in vacant lots and green spaces, San Antonio could reduce urban heat levels in neighborhoods most affected by the UHI effect, thus improving livability and mitigating temperature disparities across the city.

Aram et al. (2019) further emphasize that green spaces provide substantial cooling effects by reducing surface temperatures, adding that these areas can improve urban air quality and increase outdoor comfort for residents. Their findings support the implementation of green infrastructure in San Antonio, where the UHI effect is acutely felt in low-income communities that lack access to cooling resources (Zhao 2018). As Kamata et al. (2024) highlight, greening urban spaces has the dual benefit of mitigating UHI while also reducing runoff and carbon dioxide emissions, positioning vacant lot greening as a climate adaptation strategy with numerous environmental benefits.

The Texas Trees Foundation (2017) completed a UHI study in Dallas, finding that impervious surfaces, such as roads and rooftops, can exacerbate urban temperatures by up to 15°F compared to rural areas, significantly impacting vulnerable communities with limited green space. A recent study on heat vulnerability in San Antonio by the SPUR Center at UTSA found that certain neighborhoods experience disproportionately higher heat exposure due to a combination of impervious surfaces and lack of tree canopy, and are more vulnerable to its effects due to socioeconomic factors, emphasizing the need for targeted mitigation efforts (Brown 2023).

This thesis builds on these studies by proposing a comprehensive strategy for utilizing vacant lots as green infrastructure that mitigates UHI and enhances urban climate resilience. By demonstrating that adapted spaces can serve important functions such as cooling the city, reducing stormwater runoff, and capturing CO_2, this thesis will underscore the importance of interconnected solutions to San Antonio's climate challenges. This project will also incorporate the SPUR center's heat vulnerability index into evaluating the success of proposed cooling projects.

4. Viability of Vacant and Green Land

Guerry et al. (2023) define underutilized urban spaces as publicly owned lands that are currently not being used to their full potential, such as vacant lots, parks, and other natural areas within city limits. This definition will be used to designate all of San Antonio's vacant lots and green spaces to be included in this project's selection framework, as this project will seek to maximize their ecological and social potential.

Payen et al. (2022) emphasize the potential of these spaces for urban agriculture, demonstrating that even small areas can yield significant amounts of fresh produce while mitigating urban heat through increased vegetation. Similarly, Specht et al. (2014) highlight how protected green spaces provide an ideal setting for sustainable interventions, such as water retention systems and urban farming, as these areas are less vulnerable to redevelopment pressures. As San Antonio is confronted with increasing residential and commercial demands as its population grows, the utilization of these spaces emerges as necessary to tackle these challenges.

Greening vacant lots and existing parks offers significant ecological benefits beyond cooling, particularly for biodiversity and habitat connectivity. Habitat fragmentation, as Andrén (1994) highlights, reduces species survival by decreasing suitable habitat area, increasing isolation, and shrinking patch sizes. Vacant lots and parks, when repurposed for cooling, food forests, or infiltration basins, can counteract these effects by serving as critical habitat patches that enhance connectivity in fragmented urban landscapes. These spaces also foster synurbization, the adaptation of wildlife to urban environments, as described by Luniak (2004). Urban greening provides vital resources such as nesting sites, food, and shelter, enabling species to thrive amidst urbanization. Behavioral adaptations, such as extended breeding seasons and increased reliance on human-provided food, make species like urban birds and mammals particularly suited to utilizing these green spaces. Angold et al. (2006) add that brownfield sites and derelict land, often overlooked in urban planning, are unexpectedly rich in biodiversity. Transforming these areas into active green infrastructure can support diverse plant and animal communities, creating vital refuges for urban wildlife. Humphrey et al. (2013) emphasize that even small-scale greening projects can significantly impact biodiversity when they enhance habitat quality and serve as nodes in ecological networks.

This thesis builds on these findings by advocating for the strategic implementation of urban greening on San Antonio’s vacant lots and existing park spaces, emphasizing small-scale projects as a critical component of a broader ecological strategy. By focusing on smaller, underutilized areas, this approach not only aligns with the city’s growing need for sustainable land use but also demonstrates the potential for high-impact interventions to improve biodiversity, enhance habitat connectivity, and strengthen urban resilience. Through the integration of vacant lots and parks into ecological planning, this project contributes to the scholarly conversation by showing how targeted reuse through a water-heat-food framework can provide ecological solutions to interconnected problems.

5. *Environmental Justice in Food, Water, and Heat*

The lack of access to healthy foods and the oversaturation of unhealthy options in low-income and minority neighborhoods represent structural injustices linked to chronic health disparities (Hilmers 2012). In San Antonio, food deserts reflect these patterns, where spatial injustice and economic disempowerment have created pockets of severe nutritional vulnerability (SA Climate Ready). Water and heat-related injustices similarly follow historical lines of neglect and disinvestment. Miller (2014) documents how San Antonio's marginalized communities were systematically excluded from flood infrastructure planning, increasing their vulnerability to water-related hazards. Contemporary studies confirm that low-income communities also face disproportionate exposure to flooding and have less access to water infrastructure that supports long-term resilience (Montgomery 2015). These same communities often lack vegetation and cooling infrastructure, leaving them the most exposed to extreme urban heat (Hamstead 2023).

Addressing historical inequity in San Antonio's high-need areas not only builds climate resilience, but also fulfills key tenets of environmental justice by redistributing resources to those historically excluded. This thesis adds to existing literature by examining such a robust set of compounding environmental injustices and intersecting problems, providing equitable outcomes for affected residents by weaving together interventions in food, water, and heat.

6. *Policy Frameworks and Regional Cooperation*

Achieving sustainable urban transformation in San Antonio requires strong policy support and effective governance structures. Sandberg (2015) provides an analysis of Texas's policy gaps regarding food deserts and water management, advocating for reforms that promote cross-sector collaboration. Policies that support the repurposing of vacant lots for food production and water retention projects will be essential in driving sustainable development across San Antonio, enabling the city to address its environmental and social challenges comprehensively. Cisneros (1996) highlights the importance of regionalism in urban planning, emphasizing that municipalities benefit from working together to address shared challenges such as resource distribution and economic inequality. By implementing a holistic approach to urban sustainability, San Antonio can set a regional precedent for resource conservation while contributing to the health of the regionally-shared Edwards Aquifer. These insights support this thesis's call for policy frameworks that encourage cooperative, integrated resource management and sustainable land use.

Additionally, Ratcliffe (2022) underscores the need for an equity-centered policy approach in climate action, noting that San Antonio's existing climate plan initially prioritized equity but later shifted its focus to economic feasibility. This highlights the need for a policy framework that integrates justice and sustainability into environmental planning, ensuring that solutions serve all communities equitably. This thesis proposes that San Antonio pursue policies that address environmental needs in tandem with social equity, advocating for a policy shift that facilitates sustainable land development while promoting food and climate justice.

Research and Conceptual Framework

How can San Antonio adapt underutilized spaces to deal with these challenges? This thesis will demonstrate that repurposing San Antonio's vacant lots and parks for urban agriculture, water retention, and green infrastructure projects is essential as these methods create interconnected, community-centered solutions that don't interfere with greater development goals and maintain their ecological and social value.

This thesis adopts an land-based, socio-ecological framework to address the interconnected challenges of water scarcity, food insecurity, and urban heat in San Antonio. The framework is built upon the recognition that urban systems are deeply interdependent, requiring solutions that consider both environmental and social concerns. For example, increasing urban heat amplifies water demand, placing additional strain on already limited groundwater resources, while insufficient water availability undermines the viability of urban agriculture, perpetuating food insecurity. These challenges are not isolated but form a complex feedback loop, necessitating solutions that simultaneously address cause and effect.

By transforming underutilized urban spaces such as vacant lots and green spaces into multifunctional sites, this framework prioritizes interdependence between human and natural systems. Urban agriculture, especially food forests, not only improves food access but also contributes to urban cooling by increasing vegetation cover, which mitigates the urban heat island effect. Similarly, water capture projects support irrigation for agriculture while they reduce strain on aquifers and add to groundwater recharge. Evidence from urban, heat, and water interventions in West Texas, Dallas, and San Antonio, support the potential of these strategies to enhance climate resilience and social equity, especially in underserved neighborhoods disproportionately affected by resource scarcity. To ensure measurable societal benefits, this framework targets reductions in urban heat and improvements to food access towards the city's populations most vulnerable to these respective issues.

Existing scholarship addresses these issues individually, applying frameworks that only analyze one of urban agriculture, greening, or runoff capture in urban contexts. Certain studies, such as the Guerry et al. (2023), measure residual effects on carbon storage and local economies, but never directly analyze the effects of water, food, and energy solutions on each other. This project builds on the existing scholarship by creating a new framework for transforming land use that connects these pressing environmental issues to deal with them together. This framework is novel in that it combines unique land use methods into one comprehensive plan to provide actionable solutions for San Antonio's environmental problems, continuously exacerbated by climate change and demographic shifts. The principles developed in this thesis can be applied to cities similarly dealing with worsening resource scarcity and urban heat, providing feasible solutions with tangible results.

Data and Methods

This study investigates whether the adaptive reuse of vacant lots and existing green spaces can effectively address San Antonio's environmental challenges by integrating urban agriculture, water infiltration, and greening projects, estimating their collective impact on climate resilience and resource accessibility.

To assess the ability of these interventions, this study employs a GIS-based spatial selection framework, comparative case study analysis, and quantitative modeling. Public datasets from the Edwards Aquifer Authority (EAA), USDA Food Access Research Atlas, NOAA's National Weather Service, and San Antonio's Heat Vulnerability Index provide the necessary data to identify priority intervention areas and select sites for targeted projects. Metrics from case studies in similar environments are used to estimate expected groundwater recharge, food production, and cooling benefits from these proposed projects.

Each case study used in this research was selected for its relevance to San Antonio's semi-arid climate, water-stressed conditions, or urban development patterns. The Silva et al. (2024) study on water retention projects in West Texas is directly applicable due to shared climatic and hydrological conditions, providing a regional precedent for nature-based water retention solutions. Stafford et al.'s (2015) stormwater infiltration model, while developed outside of Texas, is universally applicable due to its reliance on hydrological infiltration metrics that can be adapted to the Edwards Aquifer. Similarly, the Guerry et al. (2023) study establishes yield metrics for underused land in San Antonio for both urban farms and food forests that I will apply to evaluate my own projected land transitions. The Aram et al. (2019) urban cooling study provides standardized vegetation-based cooling metrics that are translated into an applicable equation, while the Zhao et al. study establishes temperature differentials between shaded and non-shaded areas in San Antonio.

By leveraging these spatial analyses, established case study methodologies, and quantitative models, this research will determine whether adaptive land reuse in San Antonio can contribute meaningfully to groundwater recharge, urban cooling, and local food security. The results will be benchmarked against San Antonio's sustainability targets, providing a framework for adaptive reuse of these spaces to be integrated into city planning strategies.

Intervention Projects

This framework incorporates four types of intervention projects: infiltration basins, urban farms, food forests, and trees/vegetation. Each is selected not only for their role in addressing San Antonio's challenges related to water security, food access, and urban heat, but also due to their additional ecological and social benefits.

Infiltration basins (also known as stormwater retention/infiltration, infiltrating bioretention, rain gardens) are engineered depressions designed to capture and retain stormwater runoff, allowing it to gradually percolate into the ground rather than flowing directly into drainage systems or waterways. These basins are particularly beneficial in urban environments, where impervious surfaces like roads and buildings prevent natural infiltration, contributing to flooding and reduced groundwater recharge (Bhaskar 2018). By directing stormwater into these controlled areas, infiltration basins help replenish underground water sources, improve water quality by filtering out pollutants, and mitigate the impacts of heavy rainfall events (Birch 2005; Schroeder 2022). Their design can vary based on site-specific factors such as soil composition, drainage patterns, and available space and serve as natural flood control systems, reducing peak stormwater flows and preventing erosion in developed areas (San Antonio River Authority).

Figure 5. Structural diagram and image of bioretention cells designed for infiltration (i.e infiltration basins). Courtesy of San Antonio River Authority, Bexar Regional Watershed Management

Infiltration basins can be designed specifically to enhance their ecological functions, providing robust habitats, vegetative cooling, and fostering biodiversity (Monberg 2018). For this project, they will be well-vegetated with native, drought-resistant trees and plants to perform these ecological services while minimizing water usage.

Urban farms are intensively managed agricultural plots located within city limits, designed to provide fresh produce in areas with limited food access. They are particularly beneficial in food deserts, where access to grocery stores and fresh fruits and vegetables is limited. Urban farms utilize compact growing techniques, irrigation systems, and soil amendments to maximize food production in small spaces (Schroeder 2022). In addition to their role in food security, urban farms provide educational opportunities, local employment, and community-building benefits by encouraging local food production and sustainable practices (Guerry 2023). These farms are typically designed for high-yield crops, incorporating raised bed structures to optimize space and production. While they require careful management, soil preparation, and access to water, they serve as a critical intervention for addressing food insecurity in urban settings.

Food forests are perennial, self-sustaining agricultural systems that mimic natural ecosystems while producing fruits, nuts, and other edible crops. Unlike urban farms, which focus on high-yield, short-term production, food forests are designed for long-term sustainability, with multiple layers of vegetation, including canopy trees, shrubs, vines, and ground cover plants, working together to create a low-maintenance food production system (Guerry 2023). This approach promotes biodiversity, soil regeneration, and carbon sequestration, making food forests not only a source of nutrition but also an environmental asset (Bhaskar 2018). These systems require less intensive management than urban farms, as they rely on natural nutrient cycles and ecosystem interactions, but they still require initial soil preparation, tree planting, and long-term maintenance to ensure productivity.

Tree planting and vegetation initiatives focus on expanding urban canopy cover to mitigate the urban heat island effect, improve air quality, and enhance biodiversity. Trees and other vegetation reduce surface temperatures by providing shade, increasing evapotranspiration, and lowering heat retention in built environments (EPA 2008). Green infrastructure, such as street trees, park vegetation, and urban green belts, is an effective method for improving climate resilience in cities, reducing energy consumption, and supporting wildlife habitats (City of San Antonio). These projects will prioritize native and drought-resistant species to minimize water demands and ensure their long-term sustainability. In addition to cooling benefits, trees and vegetation contribute to stormwater management by reducing runoff and enhancing soil stability (Schroeder 2022).

The combination of these four interventions reflects a balanced approach, integrating water sustainability, food security, and climate resilience into a cohesive land-use strategy tailored to San Antonio's unique environmental and social landscape.

Environmental Indicators, Projection Metrics

This study evaluates San Antonio's environmental challenges through three primary indicators: groundwater levels, food desert distribution, and urban heat. Each indicator provides essential data for identifying high-priority intervention sites and measuring the effectiveness of urban agriculture, water retention, and greening projects.

Water scarcity in San Antonio is assessed through groundwater levels and spatial recharge potential. The Edwards Aquifer serves as the city's primary water source, and data from the Edwards Aquifer Authority (EAA) will be analyzed to evaluate historical water trends and recharge capability by respective aquifer zones. To quantify the impact of infiltration basins on groundwater recharge, this study applies the Stafford et al. (2015) model to estimate annual volume passed through the basin and recharge potential. The simplified recharge equation is:

$$R = P * A$$

where R is annual recharge (acre-feet), A is basin size (acres), and P is annual precipitation (feet). This equation is derived from Stafford's optimization model that also incorporates soil infiltration rate, evaporation, and drawdown time in a system where water would collect and pond within the basin. I chose to omit these variables, as optimal basin design can eliminate surface ponding. San Antonio's natural 'loamy clay' soil profile has an infiltration rate of about 0.3 inches/hour, which would typically cause severe ponding during rain events; however, San Antonio's guidelines for porous soil in infiltration basins allows infiltration rates spanning 1-6 inches/hour (SA River Authority) that can combat this effect. Point precipitation frequency in San Antonio shows that even during a 10-year storm (a storm that only occurs once every ten years/commonly used benchmark for rainfall), the peak 1-hour rainfall is approximately 2.61 inches (NOAA 2025). Basins for this project can be designed to support infiltration of 3 inches of rain per hour, thereby making them able to handle runoff during most storms. Moreover, higher-duration storm events (e.g., 6-hour or 12-hour storms) distribute rainfall over longer periods, reducing instantaneous infiltration pressure (NOAA 2025). Rapid infiltration would prevent ponding on the surface of the basin and thereby negate drawdown time, infiltration rate, and evaporation as variables, essential for a city that deals with rapid evaporation induced by its extreme heat. Therefore, we can simplify the equation down to a simple calculation of water volume passed through the basin.

Food deserts and their mitigation are measured using food desert mapping, socioeconomic indicators, and crop yield estimates. This study will use the USDA Food Access Research Atlas, which defines food deserts as low-income census tracts where at least 500 people or 33% of residents live more than one mile from the nearest supermarket in urban areas, using U.S. Census Bureau data to determine disparities in access. The ability of urban agriculture projects to mitigate food deserts will be assessed through Payen et al. (2022)'s crop yield estimation model, which provides a framework for projecting food production based on available land area. The equation is

$$Y = A * U$$

where Y is the annual crop yield (lbs), A is available agricultural area (acres), and U is yield per unit area (lb/acre). Through their case study, Guerry et al (2023) project that fully transitioning 16,800 acres of San Antonio's underused land to urban farms would produce 926 million lbs of produce annually, while transitioning the same amount of land to food forests would yield an estimated 192 million pounds (Guerry 2023). This equates to a yield per unit-area of 11,428.57 lbs/acre/year from food forests and 55,119.05 lbs/acre/year from urban farms. This metric will be applied to estimate potential food output from land designated to urban agriculture.

This study will also incorporate San Antonio's Heat Vulnerability Index to identify urban heat islands where cooling interventions can provide the most benefit. Heat vulnerability is used as it combines NOAA Landsat temperature data with economic hardship data to identify neighborhoods most affected by urban heat. The cooling impact of greening projects will be estimated using methodologies derived from Aram et al. (2019), which quantify the temperature reduction associated with increased vegetation. Cooling effects are projected using the following relationship,

$$\Delta T = \alpha * A$$

where ΔT is the expected temperature reduction (°F), α is the cooling coefficient (°F per ft^2 of vegetation), and A is the total area of greening implemented. Zhao et al., in their analysis of local climate zones in San Antonio, found that land surface temperatures beneath dense trees were 9ºF cooler than land surfaces amid densely built urban centers (Zhao 2018); the U.S Environmental Protection Agency also posits that peak air temperatures are reduced by 9ºF under shade. Therefore, this factor will be applied as the cooling coefficient to estimate the impact of urban greening projects on urban heat in San Antonio. By analyzing how green space interventions reduce heat exposure in high-risk areas, this study will determine the most effective approaches for mitigating extreme heat and improving urban livability.

Spatial Analysis, Site Selection

The spatial analysis process for this study begins with the identification and mapping of vacant lots and existing park spaces in San Antonio, which will serve as potential intervention sites for urban agriculture, water retention, and greening projects. To create a comprehensive spatial dataset, multiple sources will be used. San Antonio's public databases and ArcGIS will be analyzed to compile an inventory of municipally owned underutilized parcels.

This study employs a GIS-based site selection framework to ensure that interventions in urban agriculture, water retention, and greening are placed where they will have the greatest environmental and social impact. Selection is based on three key spatial factors: aquifer zones, land type, and food deserts, which will be analyzed using spatial layers representing data from the Edwards Aquifer Authority, the USDA Food Access Research Atlas, and San Antonio's Heat Vulnerability Index, Public Works database, and Parks Department.

All parks within the San Antonio Parks System were utilized for this study except for Government Canyon, the system's largest and most ecologically significant space. The canyon, located in the Edwards Aquifer recharge zone, already serves the hydrological and ecological responsibilities that infiltration basins or greening projects would while remaining a key recreational site for city residents. Furthermore, its location in the water sensitive recharge zone deems it unsuitable for agriculture projects.

Municipally owned lots outside of parks in San Antonio have varying degrees of suitability for these projects, and five types of vacant lot were identified and utilized in this study: remnant, surplus, possible surplus, easement, and row. Surplus/possible surplus lots are municipally owned land that are undeveloped and deemed excess by the city, easement lots are readily usable by the city as needed, remnant lots are free to use but contain vestiges of development, and row lots are small, thin vacant spaces typically adjacent to transportation, and thereby heat-absorbing materials such as asphalt; their allocation to vegetative cooling will hopefully mitigate this effect.

Infiltration basins will be prioritized in the Edwards Aquifer drainage and recharge zones, where they can maximize groundwater infiltration and ensure aquifer recharge, while urban agriculture projects will be prioritized in the artesian zone where shallow groundwater tables improve irrigation potential and enhance local water access. Parks and most vacant lots will be utilized for multi-purpose projects while row lots, too small and geometrically variable for such projects, will be designated solely for targeted greening to maximize cooling. Finally, urban agriculture projects will be prioritized in food deserts, as defined by the USDA Food Access Research Atlas, ensuring that food production efforts focus on communities with limited access to fresh, affordable produce. These layers will be overlaid onto the vacant lots and park spaces to identify priority intervention sites and allocate projects accordingly.

Parameter	Division of Vacant Lots	Division of Parks
Drainage, Recharge Zone	1.00 IB	.50 IB
Food Deserts	1.00 UF	.50 UF, .50 FF
Row Lots	1.00 TV	-
Other	.50 FF, .50 IB	.25 FF, .25 IB

Figure 6. Table depicting structured ratio framework for allocating projects by focus parameters.

The allocation of intervention projects follows a structured ratio-based approach, balancing the use of vacant lots and parks across different zones based on their suitability for each project type. In the recharge and drainage zone, all vacant lots were allocated entirely to infiltration basins (IB), while parks were split equally, with half designated for IB projects and the other half left undeveloped. This ensures that stormwater management remains the primary focus in this zone, without the interruption of water-intensive food production or vegetation projects. In food deserts, vacant lots were exclusively dedicated to urban farms (UF), maximizing their role in addressing food insecurity. Parks within food deserts were evenly divided between food forests (FF) and urban farms (UF), allowing for a mix of high-yield agriculture and long-term perennial food systems. For row lots, all available space was allocated solely to tree and vegetation (TV) projects, as these areas were not divided between multiple interventions like other parameters.

Vacant lots (besides row lots) outside of food deserts and the drainage/recharge zones were evenly split between infiltration basins (IB) and food forests (FF), ensuring a balance between water retention and food production while maximizing cooling efficiency. Parks in this category were also divided equally, with 25% allocated to food forests and 25% to infiltration basins, while the remaining portion was left undeveloped. This way, the usable park space in these areas is essentially maintained, as infiltration basins and food forests still maintain their recreational value as wooded green spaces. This structured allocation approach ensures that each intervention type is placed appropriately within its respective zone, maintaining a clear balance between food production, stormwater management, cooling initiatives, and green space access.

Assessing Impact: San Antonio's Sustainability Goals

Once sites have been selected and project impacts have been estimated from our metrics, this study will compare projected outcomes against specific benchmarks outlined in the San Antonio Climate Action & Adaptation Plan (CAAP), the SA Tomorrow Sustainability Plan, and the City of San Antonio's Water Management Strategies. These city plans establish measurable targets for water conservation, food security, and urban cooling, which provide a framework for assessing whether adaptive land reuse can contribute to San Antonio's long-term sustainability objectives.

San Antonio has set a sustainability goal of adding 100,000 acre-feet to the water supply by 2026, emphasizing the need for groundwater conservation and infiltration-enhancing projects (SAWS 2017). The effectiveness of these interventions will also be measured against San Antonio's broader water conservation strategy prioritizing increasing local water availability, promoting sustainable land use practices, and improving watershed health.

San Antonio's sustainability plans highlight the need for community-driven food solutions and increasing local food production as a way to build resilience against food insecurity. The SA Tomorrow Sustainability Plan outlines strategies such as expanding urban farming initiatives, creating sustainable food networks, and increasing access to locally grown produce in underserved communities. By comparing projected urban agriculture yields to these policy goals and the produce needs of food desert residents, this research will determine whether integrating food production into San Antonio's land-use strategy can help meet these targets.

San Antonio has prioritized reducing the urban heat island (UHI) effect as part of its Climate Action & Adaptation Plan (CAAP). The plan calls for an average reduction of 2.7℉ across the city and targeted cooling interventions in heat-vulnerable neighborhoods, where rising temperatures disproportionately impact public health and livability (City of San Antonio). This research also aligns with CAAP recommendations that emphasize increasing tree canopy coverage, urban reforestation, and nature-based solutions as primary tools for climate adaptation.

By comparing projected outcomes to San Antonio's officially stated sustainability goals, this research will determine whether adaptive land reuse is a viable, scalable solution for addressing food insecurity, water conservation, and urban climate resilience. If the study finds that the proposed interventions can significantly contribute to water retention, food production, and heat mitigation, the results will advocate for integrating vacant lots and green spaces into urban sustainability strategy through this comprehensive, land-based framework. This study will also highlight the importance of strategic land use in creating climate-resilient, community-driven solutions that benefit both the environment and local populations.

A challenge that emerges from these methods is the availability of more specific site information, such as site specific precipitation and soil conditions; these parameters were more easily defined on a city-average level or in specific zones around measuring stations. I will generalize these values as is applicable and justifiable, although this may affect some of the projections for these interventions.

Data Analysis, Results

This section examines the physical effectiveness of adaptive land reuse in addressing insecurity and water scarcity in San Antonio. This framework sought to alleviate food deserts and enhance groundwater recharge by converting vacant lots and parklands into urban agriculture sites and stormwater retention ponds, providing additive cooling through these projects and supplementary vegetation.

This discussion first evaluates the success of urban agriculture, emphasizing how the substantial food yield from repurposed land could provide fresh produce to a significant portion of the food-insecure population. It will then transition to an assessment of groundwater recharge efforts, illustrating the short and long term contributions of stormwater retention basins relative to San Antonio's ambitious water sustainability targets. Next, this project will analyze projected temperature reductions from vegetated row lots, food forests, and infiltration basins against San Antonio's lofty 2.7 degree reduction, and focus more so on providing residents shelter from extreme heat. The analysis further explores the role of land availability, highlighting the overwhelming dominance of parkland over vacant lots and how this distribution influenced these interventions. These findings will be situated within broader urban planning considerations, discussing the implications for future sustainability initiatives and the need for strategic and effective adaptive land reuse. Finally, this section will contextualize these results within the scope of environmental justice, exemplifying this project's devotion to curing historical inequities and providing relief and resources to San Antonio's most neglected and underinvested communities.

Spatial Analysis

Spatial analysis of park boundaries and vacant lots determined the acreage of available land both within priority aquifer zones and food deserts, and outside of them. The following table reviews the structured allocation ratios for projects and details total acreage by intervention parameter and project type.

Parameter	Park Acreage	Vacant Acreage	Total Project Acres	Division of Vacant Lots	Division of Parks
Drainage, Recharge Zone	5,247.76	.98	2,624.86 acres IB	1.00 IB	.50 IB
Food Deserts	5,299.45	8.66	2,649.72 acres FF 2,658.39 acres UF	1.00 UF	.50 UF, .50 FF
Row Lots	-	16.79	16.79 acres TV	1.00 TV	-
Non-Priority	8,211.00	16.02	2,060.76 acres FF 2,060.76 acres IB	.50 FF, .50 IB	.25 FF, .25 IB

Figure 7. Table detailing total usable land acreage and spatial allocation of parks and vacant lots into identified focus parameters, reviews project allocation ratios.

The map below illustrates the spatial distribution of both vacant lots and parks throughout San Antonio, with data derived from the City of San Antonio's GIS data portal and its Public Works Database, showing park boundaries in green, blue points for municipally owned surplus, remnant, and easement lots (meant for multi-purpose interventions), and smaller tree symbols for row lots. These site locations are overlaid onto the spatial boundaries of food deserts and aquifer zones that determine project types and the division and allocation of each land parcel. These layers were also overlaid onto the heat vulnerability map to demonstrate the prevalence of intervention projects in San Antonio's most heat vulnerable neighborhoods.

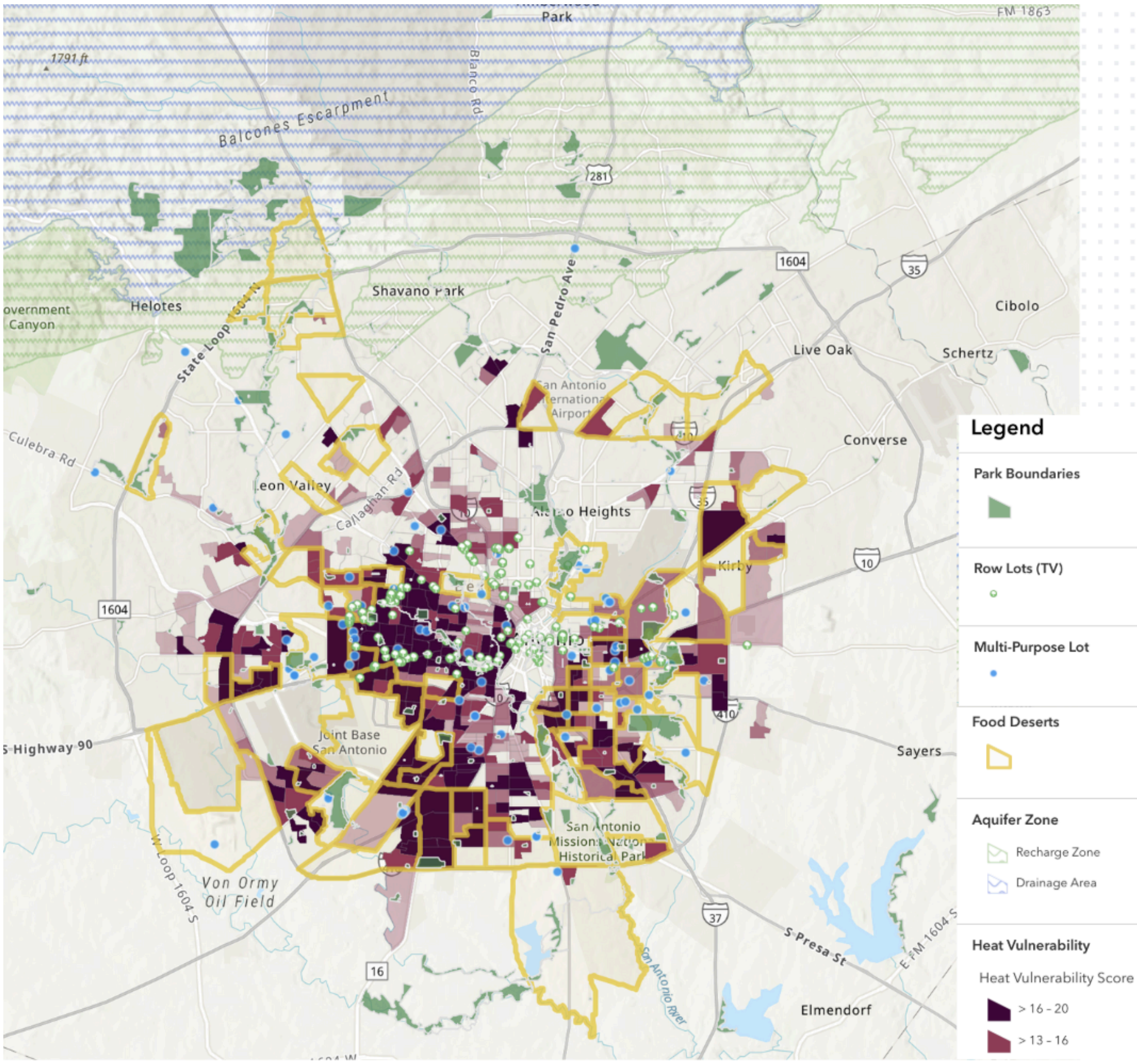

Figure 8. ESRI GIS Map overlaying proposed project sites onto food deserts, the Recharge and Drainage zones of the Edwards Aquifer, and heat vulnerable neighborhoods with an index score >13. Data made available by the EAA, USDA, University of Texas San Antonio, City of San Antonio. ***Click here or on the map to open in a new window***.

Urban agriculture projects were primarily concentrated within food deserts, as all 8.66 acres of vacant land within this boundary were converted into urban farms (UF), while 5,299.45 acres of parkland were divided evenly between urban farms and food forests. Stormwater infiltration projects were prioritized within the Edwards Aquifer drainage and recharge zones, with 0.98 acres of vacant land there fully allocated to infiltration basins in addition to half of

5,247.76 acres of parkland. Row lots, totaling 16.79 acres, were exclusively allocated to tree and vegetation (TV) projects, reinforcing their role in urban cooling and providing environmental benefits without being divided among other interventions. Besides row lots, usable land parcels outside of designated aquifer zones or food deserts, which include 16.02 acres of vacant land and 8,211 acres of parkland, were evenly split between food forests and infiltration basins. All vacant land was evenly divided between these two interventions, while remaining parks were split in half, one half accommodating both food forests and infiltration basins and the other left undeveloped.

The spatial distribution of vacant lots and parklands played a crucial role in determining these interventions. San Antonio has 25.66 acres of municipally owned vacant lots, a relatively small amount compared to its 30,307.26 acres of parkland (recall that Government Canyon was omitted from these projections but is still included in the Parks System). While vacant lots were initially considered a prime target for urban agriculture and stormwater retention, their limited availability suggests that they may not be the most scalable solution in San Antonio's case. Instead, parks provided a far greater opportunity for adaptive reuse. The majority of urban agriculture took place within parklands, both inside and outside of food deserts, due to the prevalence of public green spaces. Similarly, stormwater retention efforts were primarily located within parks, particularly within the Edwards Aquifer priority zones. This spatial reality suggests that while vacant lots can contribute meaningfully to urban sustainability, their impact is inherently constrained by availability. Cities like San Antonio, with limited vacant land, may find greater success in leveraging public parklands for sustainability interventions rather than relying on scattered vacant parcels. This framework includes both land uses for this reason, as cities have varying degrees of both vacant lots and usable park spaces.

Projected Yields

The implementation of urban agriculture and stormwater retention projects across San Antonio's vacant lots and parklands resulted in significant increases in food production while contributing modestly to groundwater recharge and providing adequate refuge from severe urban heat. The table below outlines applicable data, equations, constants, and projects yield metrics.

Problem	Intervention	Total Project Acreage	Constants	Model	Yield
Heat	Trees, vegetation (TV) Food Forests (FF) Infiltration Basins (IB)	TV: 16.79 FF: 4,710.48 IB: 4,685.62	α = 9ºF cooler per acre Total Area (TA) = 294,995.2 acres	$\Delta T = (\alpha * A)/TA$	**9,412.89 acres cooled by 99 ºF** **0.29°F decrease in entire city average**
Water	Infiltration Basin (IB)	IB: 4,685.62	P = 30 in/year = 2.5 ft/year	$R = P * A$	**11,714.05 acre-feet per year**
Food	Urban Farms (UF) Food Forests (FF)	UF: 2,658.39 FF: 4,710.48	Unit yield (U): FF: 11,428.57 lbs/acre UF: 55,119.05 lbs/acre/year	$Y = A * U$	**200,361,982 lbs per year (176,810,442 lbs/year within food deserts)**

Figure 9. Table depicting intervention allocation by acreage, and projected impacts on heat, water, and food problems in San Antonio.

The total annual food production from urban agriculture interventions was estimated at 200,361,982 pounds, 88% percent of which (176,810,442 pounds) to be produced within food deserts alone. According to federal diet guidelines, a healthy adult should consume roughly 360 pounds of vegetables in a year (USDA); by this metric, the projected yield would nearly double the vegetable consumption of all 307,277 people (110,619,720 lbs) currently living in San

Antonio's food deserts. This framework would erase the city's food desert problem entirely from within these communities by providing them with stable sources of fresh produce. Furthermore, the 200,361,982 pounds of produce grown throughout the entire city would make up nearly 39% of the entire city's produce consumption, reducing San Antonio's reliance on surrounding farms and foreign imports.

In a year experiencing average rainfall, stormwater infiltration basins allocated across San Antonio would contribute 11,714.05 acre-feet of groundwater recharge annually, which represents 11.71% of San Antonio's goal of adding 100,000 acre-feet to the city's water supply by 2026. Over the course of a few years, the long-term enrichment of the water supply provided by these sites would eventually surpass 100,000 acre-feet, especially if the city were to experience periods of above-average rainfall. This indicates that while these interventions provide significant benefits, they alone are insufficient to meet the city's immediate water sustainability target. In addition to long-term groundwater recharge, these projects help build the Edwards Aquifer's resilience to environmental stresses, decreasing risks of drought, desertification, and erosion by strengthening the local watershed and ecosystem.

The urban greening efforts, including tree planting, food forests, and vegetated infiltration basins, contributed to 9,412.89 acres of land experiencing a localized temperature reduction of 9°F. While this effect provides significant relief in concentrated areas, its overall impact on citywide temperatures was modest, leading to an average temperature decrease of just 0.29°F across San Antonio. This demonstrates that while urban forestry and vegetation projects are effective at mitigating extreme localized heat, they are not sufficient alone to counteract the broader urban heat island effect. However, these cooling benefits still play a crucial role in improving public health and increasing urban resilience, particularly in areas most vulnerable to heat exposure.

Environmentally Just Outcomes

From an environmental justice standpoint, this project addresses the spatial and structural inequities that have long affected San Antonio's most vulnerable communities. By providing nearly double the amount of produce needed to meet the dietary needs of all residents currently living in food deserts, the framework eradicates one of the city's most persistent public health and equity challenges, supplying healthy food and reducing residents' dependency on distant grocery stores. This shift lessens the physical and economic burden of traveling long distances in extreme heat and removes a key barrier to nutritional access, aligning with environmental justice by enhancing access to essential resources. Additionally, the placement of stormwater infiltration basins in underinvested communities mitigates historical flood vulnerability (Miller 2014), controlling erosion and flooding by replacing deteriorating drainage infrastructure with climate-resilient, nature-based design.

The project's urban greening efforts, in addition to food forests and vegetated basins, also deliver critical environmental justice benefits in areas suffering from both food insecurity and extreme heat exposure where vegetative cover and cooling infrastructure are scarce (Brown 2023). The cooling of 9,412.89 acres by 9°F, especially in these overlapping zones of vulnerability, provides direct relief to residents who face compounding food, water, and heat challenges. In sum, this thesis not only demonstrates the ecological potential of adaptive land reuse but exemplifies how strategically placed interventions can mitigate harmful environmental injustices.

Limitations

While the results of this framework demonstrate promising potential in addressing food insecurity through urban agriculture and water retention, several limitations complicate the full realization and scalability of these interventions.

Generalized Data, Equations

One major constraint is the lack of site-specific rainfall data, which could significantly affect the accuracy of both the groundwater recharge projections and agricultural yield estimates. The 30 inches of annual rainfall used in recharge calculations represents a city-wide average already extremely variable year to year, and precipitation can still vary across different neighborhoods and seasons. This variability could not only complicate modeling groundwater recharge, but also impact water availability for crops.

Another limitation of this study is the use of simplified equations to estimate groundwater recharge, food production, and urban cooling impacts, which inherently reduce the complexity of real-world hydrological, agricultural, and atmospheric processes. By relying on uniform yield estimates and average cooling coefficients, this approach does not fully account for spatial variability in soil composition, rainfall distribution, microclimates, or land-use interactions, all of which could influence the accuracy of the results.

Additionally, a more detailed urban agriculture model could include variables such as soil fertility and crop diversification to refine food production estimates, while urban heat reduction models could integrate wind flow, shading effects, and surface albedo changes to improve precision in temperature reduction projections. Similarly, more advanced hydrological modeling would incorporate factors like evapotranspiration, runoff coefficients, and subsurface flow dynamics. It is worth noting that this study does not incorporate runoff from nearby areas into infiltration basins, which is integral to their design; this means that these projections still underestimate stormwater infiltration even while not accounting for water losses due to neglected variables.

However, despite these simplifications, the chosen equations allow for a practical analysis of land repurposing strategies without requiring highly localized data that may be unavailable or difficult to integrate at a citywide scale. This study prioritizes a more general approach to demonstrate the potential impacts urban agriculture, stormwater retention, and urban forestry can have on city-scale problems. Before the implementation or construction phase, further research should refine these estimates with more granular data and advanced modeling techniques. This simplified approach, however, provides a foundational understanding of the feasibility and impact of adaptive land reuse strategies in San Antonio.

Cost

Additionally, the economic feasibility of implementing large-scale urban agriculture and retention projects remains uncertain. Costs associated with soil preparation, irrigation infrastructure, crop maintenance, and stormwater management could be substantial, and without sustained financial investment, these projects may not be scalable. Redevelopment costs, especially on parcels with remnant development, can be very high, and routine inspection is required for most infiltration projects.

However, while initial costs can be high, investments in local food systems have been shown to lead to long-term savings by reducing food transportation costs and strengthening local economies (Golden 2013). Similarly, stormwater retention projects can help reduce flood damage and ease pressure on municipal water supplies, leading to potential cost savings for city governments (Guerry 2023). Lastly, the approach assumes that all allocated land would be effectively utilized, but bureaucratic hurdles, zoning restrictions, and local opposition could slow down or prevent implementation in certain areas; however, underutilized municipally owned land allows for interventions to be implemented more efficiently and cheaply than on privately owned land that can require extensive negotiations, incentives, or land purchases (Guerry 2023).

Temporality

A reasonable criticism of this framework might be that repurposing urban land for agriculture and water retention is not a permanent or scalable solution, particularly in fast-growing cities like San Antonio where land availability is constantly changing. Critics may argue that as cities expand, the demand for housing and commercial development could outcompete urban agriculture and retention projects, rendering them temporary rather than long-term solutions.

While this is a valid concern, urban agriculture and water retention do not have to conflict with urban growth. Many cities have successfully integrated food production into existing urban spaces without hindering development, such as through community gardens, mixed-use developments, and land trusts (McClintock 2014). Additionally, urban agriculture projects can be adapted over time, allowing cities to reallocate land as needed while still benefiting from increased local food production in the short term (Grewal 2012). Furthermore, most of the projects lie on land parcels either protected as park spaces or too small to be effective in mitigating the housing problem; development should prioritize larger-scale, multifamily housing projects that this framework does not interfere with.

The Park Problem

Finally, the framework relies heavily on repurposing public parklands, raising significant concerns about the loss of recreational space and its broader social implications. Parks serve as vital community hubs that provide residents with spaces for exercise, relaxation, and social interaction, all of which are essential for physical and mental well-being. Converting large portions of these spaces into urban agriculture sites or stormwater retention ponds could reduce available recreational areas, limit opportunities for outdoor activities, and alter the aesthetic and functional landscape of neighborhoods. Moreover, the ecological and environmental functions of urban parks must also be considered. Repurposing them for agriculture could disrupt local ecosystems, reducing habitat for native plants and animals while potentially increasing soil degradation, pesticide runoff, and irrigation demands. Additionally, stormwater retention basins, while beneficial for water management, may require modifications that restrict public access, reduce usable space, or introduce safety concerns such as standing water or mosquito breeding.

However, transformed park spaces can still conserve at least some of their ecological and recreational services. For example, larger recharge basins in parks can be designed to enhance biodiversity, create habitat, and provide additional benefits like flood mitigation and water purification, mitigating the ecological impact of water retention projects. In the absence of rain, especially given San Antonio's semi-arid climate, most infiltration basins are essentially functional green space that can be easily enjoyed by residents. Furthermore, publicly-accessible urban farms can still provide recreation for city residents with the dual benefits of accessible produce and outdoor spaces where residents can socialize and learn new skills, and food forests retain most of the ecological and recreational value of traditional forests. While no longer "traditional" park space, the repurposed park areas in these projects still are usable for recreation and leisure, while bringing educational benefits to San Antonio communities as well. Furthermore, the majority of transitioned vacant lots underneath this framework become usable green space in the form of infiltration basins, food forests, and vegetated lots, effectively proliferating small pockets of park space throughout the city.

Applications

Despite these limitations, this framework does effectively provide a valuable blueprint for other cities seeking to enhance food security and water sustainability through adaptive land reuse. While San Antonio's semi-arid climate and limited vacant land shaped the specific outcomes of this study, the core concept of repurposing underutilized spaces for urban agriculture, water retention, and cooling can be adapted to various urban environments. In cities with abundant vacant land, such as Detroit or Cleveland, large-scale urban farming initiatives could provide even greater food yields, potentially eliminating food deserts entirely without the need to convert park spaces. Conversely, cities with severe water scarcity, such as Phoenix or Las Vegas, may find that stormwater retention efforts can aid groundwater recharge and supplement existing water conservation measures. In cities where land is highly constrained, such as New York City or San Francisco, adapting the framework to integrate other underused urban spaces such as rooftops, vertical walls, or community gardens into water, food, and heat solutions may be a more viable solution than reallocating ground-level spaces.

The limitations observed in San Antonio highlight the importance of tailoring these interventions to a city's specific geographic, regulatory, and social conditions. Furthermore, this framework is designed to accommodate San Antonio's rapidly rising population in the face of climate-induced resource scarcity and variability; it is paramount that this land-based framework be coupled with prioritizing multifamily housing so that this project does not interfere with the city's greater ability to support new residents. While no single model will work universally, the goal of this project was to offer a scalable and adaptable framework for cities aiming to improve local food and water systems by integrating food production, water retention, and urban cooling into city planning and maximizing the output of underutilized urban spaces.

Conclusions

This study set out to determine whether the adaptive reuse of vacant lots and parklands could effectively address food insecurity and water scarcity in San Antonio. The interventions proposed by this framework erase the problem of food deserts and provide 39%% of all produce needed by the city, provide over 11% of the city's lofty goal to add 100,000 acre feet to the annual water supply by 2026, and cooled peak air temperatures by 9 degrees Fahrenheit on over 9,000 acres within the city, decreasing the city-wide average by .29 degrees Fahrenheit.

This strongly supports the hypothesis that urban agriculture can be a viable tool for alleviating food insecurity, especially when strategically placed in areas with limited access to fresh produce. The water recharge efforts did not yield comparable success, contributing about 11,714 acre-feet per year to San Antonio's water supply but falling short of the city's immediate goal. These findings suggest that while stormwater infiltration basins provide great benefit to local water conservation, they are not sufficient on their own to meet short-term sustainability targets, instead being more valuable in long-term aquifer enrichment. Finally, the reduction in the city's average temperature by .29 degrees Fahrenheit does not do much to meet the city's goal of reducing the citywide average by 2.7 degrees Fahrenheit, but does more to create nearly 9,000 acres of refuge from urban heat, thousands of which are located within the city's most heat vulnerable areas. In a city that will continue to experience worsening temperatures, the cooling of such a large expanse of the city will be crucial for heat-vulnerable residents looking to escape the sun.

Additionally, the limited availability of vacant lots in San Antonio meant that many interventions relied on repurposing park spaces, raising questions about the trade-offs between sustainability initiatives and the preservation of recreational areas. Ultimately, these results answer the initial research question by demonstrating the potential of adaptive land reuse as a targeted, localized solution for food insecurity but highlighting some limitations as a large-scale water conservation strategy. The study underscores the need for complementary approaches, such as improved irrigation efficiency and alternative water sourcing methods, to meaningfully address San Antonio's broader environmental challenges. While adaptive land reuse can play a crucial role in building climate resilience, it must be integrated into a larger, multi-faceted sustainability framework to maximize its long-term impact.

In public health, the snowball effect refers to a positive feedback mechanism in which small, localized actions lead to increasingly larger impacts over time, amplifying the overall effect of an intervention (Green 2014). This dynamic is particularly important in the context of environmental and urban health planning, where individual improvements in access to shade, food, or water can cascade into broader public health outcomes. For example, reductions in surface temperatures as a result of these projects can lead to decreased incidence of heat-related illnesses, reduced stress, and lower rates of respiratory and cardiovascular issues (Stone 2010). Infiltration basins that incrementally recharge groundwater can also extend the lifespan of local aquifers and buffer communities against future water shortages during periods of drought. When combined with expanded access to fresh produce from urban agriculture, these interventions collectively improve physical and mental health, community resilience, and resource equity.

Furthermore, these interventions will disproportionately benefit those most affected by food deserts and extreme urban heat. The residents who currently struggle most to find fresh vegetables will be provided robust access to cheap and fresh produce in their communities, and residents in heat-vulnerable neighborhoods will utilize shaded refuge the most. As such, the framework proposed in this project functions not only as a set of interconnected environmental strategies, but as a public health multiplier that delivers long-term, compounding benefits to San Antonio's most vulnerable communities.

The framework adopted by this study is ambitious and, considering the aforementioned limitations, not likely to be implemented in full. However, as previously stated, that was not the goal of this project; rather, this project's goal was to explore the feasibility and *maximum* impact of adaptive land reuse in addressing San Antonio's food, water, and heat challenges. By examining these interventions at the city scale, this study provides proof for how underutilized urban spaces can be leveraged against resource scarcity, offering a foundation for future research and policy development. While full implementation may be hindered by land availability, economic constraints, and competing urban priorities, the results highlight key opportunities for localized agricultural initiatives, water retention projects, and urban cooling efforts that can be integrated into broader municipal planning efforts. This framework can even be used as a selection tool for applying green infrastructure projects to environmental problems, with more precise measurements and projections upon actual implementation on the scale of individual sites.

This framework can also be adapted to just focus on the priority areas, reducing overall yield but making implementation more feasible. This modified framework would still achieve the goals of this project to target solutions at the most affected and vulnerable populations. Moving forward, cities aiming to replicate elements of this framework should consider hybrid approaches such as these that blend urban agriculture, green infrastructure, and engineered water conservation strategies to create a more resilient and resource-efficient urban landscape. The insights gained from this study reinforce the idea that strategic interventions, even those at the neighborhood scale, can contribute meaningfully to urban sustainability and community well-being in the face of worsening climate change.

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