城市再造与韧性提升： 以绿色基础设施为导向的 闲置土地再利用的经济绩效评估

RESILIENCE THROUGH REGENERATION: THE ECONOMICS OF REPURPOSING VACANT LAND WITH GREEN INFRASTRUCTURE

1 引言

1.1 城市中日益增长的闲置土地

闲置土地现象普遍存在于城市之中^[1]。历史上，“闲置土地”（Vacant Land）一词偏向贬义，且常在与城市衰落相关的研究中被提及。少量闲置地块可能象征着经济增长（通常是人口增长型城市的特征），而大量闲置地块则意味着城市衰落（通常是人口减少型城市的特征）^[2]。随着闲置状况日益严重，城市研究者和设计师目前正在尝试建立一种机制，通过赋予其临时和永久性功能实现闲置土地的再生。

美国大城市有平均17%的土地被认定为闲置土地，同时，城市构筑物闲置率达4%^[3]。商业撤资、郊区化和城市区域兼并是闲置土地增加

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摘要

闲置土地的增多使得很多原本就遭受洪水困扰的城市的生态和社会肌理变得更加碎片化。在谈及闲置土地再利用时，重建往往被视为首要目标，但除此之外，它们本身也具有潜在的生态和水文价值。在高洪水风险社区中，与其盲目追求以发展建设为目标的闲置土地再造措施，更重要的是要在新增开发用地和建设绿色基础设施之间寻求平衡，以削减雨水径流、降低洪水影响，由此，我们提出了“通过再造提升韧性”的规划设计理念。以美国德克萨斯州休斯顿市的三个边缘化社区的规划设计实践为例，本文使用景观绩效评估方法评价绿色基础设施再利用项目的经济和水文影响。这三个规划设计场地都面临着闲置土地过剩和雨洪问题。评估结果表明，使用绿色基础设施实现闲置土地再利用将使得雨洪风险不断降低，（与传统开发模式相比）短期内前期投入成本增加，但长期经济回报显著提升。

关键词

城市再造; 社区韧性; 景观绩效; 绿色基础设施

ABSTRACT

Many urban areas affected by flood disasters are also becoming increasingly ecologically and socially fragmented due to the accumulation of vacant properties. While redevelopment is often viewed as the primary objective in regenerating vacant properties, they can also potentially provide ecological and hydrological land uses. Rather than chasing development-based incentives for regenerating vacant lots in high flood-risk communities, a balance should be sought between new developmental land uses and green infrastructure to help counteract stormwater runoff and flood effects, or “Resilience through Regeneration.” This paper uses landscape performance measures to evaluate the economic and hydrologic performance of green infrastructure regeneration projects for three marginalized neighborhoods in Houston, Texas, USA. Each project site is characterized by excessive vacant lots and flood issues. Results suggest that, when using green infrastructure to regenerate vacant properties, 1) flood risk continually decreases, 2) upfront economic costs increase in the short term (when compared to conventional development), and 3) the long-term economic return on investment is much higher.

KEY WORDS

Urban Regeneration; Community Resilience; Landscape Performance; Green Infrastructure

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1. 2017年休斯顿市的土地闲置状况以及三个设计场地所在位置
1. Vacant land in Houston in 2017 and locations of three case sites

的主要原因，而当地经济增长、人口迁入和城市政策利好往往有助于减少闲置土地面积^[4]。自1998年以来，城市范围内闲置土地的占比增加了1.3%，表明这一问题正日益加重^[3]。虽然不同区域间城市闲置土地的数量和类型存在差异，但面积小、形状不规则和碎片化的共性使其被再度开发利用的难度增大。

1.2 雨洪灾害和闲置土地

灾害事件可能会加剧土地闲置状况，导致闲置土地和废弃构筑物大量增加，该问题的缓解完全依赖灾后重建项目的开展。德克萨斯州海岸是全球最常遭受沿海风暴影响的地区之一。隶属该州的休斯顿市是美国发展最快的城市之一，却也是过去50年来雨洪灾害造成人员伤亡最惨重的城市之一^[5]。尽管城市发展迅速，仍然有近11%的土地处于闲置状态^[6]（图1）。其中，很多闲置土地都是郊区绿地，且已被纳入城市储备用地。非绿地性质的闲置土地多集中在城市的边缘化地区，且这些地区通常极易遭受雨洪灾害^{[7][8]}。但我们不必总是将闲置土地视为一个问题；如果得到恰当管理或重新利用，闲置土地完全可以帮助城市提升应对雨洪的韧性。因此，闲置土地不仅为城市转型创造了宝贵机遇，也为解决雨洪问题提供了潜在方案。

1.3 将闲置土地作为孔洞——一种另类的“海绵城市”

尽管面临着易遭受洪水侵袭、社会矛盾突出、城市闲置土地碎片化等挑战，但针对闲置土地再造的细致研究和设计尝试也为城市改造

1 Introduction

1.1 The Growing Issue of Vacant Urban Land

Vacant land is a ubiquitous urban phenomenon^[1]. A small number of vacant parcels can be an indicator of economic growth (typically characteristic of populating cities), while larger proportions of vacant area typically indicate urban decline (typically characteristic of depopulating cities)^[2]. Historically, the term “vacant land” has carried a negative connotation, and is often referred to alongside research on urban decay. The vacancy condition has grown to the extent that scholars and designers have now developed an agenda to begin to regenerate such properties through both temporary and permanent uses.

Nearly 17% of each large U.S. city’s land area is considered vacant, with an average of 4% of city structures unoccupied^[3]. Disinvestment, suburbanization, and annexation are reported as the primary causes of increases in vacant land, while growing local economies, population immigration, and city policies tend to help reduce the amount of vacant land^[4]. The ratio of vacant land to city size has increased by 1.3% since 1998, indicating a growing problem^[3]. While regional variations exist in both the amount and type of urban vacancies, many vacant parcels are small, odd-shaped, and disconnected, making them difficult to regenerate or repurpose.

1.2 Flood Disasters and Vacant Land

Disaster events can exacerbate the vacancy condition, resulting in massive increases in vacant parcels and abandoned structures until recovery can occur. The Texas coast is one of the most frequently impacted areas by coastal storms globally. Houston in Texas, is one of the fastest growing U.S. cities, and has one of the highest numbers of flood-related fatalities in the past 50 years^[5]. Despite its fast development, Houston reports nearly 11% of its land as vacant^[6] (Fig. 1). Many vacant properties in Houston are peripheral greenfields which have been annexed for future development, while the non-greenfield ones are mostly concentrated in marginalized communities, which are also typically characterized as highly vulnerable to flooding^{[7][8]}. Vacant land, however, does not always need to be viewed as a problem and, if managed or repurposed correctly, can contribute to flood resilience. Vacant land can present valuable opportunities for urban transformations as well as a potential solution to the flooding issues.

1.3 Vacant Land as Pores — A Prototype for the Sponge City

Despite the challenges associated with the flood vulnerability, social conditions, and disconnection of urban vacant land, careful

提供了巨大机遇。“海绵城市”这一理念将适应性水资源管理作为城市规划和政策制定的关键^{[9][10]}。海绵的多孔结构对于其吸收和保持水分至关重要。传统的以灰色基础设施为主的城市规划力求尽快将雨洪排出场地，而在不影响现有经济社会和其他城市功能的前提下，在这些城市中选址和布设海绵城市孔隙是非常困难的^{[11][12]}。因此，对于城市建成区而言，无论其正在经历增长或衰败，城市闲置土地再造策略都具有很强的适宜性和可行性，这些地块可以作为提高城市水适应性的孔隙。不同于其他常见的海绵城市实践，在这种策略下，海绵城市的实施并不会引发环境目标和经济目标的冲突，而是为闲置土地提供了前所未有的改造机遇，使其能够在提供生态系统服务的同时创造各种社会经济效益^{[13][14]}。

2 研究目的与设计流程

2.1 研究目标

“通过再造提升韧性”是指通过将闲置土地再利用为绿色基础设施（GI），从而减轻社区尺度雨洪影响的设计方法。运用这一方法，本研究以闲置土地改造为核心，提出了将GI纳入社区发展规划的策略，并针对其经济成本及效益进行分析。本文展示了位于德克萨斯州休斯顿市的三个社区——南方公园社区、曼彻斯特社区和向阳社区采用“通过再造提升韧性”方法的设计过程和绩效研究。三个社区均面临着雨洪困扰和高闲置率问题。笔者所在的美国德州农工大学景观设计与城市规划系的设计团队分别对三个社区进行了总体规划，提出新的开发和GI方案。每个规划方案都基于公众参与的设计方法，运用反馈链加强来自高校的设计师与当地社区居民的互动，从而辅助设计决策。设计完成后，我们对每个方案的经济和水文效益进行了评估和对比。目前，这些规划方案已经交由社区和地方规划机构汇编为官方施工文件，并纳入当地总体规划。

2.2 影响评估

研究应用了同一景观绩效评估工具对三个总体规划的水文与经济影响进行了分析。景观设计基金会（LAF）近年来开发和推广了一系列景观绩效评估工具，用以评价建成景观或规划设计方案与设计预期的

research and design efforts toward regenerating vacant land prove to be a huge opportunity for cities. The idea of “Sponge City” has raised attention to adaptive water management as a critical part of urban planning and policy-making^{[9][10]}. For a sponge to absorb and hold water, the composition of numerous small pores is essential. For cities that have been built based on traditional grey infrastructure to get water off site as soon as possible, siting and implementing these pores are often difficult without impeding the economic, social and other functions^{[11][12]}. Therefore, for existing cities that are either growing or shrinking, urban vacant land regeneration presents great suitability and feasibility to serve as the pores to enhance the water adaptivity of cities. Rather than creating conflicting environmental and economic objectives, as is noted with literature outlining the challenges of Sponge City, transforming vacant land offers unprecedented opportunities for ecosystem services, as well as a variety of economic and social co-benefits^{[13][14]}.

2 Research Objectives and Design Process

2.1 Objectives

“Resilience through Regeneration” refers to a design approach which seeks to mitigate community-scaled flood effects through repurposing efforts of vacant properties around green infrastructure (GI). Using this approach, this research examines the economic costs and benefits of retrofitting GI into community growth plans as a strategy for vacant land regeneration. The paper describes three design projects in Houston, which utilize the “Resilience through Regeneration” approach: South Park, Manchester, and Sunnyside. Each neighborhood is characterized by flood issues and elevated proportions of vacant land. Within each, a master plan which retrofits vacant lots and proposes new development and GI is developed by our team from Department of Landscape Architecture and Urban Planning, Texas A&M University. Each plan was created following a participatory design approach which utilized feedback loops between university personnel and community members to assist in design decision making. Then, we evaluated and compared the economic return and hydrologic benefits of each design. These plans have been given to the communities and local planning agencies and are being used to develop official construction documents for portions of each plan.

2.2 Performance Assessment

The performance evaluation process utilizes consistent landscape performance tools to capture the hydrologic and

匹配程度^[15]。这个工具包提供了各个方面的计算工具，可用来分析规划设计的社会、水文、经济影响。近年来，GI的经济效益逐渐显现，成为雨洪管理策略的重要组成部分^[16]。作为LAF工具中的一部分，美国社区技术中心（CNT）开发的“全国雨洪管理计算器”，也称为“全国绿色价值计算器”（GVC）是一款交互式工具，可以对比GI与传统雨洪实践在绩效、成本、收益等方面的差异。这款工具已在评估雨洪管理措施在提升水质^[17]、防洪^[18]等方面的效用，预测径流减少量^[19]，以及评估洪水径流蓄水量^[20]等方面得到广泛应用。其优势在于能够应用于社区尺度的规划设计，直观地反映GI的影响，以及集成了全美各地的雨洪、水文等信息。其计算流程包括：1）确定设计场地的平均降雨量；2）设定预期减少的雨洪径流量；3）界定不改建为GI的不透水地表面积；4）输入应用在场址设计中的GI类型。随后，GVC即能够计算出地表径流减少所带来的成本效益。GVC涉及各种GI的绩效评估，包括绿色屋顶、种植池、雨水花园、蓄水池/储水桶、本土植被、过滤带、改良土、路旁洼地、树木、停车场洼地、透水铺装等。在本研究中，我们应用GVC比较了GI和传统雨洪管理实践在成本、收益和绩效方面的差异^[21]。其中，绩效评估包括地表覆盖变化、为提供实用功能和休闲功能增加的GI、雨洪滞留量，以及经济收益。其中经济收益的评估是基于雨洪滞留、碳封存、空气污染减少、树木补偿价值、地下水补给、降低能耗，以及减少水处理开销等间接效益计算得出的。

2.3 土地闲置原因及选择

研究对在三个场地进行的研究中采取了同一套“闲置土地”界定标准，且使用的闲置土地数据均来源于休斯顿—加尔维斯顿区域委员会土地利用平台^[22]。该平台对“闲置土地”的定义为“已清理完毕但目前未被使用的土地”。在平台提供的数据库中，闲置土地被归为一种单独的用地类别。同时，数据库还对“未开发土地”（Undeveloped Land）与“闲置土地”进行了区分，将前者定义为“大部分面积仍被植被覆盖而无实质性改造的土地”。也就是说，开发潜力较小的土地

economic performance of the three master plans. The Landscape Architecture Foundation (LAF) has developed and recommended a series of landscape performance tools to measure the effectiveness with which existing or designed / planned solutions fulfill their intended purpose^[15]. The LAF's Toolkit offers a broad range of calculators to analyze social, hydrologic, and economic performance of designs and plans. Economic rationale of GI is emerging as an essential component of flood provision strategies^[16]. As one of the tools included in the LAF's Toolkit, the Center for Neighborhood Technology's (CNT) National Stormwater Management Calculator, also known as the National Green Values Calculator (GVC), is an interactive tool for comparing the performance, costs, and benefits of GI to conventional stormwater practices. This tool has been used to assist in assessing the effectiveness of stormwater management practices on water quality^[17] and flood proofing^[18], predicting runoff capture^[19], and evaluating stormwater runoff storage^[20]. The strengths of this calculator include its ability to be applied at the community scale, its emphasis on the performance of GI, and its integration of datasets regarding local storm events and other conditions. Through 1) determining the average precipitation of the site under investigation, 2) selecting a stormwater runoff volume reduction goal, 3) defining the impervious areas under development with no GI, and 4) inputting the types of GI utilized within the site plan, the GVC can be used to determine the cost-efficiency of runoff volume reduction. The GVC offers a range of GI facilities to be chosen from including green roofs, planter boxes, rain gardens, cisterns / rain barrels, native vegetation, filter strips, amended soil, roadside swales, trees, parking lot swales, and permeable pavement. In this research, the GVC was used to compare costs, benefits, and performance of GI compared to conventional stormwater management practices^[21]. And the performance evaluation included the land cover change, the increased amount of green space for utilitarian and recreational purposes, the amount of stormwater retention, and economic benefits. The economic benefits are evaluated based on stormwater retention, carbon dioxide sequestration, reduced air pollutants, compensatory value of trees, groundwater replenishment, reduced energy use, and reduced treatment costs.

2.3 Vacant Land Drivers and Selection

For this research, identical definitions of vacant land were used by all sites under investigation. Vacant land data was

被归为闲置土地，而其他空地则属于未开发土地——这种定义方式使闲置土地多以非开发式土地再利用的方式得以改造，GI建设是其中的途径之一。但是，由于三个社区都被视作服务水平低下的和/或边缘化的，尝试提高社区的当地经济、就业机会和社会凝聚力十分必要，因此我们仍然在部分闲置地块上引入了开发项目。

由于研究使用统一的土地利用数据库确定三个社区中闲置土地的区位，并利用同种工具——GVC评估三个总体规划的景观绩效，因此汇总的研究结论和比较结果可以概括“通过再造提升韧性”方法的潜在影响。在研究中，我们确保：1）采用统一的闲置土地定义和筛选方法；2）采用近似的设计过程和同样基于公众参与的流程；3）使用相同影响评估方法，从而增加了研究结论的可类推性。

3 设计和评估结果

3.1 德克萨斯州南方公园社区

3.1.1 项目背景

南方公园社区位于休斯顿南部且紧邻清溪河——这条与墨西哥湾航道相联通的河流导致该社区极易遭受洪涝灾害。但在飓风“哈维”期间，南方公园社区中发生的洪涝多数不是因为河流水位过高，而是由于明渠排水设施低效、老旧。尽管休斯顿的人口飞速增长，但南方公园社区长期存在土地闲置率居高不下的问题。2006~2017年间，休斯顿市的平均土地闲置率从20%下降到了11%，但南方公园社区的土地闲置率仍然保持在16%左右。目前，社区内大多数的闲置土地已闲置三年以上，这导致该社区的土地价值比休斯顿平均值低82%，比休斯顿中位值低61%（图2）。

obtained by the Houston-Galveston Area Council Land Use Portal^[22]; it defines vacant land as “land which was cleared but had no current land use.” Vacant parcels were coded as a separate land use within the dataset. Defined as still largely vegetated with no major apparent alterations, “undeveloped land” was also differentiated from “vacant land” within the dataset. Lands with lower development potential were listed as “vacant” while others were listed as “undeveloped,” making vacant land prime parcels for non-developmental repurposing through means such as GI. However, we also included some developmental program on selected vacant lands because each of these neighborhoods was considered underserved and / or marginalized, and it was important to try to increase their local economy, job opportunities, and social cohesion.

Because the same dataset was used to map all vacant lands across all three neighborhoods and the same tool (GVC) was used to measure landscape performance of each master plan, valid conclusions and comparisons across all projects can be made to generalize the potential effects of the “resilience through regeneration” approach. Purposeful efforts were made to 1) utilize the same definition and inventory method for vacant properties, 2) utilize similar design processes and equivalent engagement procedures, and 3) utilize the same performance assessment methodology to increase the generalizability of conclusions.

3 Design and Evaluation Outcomes

3.1 South Park, TX

3.1.1 Background

South Park is located in southern Houston along Clear Creek which connects to the Gulf of Mexico Ship Channel and makes it highly vulnerable to flood-related disasters. However, most of the floodings in South Park during Hurricane Harvey occurred because of ineffective and outdated open ditch drainage infrastructure, not from overtopping from the bayou. High vacancy rate has been a long-term problem in South Park, despite intense population growth in Houston. While the vacancy rate of Houston decreased from 20% to 11% from 2006 to 2017, the South Park community maintained a vacancy rate near 16%. Currently, a majority of lots have remained vacant for more than 3 years within the neighborhood. The land value in this neighborhood is 82% lower than the Houston average and 61% lower than Houston median (Fig. 2).

- 2. 南方公园社区的土地闲置情况
- 3. 南方公园社区总体规划
- 2. Vacant land conditions within the design site in South Park
- 3. Master plan for South Park

3.1.2 总体规划

为了改造城市闲置土地，设计提出沿主干道布设大量新开发项目，并创建多个大尺度社区公园，以刺激社区未来的经济发展（图3）。居住区中包括联排别墅、公寓，以及可负担的独栋住宅等各式各样的住宅类型。设计还为社区提供了许多新的功能性空间，包括商住两用房、家庭中心，以及沿次干道布设的宗教建筑。双侧的人行道以及社区花园可供居民开展户外休闲活动。为了有效减少洪水对社区的影响，设计建造了多个生态洼地以弥补明渠系统的不足，并将雨水从最易遭受洪水侵袭的地区导流至两个现有的滞留池中。在受洪水影响严重的区域设置了几个低影响生态洼地及雨水花园，以促进雨水的渗透和蒸散。设计对场地内的生态洼地、雨水花园、明渠、滞留区，以及下水道系统进行了改进，创造了一个相互联通的雨洪管理系统。

3.1.2 Master Plan

The design retrofits vacant land and proposes a majority of new development along the major arterial as well as larger-scaled community parks, to spur future economic growth (Fig. 3). Diverse housing types including townhouses, apartments, and affordable single family are dispersed throughout the residential areas. New functions such as live-work houses, a family center, and religious structures along secondary arterials are also proposed. Two-sided sidewalks and community gardens increase outdoor recreational opportunities for community members. In order to efficiently reduce the impact of floods, several bio-swales are built to enhance the inadequate open ditch system and convey stormwater from the most flood-vulnerable areas to two existing detention ponds. Several low impact bio-swales and rain gardens are integrated within severe flood-areas to promote infiltration and evapotranspiration. Improvements and connections are made for all designed bio-swales, rain gardens, open ditches, detention areas, and sewers to create an interconnected stormwater management system.

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3.1.3 设计影响

根据GVC的分析结果，该地块中85%的闲置土地将会被重新利用，90%的弃置构筑物将会被翻新、重建或拆除；15%的闲置土地将被改造成GI；约7hm²的新建GI将保护居民和财产安全，并显现生态以及经济效益。分析显示，与传统设计方法相比，设计使可渗透地表覆盖率增加15%，并减少超过45%的径流量；同时，每年可以收集186万立方米的雨水径流，创造260.6万美元的绿色收益（图4）。

3.2 德克萨斯州曼切斯特社区

3.2.1 项目背景

曼切斯特社区位于休斯顿东南部，被工业用地所环绕。同时，这里也是德克萨斯州水道老化情况最严重、水质最差的区域之一。其洪水受灾率在全美范围内排在前列。当地政府发起了名为“毒素之旅”的观光旅游项目，以促使居民及游客意识到社区严重的洪涝灾害及污染情况^[23]。社区内包含16%的闲置土地/废弃建筑，不透水铺装率高达68%。开放空间的极度缺乏使现有基础设施难以应对由频发的强降雨引发的洪涝灾害。

3.1.3 Projected Performance

According to the GVC, 85% of the site's existing vacant lots will be regenerated and 90% of existing abandoned structures will be refurbished, redeveloped, or demolished. Fifteen percent of the vacant properties will be regenerated into GI. Seventeen acres of new GI will protect residents and properties and provide both ecological and economic benefits. The GVC shows that, compared with conventional approaches, this design increases the site's permeable area by 15% and captures more than 45% of the runoff volume. Simultaneously, the design can capture about 65.7 million ft³ of runoff, creating over 2.6 million dollars in annual green benefits (Fig. 4).

3.2 Manchester, TX

3.2.1 Background

Manchester is located in southeast of Houston, surrounded by industries, and has one of the highest river impairments and lowest water qualities in the state. It is also one of the most flood-prone neighborhoods in the U.S. Local authorities provide sightseeing ventures named “Toxic Tours” for visitors and residents to raise awareness of the serious flooding and pollution conditions in the neighborhood^[23]. The site is composed of 16% vacant parcels / abandoned structures; 68% of the neighborhood's surface is currently impervious. A significant lack of open space makes the current infrastructure ineffective in preventing flooding caused by both frequent and intense storms.

- 4. 南方公园社区总体规划的影响评估
- 5. 曼切斯特社区总体规划
- 4. Projected performance summary of the master plan for South Park
- 5. Master plan for Manchester

3.2.2 总体规划

在设计中，大部分闲置土地被重新利用为GI（图5）。基于在公众参与环节收集到的社区反馈，绿地的新功能包含了集会空间、娱乐设施、可食性花园，以及包纳各种雨洪管理设施的公园。每一个居住街区都有由闲置土地改造而成的独立的健身花园。为了满足不同年龄层居民的需求，设计愿景中引入了更多的社区支持型服务，包括社区中心、儿童中心、老年俱乐部、医疗卫生设施、书店和图书馆。集市和社区中心成为推动当地发展的两大支柱，它们能够提高地方的商业收入，增加邻里活动，增强居民对社区的归属感。活动空间和社区中心为居民提供了举办传统文化与节庆活动的场所，而快闪集市能够让他们出售当地手工艺品和其他商品。食物配销中心可以将当地农民与食品店和菜场联结起来，并为贫困家庭提供粮食援助。通过提升街景和新建雨洪管理设施，可以抵消预景开发可能带来的负面影响。由于雨水流经和积水区主要位于街道上，因此设计主要考量了街景设施在解决雨洪问题时所能发挥的作用。设计在公路沿线采取了一系列低影响雨洪缓解措施来收集雨水，以弥补目前可用于收集雨水的排水沟和下水道系统容量不足的问题，同时还策略性地使用路缘坡道将雨水引

3.2.2 Master Plan

According to the design (Fig. 5), most of the vacant properties are repurposed as GI. Based on community feedback, new functionality of green spaces includes event space, recreational opportunities, edible gardens, and parks along with a mixture of stormwater management facilities. Each residential block was incorporated with its own fitness garden, which is retrofitted from existing vacant parcels. To satisfy the demand of various age groups, more community support services are also designed into the vision, including a community center, a children’s center, a senior club, health care facilities, a bookstore, and a library. The market and community center are two anchors to spur development, generate local business revenue, increase activities in the neighborhood, and strengthen residents’ sense of belonging to the community. Event spaces and the community center provide a site for residents to hold their traditional cultural celebrations / festivals while a pop-up market allows for selling local crafts and goods. A proposed food distribution center will connect local farmers with grocery stores and food markets, as well as offer nutrition assistance to disadvantaged households. Streetscape improvements and new stormwater mitigation facilities are proposed to counteract effects of any proposed development. Because the flow paths

入生态洼地中。雨水溢流则被引入到洪水削减系统中的其他雨洪设施中。经过设计的雨水花园在旱时亦可作为绿地供居民使用。

3.2.3 设计影响

在设计实施之后，绝大部分现有闲置土地将实现再利用。同时，绿地面积将增至当前的7倍，而透水地表面积的比例将从36%增至51%（图6）——这种变化可以显著提高雨水渗透能力。根据GVC的评估，该设计每年可以吸纳超过15万立方米的雨水，每年由多用途GI创造的绿色收益将超过500万美元。

3.3 德克萨斯州向阳社区

3.3.1 项目背景

向阳社区是位于德克萨斯州休斯顿南部的一个边缘社区，与南方公园社区相邻，同时也是极易遭受洪水灾害的超级社区。由于基础设施老旧而低效，向阳社区经常会遭受强降雨事件的严重影响，其中大部分洪水事件是由于明渠系统无法强效排水所导致的。向阳社区亟需解决的问题主要有4个：洪水影响、大量闲置土地、社区活动锻炼场所不足，以及GI匮乏。据当地居民称，导致这些问题的原因包括：落后的居住条件（9%）、基础设施不足（31%）、缺乏维护（26%）、安全隐患（22%），以及当地经济的衰退（12%）。该社区50%的面积位于百年一遇洪泛区域内。居民指出，为避免洪涝，新的开发建设应在地势较高处展开，但这将为现有住宅带来更多的洪水问题。由于明渠系统排水能力不足和缺乏有效的GI支持，在道路沿线和独栋住宅区内仍存在大量积水现象。

and ponding areas of stormwater are primarily located on the streets, streetscape amenities to deal with flooding issues are of primary concern. A series of low impact stormwater mitigation techniques are proposed along the roadways to help the current insufficient gutters and sewers collect stormwater. Curb cuts are also strategically located to direct the water to bio-swales along the streets. Excess rain water that cannot be collected is directed into the other proposed facilities as parts of a flood attenuation system. And designed rain gardens can serve as green space for residents in dry times.

3.2.3 Projected Performance

After the design is implemented, a majority of the existing underutilized parcels will be regenerated. Simultaneously, the amount of green space increases to nearly 7 times of its current amount while the percentage of pervious surface increases from 36% to 51% (Fig. 6). This change will strengthen the capability of water infiltration. According to the GVC, over 40 million gallons of stormwater can be retained annually, with over 5 million dollars of annual green benefits are generated from the multi-functional GI.

3.3 Sunnyside, TX

3.3.1 Background

Sunnyside is a marginalized and flood-prone super-neighborhood in south Houston, TX which is located tangent to South Park. Due to outdated and ineffective infrastructure, Sunnyside is severely impacted by large rainfall events and a majority of the floods were due to the inability of the open ditch system to provide adequate drainage. Four major issues affect Sunnyside: floodwaters, excessive vacant land, physical inactivity, and a lack of ecological infrastructure. The top five reasons these issues exist, as proclaimed by residents, were due to low housing conditions (9%), infrastructure inadequacies (31%), lack of maintenance (26%), security and crime concerns (22%), and local economic downturns (12%). Fifty percent of the design site is within the 100-year floodplain. It was noted by residents that in order to avoid flooding, new construction in the site is built at a higher elevation, which leads to new and increased flooding issues for existing housing. Due to the inadequate open ditch system and a lack of effective GI, many of the stormwater ponds are along the roads and within single-family residences.

3.3.2 Master Plan

The master plan (Fig. 7) proposes a GI system that will help mitigate the impact of future severe rainfall events. The system

- 6. 曼切斯特社区总体规划的预计影响
- 7. 向阳社区总体规划
- 6. Projected performance summary of the master plan for Manchester
- 7. Master plan for Sunnyside

3.3.2 总体规划

总体规划提出构建一个GI系统，用以缓解未来强降雨事件的影响（图7）。该系统由一系列生态洼地、雨水花园、滞留池、蓄水池、河岸走廊和翻新的停车场等组成，形成了一个内部相互连通的网络。由于洪灾风险极高、土地价值相对较低、就业机会短缺、贫困率高，目前该地区的发展潜力较低，因此大部分现有闲置土地将会被改造为GI，以消除社区内的积水现象。场地中所有新设计的口袋公园将同时用作防洪设施，并在独栋住宅区当前的积水地带设置雨水花园系统。设计的露天构筑物将在洪水发生时储存雨水，而每户独栋住宅后院的生态洼地则可以将雨水引入现有的明渠和地下排水系统。

设计还对4个现有滞留池进行了改进——在滞留池边缘增设的游憩平台可以为居民活动锻炼提供更多机会。而与这些滞留池毗邻的GI会在未来的洪水事件中吸纳从滞留池溢出的洪水。拟建的宗教建筑可在洪灾发生时作为避难所。生态洼地系统有助于收集超过当前容量的雨洪，再将其分流至现有排水系统中。商业中心的大型露天透水铺装停车场也可有效改善这块原本不透水的大面积区域的雨洪管理问题。

is formed through an interconnected network of bio-swales, rain gardens, detention ponds, retention ponds, riparian corridors, and parking lot renovations. Most of the existing vacant lots will be repurposed as GI in stormwater ponding areas, due to the current low development potential for high probability of flood damage, the relatively low land value, the lack of jobs, and high poverty. All newly proposed pocket parks on site will serve as flood attenuation pockets. In the single-family districts where identified standing water exists, a system of rain gardens is proposed. Outdoor structures store stormwater during flood events while bio-swales within backyards of single-family homes distribute stormwater to the existing open ditch and sewer system.

Four existing detention ponds are also improved through the design. Recreation decks along detention ponds increase physical activity time, while proposed GI facilities tangent to these ponds capture spillover during future flood events. A proposed religious structure also serves as a flood shelter during disaster events. The bio-swale system helps to capture stormwater exceeding current capacities and distribute it into the current system. The commercial center with large exposed permeable parking lot is also a good opportunity for stormwater management where excess impervious surfaces exist.

- 向阳社区总体规划的预计影响
- Projected performance summary of the master plan for Sunnyside

3.3.3 设计影响

通过GVC得出规划设计前后场景中捕获的径流量以及社区的总体收益。整体而言，设计预期将收集径流量的能力由49.6%上升至190.7%；58hm²的闲置土地将实现再生；步行空间面积增加4倍以上；林冠覆盖率将从23.9%提高到39.8%（图8）。

4 讨论与结语

本研究检验了以GI实现闲置土地再生的水文和经济效益。应用“通过再造提升韧性”这一设计策略，我们在德克萨斯州休斯顿市的三个贫困社区分别开展了独立的设计项目。这种方法同时整合了公众参与与针对场地特征的活动策划。在景观绩效方面，我们应用GVC评估了三个项目的影响。

虽然这三个项目运用了同样的“通过再造提升韧性”设计框架，但是每个项目中闲置土地的主要问题和应对策略都是不同的。不过，从三个项目的绩效影响可以总结出一些共性。表1~3呈现了通过GVC计算得出的三个设计的景观绩效对比结果。

首先，由于我们提出的再生策略所需开发费用较低，因此可实施性强。事实上，在这三个项目中，平均有95%的闲置土地都得到了重新利用。因为大部分闲置土地改造的目的不是为了开发新的建成区，而

3.3.3 Projected Performance

The GVC was used to calculate the runoff volume captured in pre and post scenarios as well as the overall benefits to the community. Overall, the ability of the proposed design to capture runoff volume increased from 49.6% to 190.7%. One-hundred and forty-three acres of vacant space will be regenerated, four times more walkable space will be created, and dense canopy coverage increases from 23.9% to 39.8% (Fig. 8).

4 Discussion Conclusions

This research examined the hydrological and economic effects of GI as a strategy for vacant land regeneration. Three design projects were carried out independently in three underserved neighborhoods in Houston, following a “Resilience through Regeneration” approach. This approach incorporates both public engagement and site-specific programming. For the landscape performance evaluation, we applied the GVC to the three master plans to assess the impacts.

Although the three projects focused on the same “Resilience through Regeneration” framework, they diverged in terms of the critical problems related to vacant land and the solutions to the problems. However, consistent patterns were revealed from comparing the impacts of the three projects calculated by the GVC and shown in Table 1 ~ 3.

First, our strategy to regenerate vacant properties is more easily performed because of less developmental expenses. In fact, 95% of

表1: 三个社区中使用的GI类型及其平均成本
Table 1: GI Types and their Average Costs Used in Three Case Sites

	南方公园社区 South Park			曼切斯特社区 Manchester			向阳社区 Sunnyside		
GI类型 GI Type	建造成本 (美元) Construction Costs (USD)	年维护成本 (美元) Annual Maintenance Costs (USD)	100年生命周期总成本 (美元) Total 100-Year Life Cycle Costs (USD)	建造成本 (美元) Construction Costs (USD)	年维护成本 (美元) Annual Maintenance Costs (USD)	100年生命周期总成本 (美元) Total 100-Year Life Cycle Costs (USD)	建造成本 (美元) Construction Costs (USD)	年维护成本 (美元) Annual Maintenance Costs (USD)	100年生命周期总成本 (美元) Total 100-Year Life Cycle Costs (USD)
绿色屋顶 Green Roof	---	---	---	63,000	150	79,859	323,678	514	410,294
本土植被 Native Plants	909,108	34,570	5,510,911	---	---	---	81,729	6,864	29,867,697
雨水花园 Rain Garden	2,493,960	51,135	6,874,389	7,000,112	41,147	15,918,221	709,618	32,467	2,956,002
透水铺装 Permeable Pavement	---	---	---	---	---	---	213,017	880	390,046
停车场洼地 Swales in Parking Lots	---	---	---	---	---	---	157,500	4,260	381,652
集雨桶/箱 Rain Barrels and Cisterns	---	---	---	410	14	1,041	---	---	---
树木 Trees	2,532,000	40,000	3,748,082	---	---	---	---	---	---
滤水性种植池 Tree Box Filters	19,444,160	52,320	26,537,918	---	---	---	---	---	---
路旁洼地 Roadside Swales	495,300	2,072	328,700	1,053,145	3,361	2,567,969	4,566,180	50,944	7,928,579

表2: 三个社区的GI效益
Table 2: GI Benefits in Three Case Sites

	南方公园社区 South Park		曼切斯特社区 Manchester		向阳社区 Sunnyside	
GI效益 GI Benefits	年收益 (美元) Annual Benefits (USD)	100年生命周期总收益(美元) 100-Year Life Cycle Benefits (USD)	年收益 (美元) Annual Benefits (USD)	100年生命周期总收益(美元) 100-Year Life Cycle Benefits (USD)	年收益 (美元) Annual Benefits (USD)	100年生命周期总收益(美元) 100-Year Life Cycle Benefits (USD)
减少空气污染 Reduced Air Pollutants	1,448	35,201	---	---	---	---
减少水处理开销 Reduced Treatment Benefits	80,787	1,629,625	2,071,085	65,402,290	60,646	19,050,168
降低能耗 Reduced Energy Use	---	---	1,323,885	40,597,038	1,036,103	40,008,531
碳封存 Carbon Dioxide Sequestration	960	30,420	---	---	---	---
树木补偿价值 Compensatory Value of Trees	1,913,000	48,212,702	---	---	---	---
地下水补给 Groundwater Replenishment	610,220	10,112,152	1,729,116	10,360,356	2,970	28,092,111

表3：三个社区的GI绩效及投资回报周期
Table 3: GI Performance and Return on Investment of Three Case Sites

	南方公园社区 South Park	曼切斯特社区 Manchester	向阳社区 Sunnyside
闲置土地减少率 Vacant Land Decrease	85%	100%	100%
绿地增加率 Green Space Increase	15%	8%	11%
年蓄洪量 Annual Stormwater Retention	73 806m ³ 19,497,528 gal	25 512m ³ 6,739,497 gal	152 899m ³ 40,391,716 gal
GI建造开销 GI Construction Cost	USD 29,874,528	USD 6,501,722	USD 8,116,667
GI年维护年开销 GI Annual Maintenance Cost	USD 180,097	USD 95,929	USD 44,672
GI生命周期开销 GI Life Cycle Cost	USD 43,000,000	USD 41,934,270	USD 18,567,090
GI年收益 Total Annual Green Benefits	USD 2,606,415	USD 1,099,719	USD 5,053,001
GI生命周期收益 Life Cycle Green Benefits	USD 60,020,100	USD 87,150,810	USD 116,359,684
投资回报周期 Return on Investment Time	70年 70 years	30年 30 years	20年 20 years

是用作GI，所以如果将来有建设需求，这些用作GI的空间仍可以转变为开发用地。设计新增的绿地可以提供暂时性或永久性的社会活动和雨洪管理功能。新增的节点能促进不同人群的社会网络、资源网络和活动网络之间的互动，激发城市活力，促进土地优化利用。

其次，新增绿地也有助于显著提高雨水滞留量。在三个项目中，绿地面积将平均增加11%以上。这些绿地每年可以滞留超过8.4万立方米的雨水，相当于休斯顿两个主要水库之一的阿迪克斯水库40%的储水量^[24]。

再次，设计中增加的绿地和GI在100年的生命周期中产生的经济收益远远大于前期的建造和维护成本。三个设计的平均总预算开销（包括建造和维护费用）为3 450万美元，而平均经济收益为8 780万美元，平均40年时间即可实现成本—收益抵消，开始获得投资回报。分析显示，建设开支是总成本中的重要组成部分，其中绿色屋顶的建设开支（约250美元/m³）较其他类型更高，而雨水花园在成本最低（约180美元/m³）的情况下能获得最高收益。

在很多案例中，项目初期成本极高，这使得边缘化社区不得不寻求额外的资金支持并分期进行开发建设。然而，本研究显示，若采用通过GI辅助闲置土地再生的方案，尽管项目初期阶段的短期成本有所增加，但长期的投资回报非常可观。需要强调的是，我们计算的成本—收益对比并不包括新增就业岗位、对当地经济的促进，以及节约的社

pre-design vacant lands were regenerated, on average across all three sites. Because a large proportion of the repurposed vacant properties were not based on developmental pursuits but GI, we could still transform the lands of GI into development lands in the future if needed. The green spaces can provide temporary or permanent functions to assist with social or hydrological needs. These newly created nodes will spur diverse interaction and networks of people, resources, and activities, which will potentially contribute to urban vitality and land use optimization.

Second, this increase in green space significantly assists in stormwater retention. Across all sites, the plans called for an average of over 11% of increase in green space. This results in over 22.2 million gallons of stormwater retained annually, which equals approximately 40% of the storage capacity of one of Houston’s two major reservoirs, Addicks Reservoir^[24].

Third, the economic benefits created by this increase in green space and GI over a 100-year life cycle greatly outweigh the upfront construction and maintenance costs. With an average total cost (including construction and maintenance) of 34.5 million dollars but an 87.8 million dollar economic benefit across all three sites. These benefits generally take around 40 years to produce a return on investment. Construction costs appear to claim a bulk of the overall cost total, green roofs have the highest overall costs (about USD 250 / m³) to construct while rain gardens provide the most benefits for the least cost (about USD 180 / m³).

In many cases, upfront costs are extremely high, so marginalized communities will need to seek additional funding and phase in such projects. However, this research shows that when using GI to assist in regenerating vacant properties, upfront economic costs increase in the short term while the long-term return on investment is much higher. It should be noted that this total cost-benefit comparison, however, does not include jobs created, local economy increases, social and public health savings, and savings from flood recovery costs. Although these benefits are not immediately capitalized, they are likely to serve as catalysts for growth and sustainability of the city.

Fourth, although all three designs explore the strategy of regenerating vacant land with GI and stormwater management, they propose different strategies for regeneration, based on the pre-design vacant land conditions and design priorities identified by residents. Future designers can draw lessons from the three prototypes. The South Park design represents a solution for an inland neighborhood that faces severe challenges in high percentages of vacant

会和公众健康开支及灾后重建费用等。尽管GI收益很难在短时间内兑现，但它们能够催化城市的增长和可持续发展。

最后，尽管三个设计方案均采用了以GI和雨洪管理为核心的闲置土地再利用策略，但具体措施却根据场地闲置土地现状和居民提出的设计重点而有所不同。未来对类似项目进行设计规划时，可以从本研究的三种设计原型中获得经验：南方公园社区的设计为同样面临超高闲置率（超过35%）的内陆社区提供了解决方案；曼切斯特社区的设计展示了一个受洪水影响严重、居民身心健康情况较差的滨水社区的改造方法；而向阳社区的设计则意在解决强降雨时由于老旧明渠排水系统造成的内陆洪灾。

本研究是首先提出在建成城区中通过渐进式设计再造来应用和评估海绵城市理念的尝试之一。设计方案展示了将闲置土地作为海绵城市中的孔洞对其进行利用和重建的原型。三个设计项目中水文和经济绩效的提高，证明这种设计策略有潜力应用在同样面临高闲置率和洪水灾害的城市。**LAF**

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land (more than 35%); The Manchester design demonstrates a solution for a riverfront neighborhood that is impacted by flooding and low physical and mental health; And the Sunnyside design provides an example for a neighborhood that has an outdated open ditch drainage system, which caused inland flooding during excessive rainfall.

As one of the first attempts to apply and evaluate the Sponge City principles as incremental strategies in existing cities, these projects demonstrated the prototype of utilizing and repurposing vacant land as the pores within the Sponge City. Based on the improved hydrological and economic performance across three different projects, it is indicated that these prototypes have the potential to be applied in cities that face similar challenges in increased vacancy rate and flood hazard. **LAF**

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