Environment Pollution and Climate Change
ISSN: 2573-458X
Kim et al., Environ Pollut Climate Change 2023, 7:6
Research Article
Open Access

Mapping Green Infrastructure for Storm Water Management: A Spatial Analysis in Northern Virginia, USA

Younsung Kim*[1], Colin Chadduck[1] and Vanessa Guerra[2]

[1]*Department of Environmental Science and Policy, George Mason University, USA*
[2]*School of Architecture, University of Virginia, USA*

Abstract

Green infrastructure is a range of measures that use plant or soil systems, permeable pavement, storm water harvest, and reuse to store, filtrate, or evapotranspiration storm water and reduce flows to sewer systems or to surface waters. Modifying regional capital assets with green infrastructure systems can provide multiple benefits, such as slower rates of evaporation, reduced regional heat, and social benefits like communal green spaces. In this study, we aim to create a spatial methodology to identify desirable places for green infrastructure where those benefits could be maximized in communities. To apply the methodology, the eastern Fairfax County, along the Route One Corridor in Virginia, was chosen as an experimental case. We find that multidimensional considerations can facilitate the creation of green infrastructure systems in places where storm water mitigation capacity and capital flow are strengthened, and long-term communal benefits are reaped more significantly.

Keywords: Green infrastructure; Digital elevation model; Spatial analysis tools; Urban planning

Introduction

Cities and regions worldwide face climate risks more than ever these days. The climate-induced ecological and social challenges include sea level rise, flooding from severe precipitation, damage to infrastructure, heat-caused mortality and illness, food and water scarcity, energy shortages, migration, and social conflicts, among others. Those challenges tend to exacerbate poverty and income inequality, making low-income communities or people more vulnerable to climate-induced risks [1].

Green infrastructure has emerged as a nature-based solution to mitigate or adapt to climate change and alleviate climate risks. At the macro level, green infrastructure is considered a landscape's entire network of natural and conservation areas, wilderness, parks, greenways, and other green spaces. At the micro-level, green infrastructure is defined as the range of measures that use plant or soil systems, permeable pavement or other permeable surfaces, storm water harvest, reuse, or landscaping to store or infiltrate storm water. Exemplary design solutions are bio swales, rain gardens, green roofs, or other relatively smaller regional or local scale installations to enhance ecological services [2].

In environmental planning, spatial mapping tools have been useful in mapping out green infrastructure and supporting environmental decision-making that frequently entails tensions regarding managing limited natural resources and land uses [3-33]. In visualizing green infrastructure, spatial mapping tools can showcase the need to build environment and natural ecosystems and maintain green infrastructure networks in ecologically sensitive areas like vegetated riparian zones [5,32]. As the concept of green infrastructure has been relatively new to traditional urban planners or landscape architects, civil engineers, and others interested in spatial structure, spatial mapping tools have played an essential role in improving urban sustainability [33]. However, prior scholarship is still lacking with respect to understanding key factors attributed with green infrastructure design in a way to maximizes ecological, economic, and social values.

This study intended to showcase a unique methodological approach to identifying a potentially desirable green infrastructure area in consideration of combined ecological design strategies and traditional urban planning models. Multi-level hydrologic, geographic, and economic factors have been combined, and Fairfax County and Alexandria City in Virginia were chosen as exemplary regions. Historically, the swampy portions of eastern Fairfax County were not densely settled except for river shipping ports like Alexandria City. The county's western part is less damp but still has considerable rain and water flow through the soil. Those geographic and geological conditions were considered when determining areas appropriate for green infrastructure for storm water mitigation, over-used nutrients or water pollutants filtering, and climate adaptation. In the following sections, we discuss the multifunction benefits of green infrastructure in cities or regions, describe a flow accumulation model, and explain how the model has been used in the case study context.

Literature Review: Benefits of Green Infrastructure

In the face of increasing climate risks and urban sustainability threats, infrastructure development must consider both economic and environmental factors. Also, regions' geographies and communities' unique social contexts should be factored when designing green infrastructure in urban areas [5]. Those considerations must also incorporate the input of neighbourhoods and community members placed with higher risks to climate change in light of a justice-oriented approach. Brownfield development that entails ecological restoration and long-term remediation process supports the development of green infrastructure [6,19].

Once green infrastructure is placed in communities, it provides

***Corresponding author:** Younsung Kim, Department of Environmental Science and Policy, George Mason University, USA, E-mail: ykih@gmu.edu

Received: 03-Nov-2023, Manuscript No. EPCC-23-120614; **Editor assigned:** 06-Nov-2023, PreQC No. EPCC-23-120614 (PQ); **Reviewed:** 20-Nov-2023, QC No. EPCC-23-120614; **Revised:** 23-Nov-2023, Manuscript No. EPCC-23-120614 (R); **Published:** 30-Nov-2023, DOI: 10.4172/2573-458X.1000358

Citation: Kim Y, Chadduck C, Guerra V (2023) Mapping Green Infrastructure for Storm Water Management: A Spatial Analysis in Northern Virginia, USA. Environ Pollut Climate Change 7: 358.

several, multifunctional benefits [7]. The first direct environmental benefits are ecosystem services to enhance biodiversity and ecological functions [6-8,20,21]. The benefits of ecosystem functions are based on discussions of rainfall events and flood control and include reducing non-point pollutant sources that result from decreased rainfall effluence [7-12]. Diminishing rainfall effluence and non-point pollutant sources offers benefits by protecting a region's ecosystems and maintaining water circulation [24]. By providing cities with green areas, green infrastructure adapts to and alleviates climate change impact through cooling. Also, green infrastructure protects biological diversity and habitats, contributes to ecological networks, improves the environmental quality of land, water, and the atmosphere, enhances microclimates, and reduces carbon emissions [13].

Secondly, green infrastructure systems produce economic benefits [14,25]. The economic benefits are understood in two ways. Capital deprecation due to climate change is the first juncture for economic gains. As climate change alters our ecosystem and economy at a fast speed, the rate of capital stock depreciation and destruction to roads, power lines, and homes will also increase and become more varied across geography. Capital depreciation is part of a regional system, and green infrastructure can alleviate capital depreciation in regional incomes. Furthermore, storm water could hurt regional economic stability, and mitigating storm water with green infrastructure can provide communal benefits [14,23].

In another setting, green infrastructure presents climate mitigation and adaptation benefits, addressing extreme heat, changes in precipitation patterns, and increased frequency of storms [15]. In particular, green infrastructure allows regional urban design leaders to mitigate against a region's environmental damage from usage patterns. For instance, if a usage pattern encourages building larger asphalt surfaces and concrete structures, those structures retrain heat, causing an increase in energy consumption that would become visible in the energy bill to manoeuvre or occupy that space. If heat can be reduced to the rise of green space in the same space, then energy to cool those urban forms would decrease, meaning energy cost would also decrease. In this way, an economic decision to add a green infrastructure system to mitigate storm water accumulation and damage would offer economic benefits. Green infrastructure promotes leisure activities and creates aesthetics in communities, offering advantages regarding nature's educational role and preserving historical natural resources [27]. Green zones expanded by applying green infrastructure and regenerating communities improve the accessibility of public services, provide safety by preventing crime and natural disasters, enhance communities' physical environments [22], and boost psychological, mental, and physical health [16]. Green infrastructure also empowers residents to manage resources by themselves to improve the environment, leading to an adaptive learning process where people can acquire knowledge to maximize ecosystem services.

The social benefits of green infrastructure include promoting fairness and reducing inequality. Related pressing challenges such as sea level rise and flooding from severe precipitation, energy shortages and damages to infrastructure, heat-related mortality and illness, scarcity of food and water, migration, and social conflicts, among others, exacerbate poverty and inequality in regions, placing human populations at risks [1]. The community health benefits would be greater in low-income and communities of colour that have been disproportionally impacted by brown infrastructure and land uses. With green infrastructure, community members can find a transformed environment and new ways of living, including vocation change [18,35-37].

To realize social benefits, assessment programs and proposals for green infrastructure siting should incorporate the input of neighbourhoods and community members from regions with higher vulnerability. Public information-gathering processes, for example, are one-way community members aim to claim their right to the city by resisting or advocating for change in city agendas. These social benefits could be significantly realized when deciding where to put green infrastructure and which area could be prioritized to install green infrastructure by replacing brown fields where non-point water pollution is rampant [19].

Methodology and Data

Geography

Fairfax County is in the far north-eastern part of the Commonwealth of Virginia. On the county's eastern side, the Potomac River and the associated marshland dominated the landscape. In the central and western portion of the county, there is a transition to what is referred to as the Piedmont region of Virginia, known more for rolling hills and a generally less marshy landscape. The Piedmont region of Fairfax County drains into the Potomac River through the eastern part of the county, creating a general west-to-east groundwater flow.

The human population of Fairfax County has been spread out throughout the space with higher-density settlements at historical centres of trade such as Fairfax city, Alexandria city, Arlington city, and Falls Church. There are more settlements around recent centres of trade and development, such as Reston, which breaks the model of regional development around historical patterns of settlement. Each should be noted for its regional importance and high population county. Our study area is in the eastern-central part of Fairfax County, just south of Alexandria City, through the Mouth Vernon Community, along the Route One Corridor. This specific study area was chosen because of the comparatively broad range of land cover types, third acre suburban lots, mixed-use multi-family developments, strip malls, and nature preserves, along with the relative economic importance of the Route One corridor in terms of regional development. A recent expansion of transit lines from single-modal design to multi-modal design indicates a regional interest and desire for development to better match the design of the community to climate change.

Route One has been listed as an area of economic importance for the Commonwealth of Virginia because of its proximity to Washington D.C., Alexandria City, Arlington City, Fort Belvoir, Fairfax City, and Quantico (Richmond). The cost of transporting people and goods from the Route One Corridor and the community in tangent is comparatively low if the calculation is based on distance travelled. However, due to the single-use transportation design around cars, this space could be more developed when shown next to regional centres such as Alexandria City, Arlington City, Fairfax City, and other similar spaces. to the east of the Route One corridor are single-family properties zoned R3, showing three houses per acre, suburbia. These properties exist on a road grid that encourages car use, and it can be assumed that most trips around this geography are conducted by car. This has the potential to change into a heavily used bike trail, which runs along the Potomac River and is easily navigable from the R3 zoning communities. Additionally, there has been a recent expansion of bike lanes alongside Fort Hunt Road that should also expand ridership in geography.

Methodology

The method for this project follows a standard hydrological approach laid out in multiple ESRI press reports on the capabilities and tools available within the ArcGIS tool series, followed by a buffer analysis [28]. The buffer analysis aims to find what social and economic characteristics match our goal of finding a community that would receive help from private investment in green infrastructure. Those social and economic characteristics included the zoning of the land within our study space and the relative amount of available assets that could be invested toward a green infrastructure project. Our choice community would have a comparatively high risk of damage due to storm water, a relatively high area of land under private ownership, and a population with a relatively high amount of private assets not spent on existing capital stocks. The community has the economic conditions of minimal rent burden. Once the model produces our chosen community, the discussion section will note variables that can be adjusted to decide communities at a proportionately equal risk but zoned differently or experiencing higher rent burdens, along with possible remedies for those conditions [30].

It can be assumed that, for instance, if the community is zoned for high-density residential space occupied by renters, green infrastructure could be structured differently and financed through some tax or bond system by state or local governments. The social benefits of such a program would also need to be framed differently to accommodate that individuals would not be investing in their communities the same way as private landowners, perhaps creating the need for public educational programs to fill the gap created by individuals not owning the land where green infrastructure is invested in. The eastern part of Fairfax County was the chosen geography for this case study. The reasons for choosing this location were three-fold. First, it was possible to ground truth our data with events on the ground. As this project is researching a new method for understanding the location of green infrastructure, having the ability to ground-truth a spatial model is imperative for the overall project's success (Figure 1).

Secondly, Fairfax County was chosen since the county has experienced rapid population growth over the past twenty years, with a population size of 1.3 million in 2020 [34].

The population growth was linked to urban sprawl in the county. The last reason is the comparatively high economic advantage over other counties within the United States. Fairfax County was the first county in the United States to post an average income over one hundred thousand dollars, which would not normally be statistically cited as important. The median would better represent the population's experience and spending toward life-amenity services and products [34]. The county's affluence would be more likely to open the possibility of developing green infrastructure with both private and public capital assets relatively quickly compared to other counties in the US (Figure 2).

The geographic data for this project is pulled from data in Land Use Zoning, available for free through Fairfax County's Open GIS platform. Within the Land Use Zoning data is a Land-cover Classification File developed by Fairfax County's Open GIS Team to map impervious surfaces. This project focuses on single-family suburban lots because those lots have a high volume of impermeable surfacing dedicated to driveways. Soil taxonomy data, also mapped by the Open GIS Team, allows mapping soil types. Water flows through different soil types at different rates, and this affects green infrastructure placement because different soils lend themselves to different construction types.

The hydrology data series was created from the digital elevation model (DEM) Shuttle Radar Topography Mission (SRTM) 1-Arc Second Global data series. The data is available for free through Earth Explorer, an online library of satellite data made available to the public through the United States Geological Survey (USGS) [31]. The sample size moving from a DEM toward hydrology data sets were as follows:

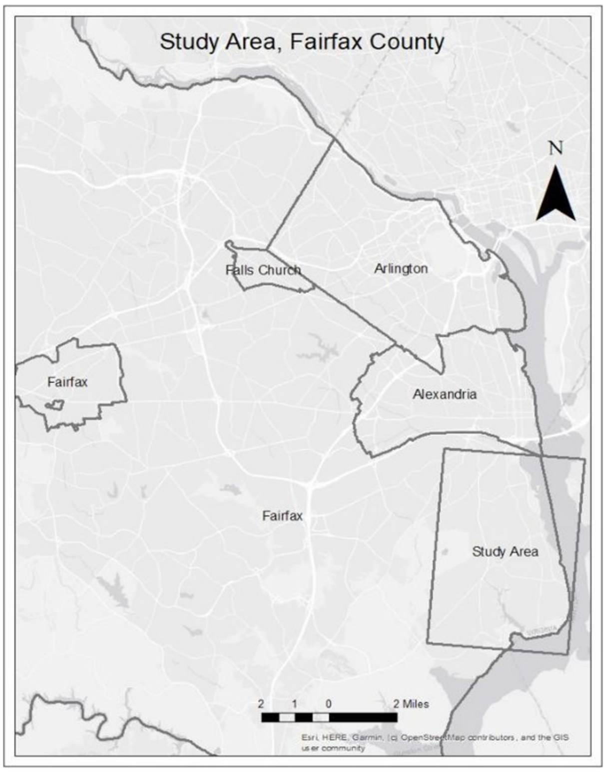

Figure 1: Study Area, Fairfax County.

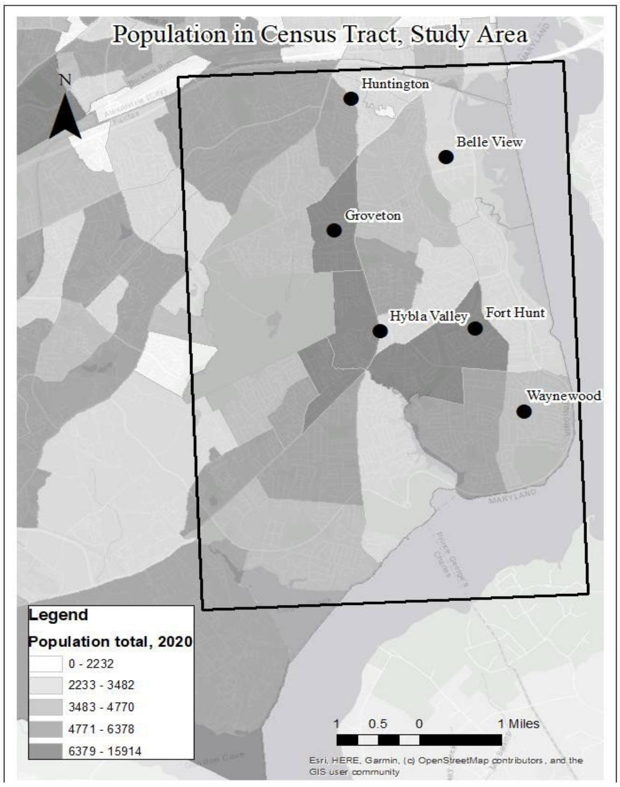

Figure 2: Population in Census Tract of Fairfax County, VA.

DEM to flow direction 2.15e9, DEM to flow accumulation 2.15e9, flow direction and flow accumulation to unsplit lines 78,430, un-split lines to endpoints 156,860, end points toward water shed delineation 156,860.

The economic extent of this project is a modified version of a census tract. The method for finding this is referred to as a Thiessen polygon. Economic data is intended to be joined to geographies known as census tracts defined by the US Census. Those census tracts are then combined to form the larger units, such as counties, to which economic functions are assigned. The issue is that environmental data does not conform to census boundaries as readily as economic data do. Water does not stop flowing through space because it leaves one country and enters another. The solution was to develop a gradient around a centroid for each census tract where economic data could be joined based on a spatial ID while the boundary of each shape file creates a proximity model where each point along a line assumes a coordinate that is the greatest distance between two centroids. The issue of geographic extent between two data series falls under the preview of the modifiable areal unit problem, and the mathematical modification chosen in this project is thought to be a reasonable solution through the literature [35]. In Fairfax County, the number of polygons created is 631.

All of Fairfax County was processed through the hydrology method and the Thiessen polygon method. The area created by the polygon developed through a sub-delineated watershed was spatially joined to the Thiessen polygon created by the modification of the census tracts along with a separate join to count the points associated with the pour points of geography. Both outcomes were used to find the risk each census tract had for an increase in water flow through geography. If an area was associated with a high number of pour points, then the area can be assumed to be a space where water would flow. This area with a high number of pour points and a high surface area of the sub-delineated watershed polygon would be a space where water would flow, and that water would have affected a large area of land. This study was looking for a geography that would have both variables: a high number of pour points and a high area of land associated with those points. After processing all of Fairfax County in the way described above, it was decided that eastern Fairfax County would be the best location to continue the study toward matching geographic variables with economic and environmental variables. The precise boundary of eastern Fairfax County was less important than the physical geography associated with eastern Fairfax County.

The US Highway Route One is the economic centre of this space, running from north to south through many of the neighbourhoods associated with eastern Fairfax County. The Potomac River is the environmental centre of eastern Fairfax County, creating wetlands along the edge of Fairfax County. All water in eastern Fairfax County flows west to east through the economic zone of US Highway One toward the Potomac River. Green infrastructure in this space could be characterized in two different forms. The first form would be options available on public lands while the second form would be on private lands. Within the options of private lands, the design of green infrastructure could be further divided based on who owns the land and what function that land serves. A parking lot associated with a commercial development would have a different set of design challenges and characteristics than a driveway. Zoning is one tool for understanding the economic design of a space. A high-resolution Zoning data series developed by Fairfax County's open GIS team was superimposed on the Thiessen polygon census map to understand the land use pattern associated with areas that would be at higher risk of increased water flow. Thus, geographic data was combined with economic data to better assess the potential locations and designs of green infrastructure projects.

The zoning type and in return, the economic use of the land chosen for further study in this project was R3 Zoning in Fairfax County. This zoning type is single-family units where there are three independent properties on one acre of land. There are several perceived advantages to studying this zoning classification. The first is that single-family units on a third of an acre are a common zoning type, meaning that this method can be applied to a range of different municipalities. The second advantage is that since each person owns their own property, each person can make the independent decision to redesign their property as they see fit within the realm of regional zoning protocol. This would reduce the time between a design idea and the action based on that idea. Changes in design are also comparatively inexpensive. A replacement roof requires much less capital than the removal of a segment of the parking lot or sideways to increase green space.

R3 zoning has another advantage, which is the grid network associated with this economic function produces a disproportionate amount of impervious surfacing to accommodate the flow of people, goods, and services through each one-third acre unit. R3 zoning is car-dependent due to the distances created between a person's dwelling and mass transit terminals, business districts, and other amenities. If each economic unit, person, or group of persons were to have several cars, then there would need to be parking arrangements for those cars and enough space that two cars can travel parallel to each other. Within this study area, four communities within eastern Fairfax County fit the criteria of having a high number of pour points, a high number of areas of watershed delineation, and a high impervious surface area from north to south in our geography: Huntington, Bell View, Fort Hunt, and Waynewood. Of those areas, only one community had the combination of geographic variables listed above plus the R3 zoning pattern to show that there was an economic function within that geography that could result in private green infrastructure development.

Results

This study found that the geography best suited for expanding green infrastructure in Fairfax County is a corridor between the Huntington Community, Wayne wood Community, and Fort Hunt Community in the eastern part of Fairfax County (Figure 3).

These areas have comparatively high concentrations of both porous and watershed surfaces, as illustrated in Figure 4. The communities around Huntington are noted here as the gradient highlights this census tract as having some of the densest watershed surfaces (Figure 4). Huntington represents an area of increased housing density, as the new apartment buildings in and around a multi-modal transit hub near this census tract's center show. Across the main street in Huntington, there are a strip mall on the right near the ground, contemporary apartments on the right, and a bridge in the distance. The bridge is the heavy rail line associated with the Huntington Metro station. That station is also the bus hub for the communities south and southeast of this multi-modal transit hub. There are some single-family units that would represent an ideal candidate for projects encouraging permaculture and other private property techniques to mitigate flooding.

Another area of interest within this model is the Fort Hunt community. This census tract represents a junction between a space dominated by single-family homes on the eastern portion of the census tract and highway construction on the western portion. The single-family homes occupy the eastern portion of the census tract. On the western part of the census tract, Route 1 is close, and some creeks

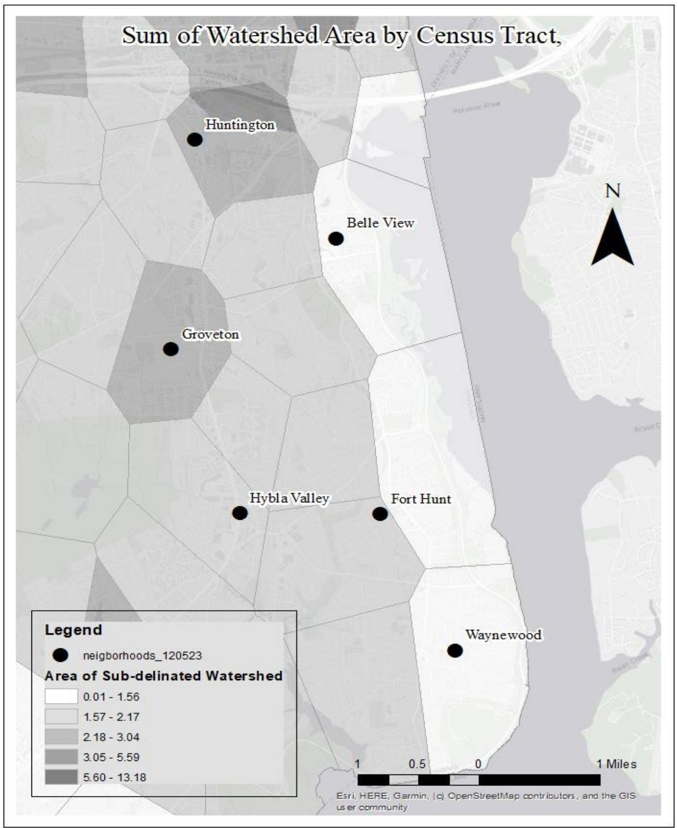

Figure 3: Watershed Area by Census Tract.

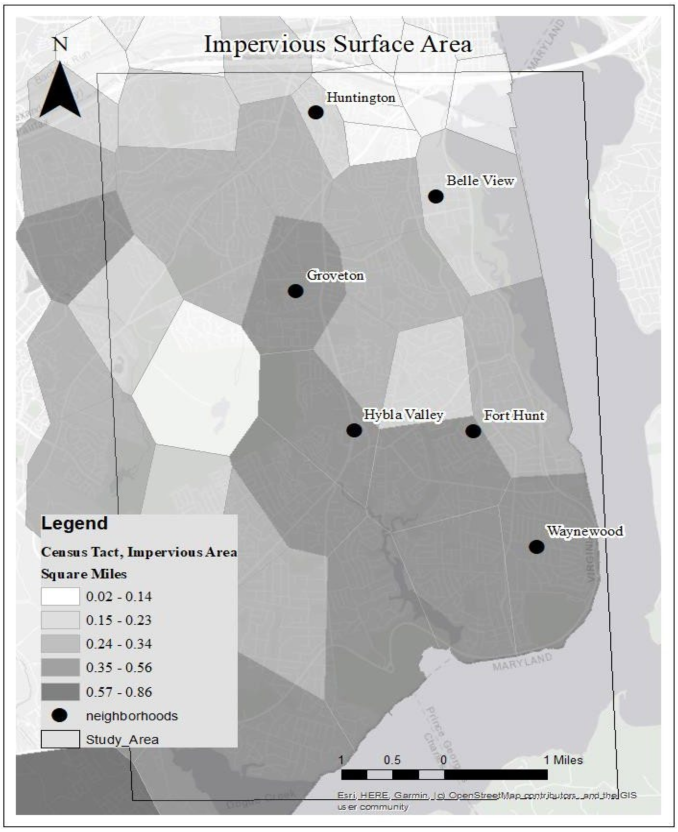

Figure 4: Impervious surface area.

and marshlands were filled in and built over as part of the highway construction. In less than a mile and a half, the geography changes from a space dominated by marshland to that dominated by non-permeable surfaces. If there were an increase in rainfall in this geography, there would be common capital depreciation as roadways and other public systems were compromised due to damage.

Both Huntington and Fort Hunt communities represent an opportunity for re-designing spaces to better account for water flow. Reducing the non-permeable surface by modifying the zoning protocol around parking lots and driveways would improve the flow rate through the space. Another idea for improving both spaces would be the implementation of permaculture around private and public lawns. In both geographies, a significant portion of the landscape is dominated by cultivated lawns and non-native land uses. If native species would cover some percentage, it would change the water flow through the ecosystem, similar to changing the driveways and parking lots to something more permeable.

Discussion

There are two points of discussion within the outcome of this project. The first is the social-economic ramifications of implementing green infrastructure across different caste brackets. This history of America's infrastructure advancement has come at the cost of minority and low-income communities across our country [36,37]. The implementation of green infrastructure could affect capital accumulation due to the spatial disparity in the destruction of property by climate change and the effects of capital accumulation, as noted by Pickett [14]. Assuming that public investment has not been properly made in green infrastructure and implementing such systems would fall to private investment, R3 residential zoning would be the most likely land-cover classification type that would start retrofitting suburban design to mitigate against storm water damage. The spatial extent is shown in Figure 5 as it applies to our geography.

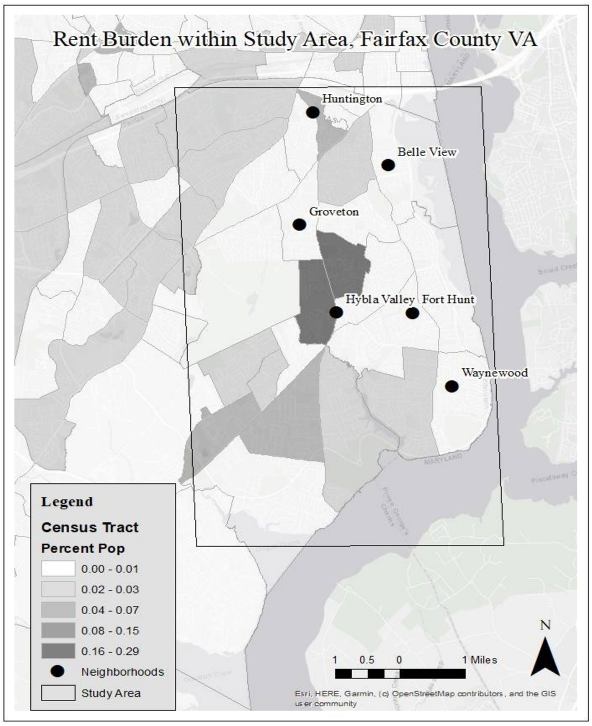

Figure 5: Rent Burden with Study Area, Fairfax County, VA.

However, the same spatial extent is mapped for rent-burdened populations, as described by the Federal Reserve System at thirty-percent monthly income. In that case, it is noted that the communities at the highest risk of economic insecurity are different from those that would be able to implement green infrastructure systems (Figure 5). This would mean that even as the risk of storm water damage would be uniform between Fort Hunt, Wayne wood, Hybla Valley, and Huntington, the communities best positioned to implement green are not the communities that would, arguably, benefit most from their implementation if economic risk is considered. This leads to an ethical dilemma that needs further exploration by community leaders and academics interested in equitable development in the Commonwealth of Virginia.

The second conversation area is a specific variant of green infrastructure, turf-grass modification. Fairfax County has 103 square miles of 'turf grass' described by the Common wealth of Virginia's land-cover database at one-meter resolution. The study area for this project is around nine square miles of turf grass. This land-cover type represents an easily modifiable sub-urban design element that could impact the storm water ecology of the region. 'Turf grass' is comparatively water, labour and nutrient-intensive to other land-cover types. Additionally, the runoff from turf grass can lead to ecological damage as the herbicides, fertilizers, and pesticides used to maintain turf grass can be washed into stream networks after storms (Figure 6).

The benefits of modifying turf grass in Fairfax County could be increased storm water filtration, a decrease in the speed of storm water flow, and decreased surface heat as impermeable surfacing is transformed into green space [38]. At the same time, the costs associated with the modification would be comparatively small when considering the other green infrastructure projects like wetland engineering, steam modification, or rain-water barrels or aquifers. There is a ready supply of labour and landscapers that can be trained to retrofit existing turf grass systems, which could spur growth in a vocational industry that could lead to salary increases or earning potentials as more green infrastructure projects come into reality. Although this study was able to identify a likely set of communities that would benefit from green infrastructure and a land-cover type that would be easily adaptable for ecological security, it should be noted that the feasibility of green infrastructure construction will hinge upon home ownership, rent-burden rate [29], and individual preference for green infrastructure [39].

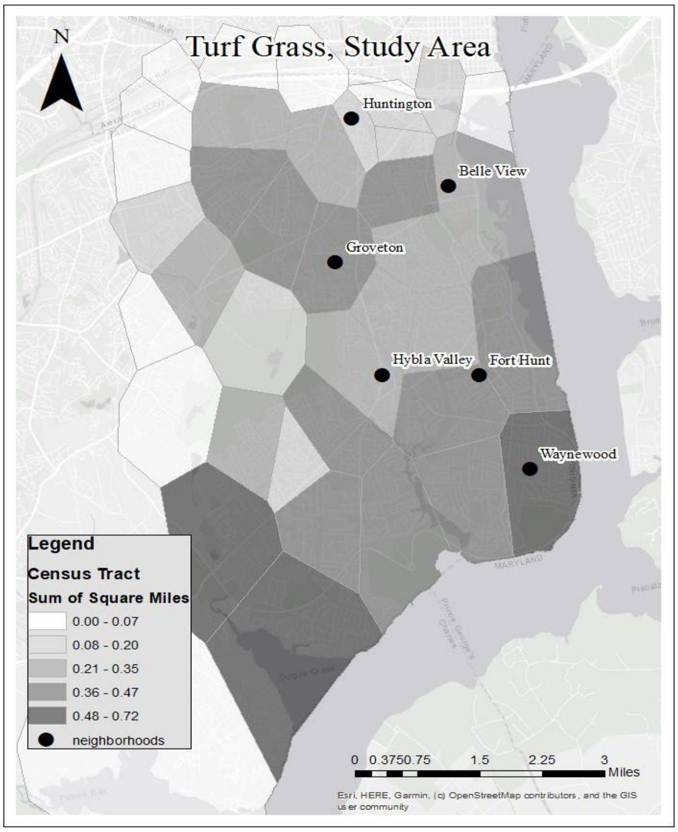

Figure 6: Turf Grass in the Study Area.

In the US political context, however, interests in green infrastructure have been heightened and subsidized in part by the Biden administration's Infrastructure Investment and Jobs Act. Green infrastructure has also been discussed in tandem with addressing environmental justice [40,41]. In this vein, future research can benefit from integrating equity in the green infrastructure siting decision-making process and its operationalization for storm water management.

Conclusion

Green infrastructure is increasingly popular as an urban sustainability strategy and provides multiple benefits, including ecological, economic, social, and climate mitigation and adaptation benefits [7-12]. While green infrastructure is broadly understood as green spaces for conservation, all green covers cannot maximize storm water management capacity. The study thus intended to understand the significance of marrying hydrological, geographic, topological, and ecological factors to identify ideal green infrastructure areas for storm water mitigation and climate adaptation. Using the highly populated area in Fairfax County, Virginia, two communities with different housing patterns, single-house dominant and multi-unit housing-based, were selected. The approach used in this study can potentially improve our understanding of multi-modal transit design, energy grid design, conservation, and hydrological design. This can help us make both existing and new infrastructures more environmentally friendly. To expand upon the current study design, exploring the relationship between hydrology, economic stability, and green infrastructure in the future would be interesting. Although the present study focuses on the benefits of storm water management, examining other multifunctional benefits could help improve regional financial income and address inequality.

Acknowledgment

This research was funded by a grant from 4-VA, a collaborative partnership for advancing the Commonwealth of Virginia.

Conflicts of Interest

The authors declare no conflict of interest.

References

1. Gaspe R., Blohm A, Ruth M (2011) Social and economic impacts of climate change on the urban environment. Curr Opin Environ Sustain 3: 150-157.
2. Hecht J (2004) The evolving system of integrated economic and environmental accounts. In Y-K. Ng & I. Wills (Eds), Welfare Economics and Sustainable Development, Vol I., Encyclopedia of Life Support Systems, pp.259-282.
3. Yeber O (2022) Application of Hypothetical Ecological Risk Analysis to Sustainable Usage of Possible Winter Recreation Areas in Seyham Basin (Turkiye). Aquat Sci Eng.
4. Shuster WD, Morrion MW, Webb R. (2008) Front loading urban storm water

management for success: A perspective incorporating current studies on the implementation of retrofit low-impact development. CATE 1: 8-15.

5. Rouse D, Bunster Ossa I (2019) Landscape Planning, Design, and Green Infrastructure. In E MH Infield, Y Abunnasr, RL Ryan (Eds), Planning for Clim Change, Routledge pp 173-183.
6. Dietz ME (2007) Low Impact Development Practices: A Review of Current Research and Recommendations for Future Directions. Water Air Soil Pollut 186: 351-363.
7. Kim D, Song SK (2019) The Multifunctional Benefits of Green Infrastructure in Community Development: An Analytical Review Based on 447 Cases. Sustainability 11: 3917.
8. The Value of Green Infrastructure: A Guide to Recognizing Its Economic, Environmental and Social Benefits; Center for Neighborhood Technology (CNI): Chicago IL USA. CNT.
9. Green Infrastructure and Territorial Cohesion: The Concept of Green Infrastructure and its Integration into Policies Using Monitoring Systems; European Environment Agency (EEA): Copenhagen, Denmark. EEA.
10. Green Infrastructure Case Studies: Municipal Policies for Managing Stormwater with Green Infrastructure; US Environmental Protection Agency (USEPA): Washington, DC, USA, 2010. USEPA.
11. Powell LM, Rohr ES, Canes ME, Cornet JL, Dzuray EJ, et al. (2005) Low-Impact Development Strategies and Tools for Local Governments: Building a Business Case; LMI Government Consulting: Tysons Corner, VA, USA.
12. Low Impact Development Manual for Southern California: Technical Guidance and Site Planning Strategies; LID Center: Beltsville, MD, USA, 2010. LID
13. Lovell ST, Taylor JR (2013) Supplying Urban Ecosystem Services through Multifunctional Green Infrastructure in the United States. Landsc Ecol 28: 1447-1463.
14. Piketty T (2017) Capital in the Twenty-First Century. Belknap Press.
15. Gill SE, Handley JF, Ennos AR,. Pauleit S (2019) Adapting Cities for Climate Change: The Role of the Green Infrastructure. In EMH Innfield, Y Abunnasr, Ryan RL (Eds.),Planning for Clim Chang. Routledge pp: 195-205.
16. The Value of Green Infrastructure: A Guide to Recognizing Its Economic, Environmental and Social Benefits; Center for Neighborhood Technology (CNI): Chicago, IL, USA, 2010. CNT.
17. Carleton TA, Hsiang SM (2016) Social and economic impacts of climate. Science: 353.
18. Kendrick K, Kim Y (2023) Abandoned Mine Land Program: Examining Public Participation in Decision-Making. Rev of Policy Res 1-29.
19. Kattwinkel M, Biedermann R, Kleyer M (2011) Temporary Conservation for Urban Biodiversity. Biol. Conserv 144: 2335-2343.
20. Connop S, Vandergert P, Eisenberg B, Collier MJ, Nash C,et al. (2016) Renaturing Cities Using a Regionally focused Biodiversity-led Multifunctional Benefits Approach to Urban Green Infrastructure. Environmental. Science and Policy, 2016, 62, 99-111.
21. Gurbey A, Nihan P (2021) The Relationship between Permaculture and Urban Land Use. In Developments in engi and Architec, St. Kliment Ohridsk University Press. Sofia.
22. Kingma B (1997) Public good theories of the non-profit sector: Weisbrod revisited. Voluntas: Internati Journ of Voluntary and Non-Profit Organizations: 8.
23. Roy AH, Cabezas H, Clagett, Hogaland T, Mayer AL, et al. (2006) Retrofit stormwater management: Navigating multidisciplinary hurdles at the watershed scale. J Kaspersen (ed.), Stormwater. Forester Communications In, Santa Barbara, CA. 7: 16-29.
24. Thurston HW (2011) Economic incentives for stormwater control (1st edition). CRC Press.
25. Berberogl S, Tanrıöver AA, Satir O, Donmez C (2022) Geospatial technologies for physical planning: Bridging the gap between earth science and planning. DRArch 3: 213-223.
26. Zhang D (2017) Classical Chinese Gardens: Landscapes for Self-Cultivation. JCUA 2: 33-44.
27. An Overview of the Hydrology Toolset-ArcGIS Pro. Fairfax County, 2023. ESRI
28. Parkikh P, Taylor MA, Hoagland T, Thurston H, Shuster W (2005) Application of market mechanisms and incentives to reduce stormwater runoff: An integrated hydrologic, economic and legal approach. Environmental Science and Policy. 8: 133-144.
29. Larrimore J, Schuetz J (2017) Assessing the Severity of Rent Burden on Low-Income Families, FEDS Notes. Washington: Board of Governors of the Federal Reserve System.
30. US Geological Survey Earth Explorer online application 2023.
31. Staccione A, Candiago S, Mysiak J (2022) Mapping a green infrastructure network: Aframework for spatial connectivity applied in Northern Italy. Environ Sci Policy 131: 57-67.
32. Maes J,Jacobs S (2017) Nature-based Solutions for Europe’s sustainable development.Conservation Letters.10: 121-124.
33. Hovland E, Khaja F, Cahill A (2017) Demographics Reports. Econ, Demo and Stat Res.
34. Openshaw S (1983) The Modifiable Areal Unit Problem. Concepts and Techniques in Modern Geography 38: 3-38.
35. Hannah Jones, N Roper C, Silverman I, Silverstein J (2021) The 1619 Project: A New Origin Story. Random House.
36. Desmond M (2017) Evicted: Poverty and Profit in the American City. Crown.
37. Felappi JF, Sommer JH, Falkenberg T, Terlau W, Kötter T (2020) Green infrastructure through the lens of “One Health”: A systematic review and integrative framework uncovering synergies and trade-offs between mental health and wildlife support in cities. Sci. Total Environ: 748.
38. Barton L, Colmer TD (2006) Irrigation and fertilizer strategies for minimizing nitrogen leaching from turfgrass. Agricultural Water Management 80: 160-175.
39. Foster D, Warren J (2022) The NIMBY problem. J Theor Politics 34: 145-172.
40. The Infrastructure Investment and Jobs Act of 2021. Public Law: 117-58.
41. Lawhorn J (2023) Interagency working group on coal and power plant communities and economic revitalization. CRS.