Class: CRP 5680 – Urban Data Science

Title: Rooftop Suitability Analysis of Urban Agriculture in New York City

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Abstract

Urban agriculture (UA) presents a promising solution to address the increasing food demands of growing urban populations and the challenges posed by climate change and supply chain disruptions. This study develops a GIS-based suitability model to identify optimal rooftop sites for urban agriculture across New York City, with a detailed case study focused on the Hunts Point neighborhood in the Bronx. Using integrated spatial criteria—including zoning, building height, rooftop area, structural capacity, slope, and solar radiation—the model evaluates rooftops for their potential to support both intensive and extensive urban farming. Results indicate over 36,000 buildings with a combined rooftop area exceeding 6,500 acres are suitable for agricultural use, offering significant opportunities to expand green infrastructure in NYC. The findings support targeted policy interventions to incentivize rooftop farming, promoting sustainability, food security, and urban resilience. This replicable framework provides urban planners, policymakers, and community stakeholders with a data-driven tool to strategically advance rooftop urban agriculture in dense metropolitan environments.

Introduction

UA can be defined as "as an industry that produces, process & markets food & fuel , largely in response to the daily demand of consumers within a town , city or metropolis, on land & water dispersed throughout the urban & peri-urban area, applying intensive production methods, using & reusing natural resources & urban wastes, to yield a diversity of crops and livestock."(Smit et.al 1996)

There is projected to be 50% rise in world population by 2050 and agriculture will struggle to meet the food requirements of the world. It is also projected that 2050, 70% of the world's population will live in urban areas.(UNPF, 2018) So urban agriculture is being looked as a potential and sustainable alternative to feed people rather than relying on the transportation of food from rural areas/ traditional areas. Urban agriculture has recently received recognition as a food source in cities, due to the production and logistics disruption of food during the COVID-19 pandemic.

Beyond food production, UA has increasing benefits in improving the socioeconomic-environmental dimension of cities. It provides economic benefits through cash sales and jobs while directly linking to other entrepreneurial activities. Social benefits include improved nutritional outcomes, individual and community wellbeing, recreation activities, educational opportunities, land reclamation, poverty mitigation and improved social integration. The environmental benefits include improved carbon and storm water capture, ground water recharge, food and organic waste composting, improved local biodiversity, contamination mitigation, improved air quality, urban cooling, energy savings. (Orsini et. al. 2020)

Modern cities have historically depended on imported resources to meet daily demands, a model that grows increasingly unsustainable as urban populations expand. New York City, facing parallel challenges of food insecurity and food sovereignty, grapples with disparities in income that exacerbate unequal access to nutritious food. Nogeire et al. (2018) identified urban agriculture as a critical strategy to address these systemic inequities by decentralizing food production and empowering communities.

The compounding threats of climate change and disruptions like the COVID-19 pandemic further underscore the urgency of resilient food systems. Gonzalez (2022) emphasizes that urban agriculture can serve as a cornerstone for food sovereignty, enabling cities to mitigate supply chain vulnerabilities. Beyond sustenance, urban farms function as multifunctional green infrastructure, contributing to ecological health and social cohesion. Ackerman et al. (2011) notes that New York City possesses substantial underutilized land—including vacant lots and rooftops—that could support expanded agricultural infrastructure, provided systemic barriers are addressed.

Ackerman et al. (2013) argue that small-scale urban farming offers distinct advantages over conventional agriculture, particularly in reducing the energy and material inputs required to deliver produce to consumers. However, integrating urban agriculture into New York's urban fabric requires deliberate policy interventions. Zoning reforms, incentives for community-led projects, and inclusion in municipal sustainability plans are essential to maximize its potential for reducing the ecological footprint of food systems and bolstering local supply chains.

Despite its promise, urban agriculture faces significant hurdles. Environmental constraints include soil contamination, which poses health risks, and limited sunlight in dense neighborhoods where tall buildings cast shadows over potential growing sites. Rooftop farming introduces additional challenges: structural load-bearing requirements restrict use to buildings constructed between 1900 and 1970 with roofs exceeding 10,000 square feet. Logistically, growers confront barriers such as securing land tenure, navigating costly municipal water access, and complying with complex regulations. Economic pressures further complicate efforts, as urban land is often prioritized for high-profit developments over agricultural uses (Gonzalez et al., 2022).

New York City has around one million buildings, with rooftops covering approximately 38,256 acres (Ackerman et al., 2011). Utilizing vacant land for urban agriculture in NYC is often economically unfeasible due to high land costs and the typically low financial returns from farming. Additionally, most vacant parcels are presumed to be contaminated to some extent, making them unsuitable for cultivating food crops. In contrast, rooftop urban agriculture offers a viable and profitable alternative to ground-level farming by making use of underutilized space. Other than photovoltaic installations, rooftop spaces generally face little competition for other uses.(Berger 2013)

This project report focuses on conducting a site suitability analysis for rooftop urban agriculture in New York City, incorporating criteria such as zoning, number of floors, area, rooftop structural capacity, rooftop slope and solar radiation. By systematically evaluating these factors through geospatial analytics, the study aims to identify locations that optimize agricultural productivity of rooftop agriculture in NYC. The framework seeks to inform policymakers and urban planners in prioritizing sites that align with NYC's sustainability goals while addressing systemic barriers to scalable rooftop urban farming.

Methedology

The primary methodology followed for this project is adopted from 'A GIS Suitability Analysis of the Potential for Rooftop Agriculture in New York City' by Danielle Berger, May, 2013.

Study Area

The study is set in New York City, a highly urbanized and densely populated metropolitan area composed of five boroughs: Manhattan, Brooklyn, Queens, The Bronx, and Staten Island. As one of the most spatially and demographically diverse cities in the United States, NYC presents a complex urban environment with varied land use, green infrastructure, and environmental conditions. In recent years, urban agriculture (UA) has been expanding rapidly across the city, driven by growing interest in local food systems, environmental sustainability, and community resilience. This project analyzes the potential of rooftop agriculture across New York City using GIS modelling.

Data Sources:

1. **Buildings Footprint Shapefile**

The primary dataset used for this analysis was the Buildings Footprint shapefile provided by NYC OTI GIS group. The data used in this analysis was downloaded on 2025/03/27. As the dataset is updated weekly, it ensures that the most current and accurate information is available for analysis. By leveraging this up-to-date dataset, the analysis aims to produce reliable insights into the utilization of rooftop spaces in NYC.

2. **Primary Land Use Tax Lot Output - Map (MapPLUTO) Geodatabase**

MapPLUTO is a comprehensive dataset that combines extensive land use and geographic data at the tax lot level in GIS format (Geodatabase). It includes detailed information on over seventy attributes derived from various city agencies, merged with tax lot features from the Department of Finance's Digital Tax Map, and clipped to the shoreline. This dataset provides valuable insights into land use, zoning, property characteristics, and more, making it an essential resource for urban planning, real estate analysis, and policy development in New York City.

3. **2020 Neighborhood Tabulation Areas (NTAs) (Geopackage)**

The 2020 Neighborhood Tabulation Areas (NTAs) dataset provides medium-sized statistical geographies designed for reporting Decennial Census and American Community Survey (ACS) data. These NTAs are formed by aggregating 2020 census tracts and are nested within Community District Tabulation Areas (CDTAs). Developed to balance geographic specificity with statistical reliability, each NTA encompasses sufficient population to reduce sampling error in ACS estimates, while offering a finer scale of analysis than Community Districts.

The NTA data was used to clip Hunts Point Neighborhood (randomly chosen) for solar potential calculations.

4. Bronx DSM 2020 (1 foot resolution) (Raster)

The Digital Surface Model data was used in ArcGIS to measure the solar radiation for the rooftops suitable for urban agriculture in Hunts Point Neighborhood. This data is a subset of the topobathymetric highest hit digital surface model (DSM) derived from the 2020 Light Detection and Ranging (LiDAR) data capture. It is created using topographic (near-infrared) and bathymetric (green) LiDAR data and uses highest hit returns to generate a 1 foot resolution gridded dataset which includes the earth's surface with all vegetation and anthropogenic features included.

Data Analysis Steps:

- Both the files for building footprints and MapPLUTO being quite big took a lot of time to load into a geodataframe using geopandas, so I used ‘pyogrio’ library which is 10-15 times faster than normal geopandas for loading files.
- Then both the geodataframes were joined using the keys ‘mpluto_bbl’ and ‘BBL’ from the building footprint and MapPLUTO data respectively.
- Then the following criteria were applied to the joined layer :-
    - Located in manufacturing and commercial districts, as industrial buildings are often more structurally robust, and such zones allow commercial activity. The residential buildings were removed from the dataset. They represent the ‘01’,’02’ and ’03’ in the LandUse attribute field.

- The next criteria identified buildings which were 10 floors or less. Because above that height climatic conditions are inhospitable for plants and people and it becomes more difficult to transport growing media, materials and equipment.
- Buildings classified as noxious or utility uses were identified and removed from the dataset as they don't have potential for urban agriculture. Building class attribute field was used for this. "F1","G3","G4","G5","U1","U2","U4", "U5", "U8", were the building classes removed.
- Then the Shape Area for each polygon was calculated. The area of the building footprint was assumed to be the rooftop area. The area decides the scale of the project. There a new column named operation_scale was created. Under 5,000 square feet was classified as small scale, 5,000 – 40,000 was classified as medium scale and greater than 40,000 square feet was classified as large scale farm.
- Then the structural capacity of the roof was used as a criteria. The construction year of the building roughly correlates to live roof load. Buildings constructed before 1968, were mandated to have at least minimum 30-40 psf. live roof load capacity. So they were assumed to have greater roof load. So the buildings built before were 1968 were classified as 'Intensive' i.e. suitable as intensive green roofs which have a deeper substrate to support a variety of larger vegetation and need a live load capacity of 35 psf. Those built after were classified as Extensive green roofs which are typically less then 6 inches deep and have maximum saturated weight of 10-35 psf.

This was the analysis conducted on the whole NYC city, but due to scare computational resources the following analysis was only conducted on Hunts Point Neighborhood.

- The Digital Surface Model for Bronx was loaded in ArcGIS Pro and the slope and Aspect were calculated.
- I tried using open source GRASS GIS library in python but was not successful , so had to use ArcGIS Pro to calculate the solar radiation for the year of 2025.
- After calculating the solar radiation for buildings located in Hunts Point Neighborhood , the layers for slope and solar radiation building footprint rasters were loaded on python.
- Two final criteria were applied for the suitability of urban agriculture. (Nadal et.al 2017)
- Slope :- Less then 10 %
- Solar Radiation :- Minimum range of 1900-2000 MJ / m2 /year or 13-14 MJ/m2 day i.e. 528.8 – 556.6 kWh/m²/year

Suitability Matrix:

Rooftop Agriculture Suitability Matrix	**Intensive (Built prior to 1968)**	**Extensive (Built after 1968)**
Small Scale Area ≤ 5,000 sq.ft.	2	1
Medium Scale Area 5,000 - 40,000 sq.ft.	5	3
Large Scale Area ≥ 40,000 sq.ft)	6	4

Results:

After applying the suitability criteria to the building footprints layer—excluding slope and solar radiation considerations—a total of 36,345 buildings were identified. The combined rooftop area of these buildings suitable for rooftop agriculture is approximately 6,502.25 acres.

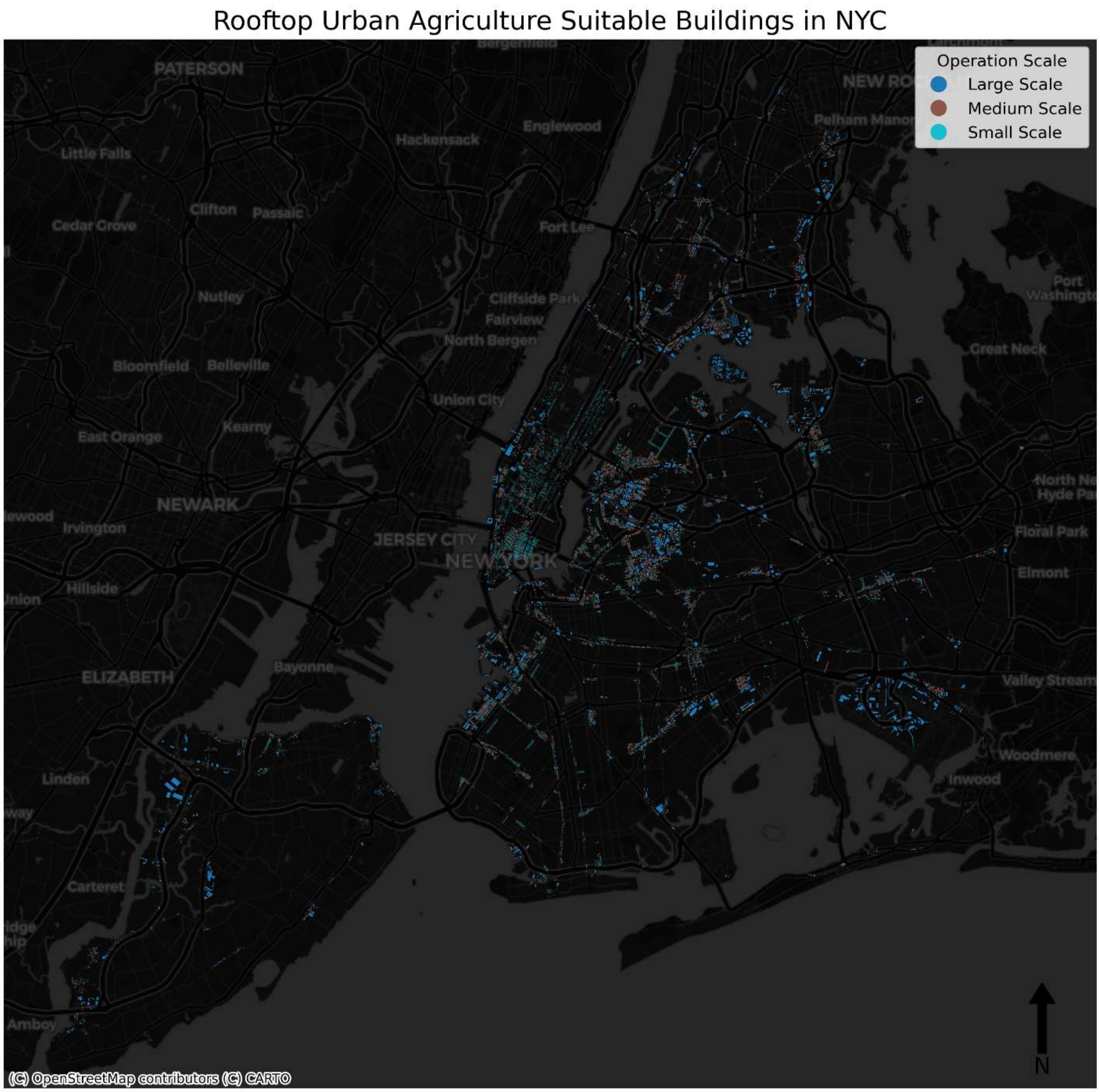

Fig 1. Rooftop Urban Agriculture Rooftop Suitability in NYC

The model identified all buildings in Hunts Point, Bronx that met the basic zoning and floor number criteria, assigning each a suitability score ranging from 1 to 6 for potential commercial roof farming. Buildings with a score of 6 were deemed to have the highest potential for a commercial roof farm, greenhouse, or intensive green roof, while those with a score of 1 were considered the least suitable for such infrastructure. Buildings that received a score of 0, which included structures with sloped roofs or residential uses, were excluded from the analysis.

The suitability scores are defined as follows:

- **6:** High potential for a commercial roof farm or intensive green roof.
- **5:** Medium potential for a commercial farm, greenhouse, or intensive green roof.
- **4:** High potential for a non-agricultural green roof.
- **3:** Medium potential for a non-agricultural green roof.
- **1 & 2:** No potential for a commercial farm, greenhouse, or intensive green roof, and low potential for a non-agricultural green roof.

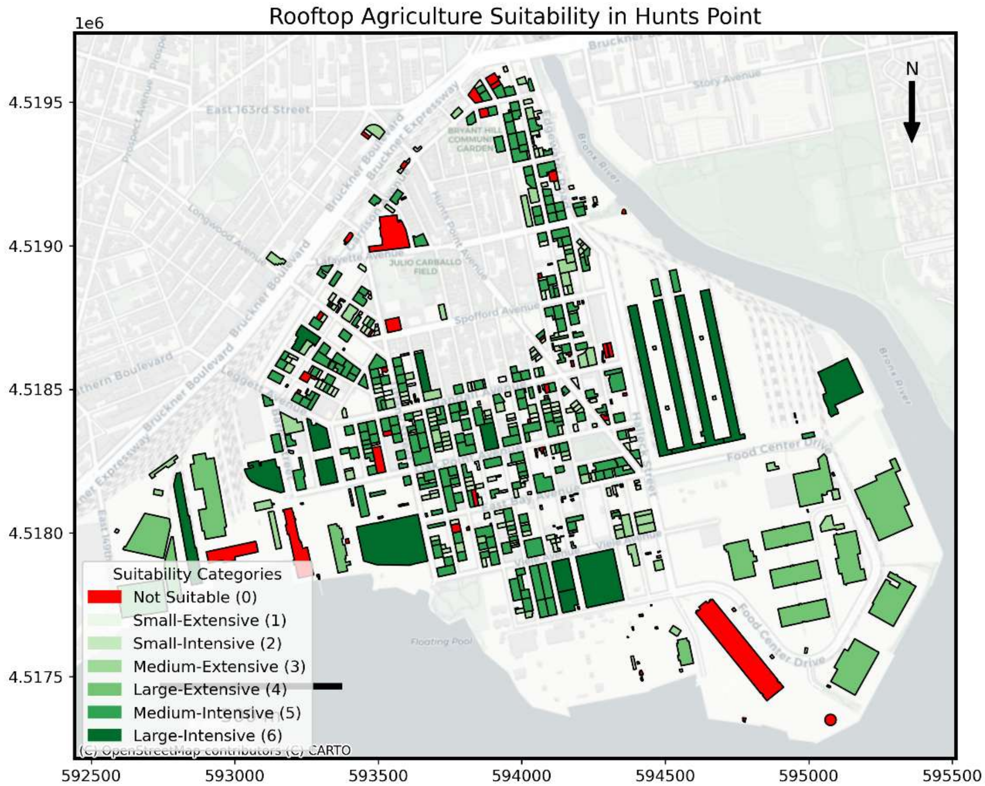

Fig 2. Rooftop Agriculture Suitability in Hunts Point

The following chart visualizes the distribution of green roof suitability as a percentage of the total building stock within the Hunts Point and number of buildings that correspond with each classification.

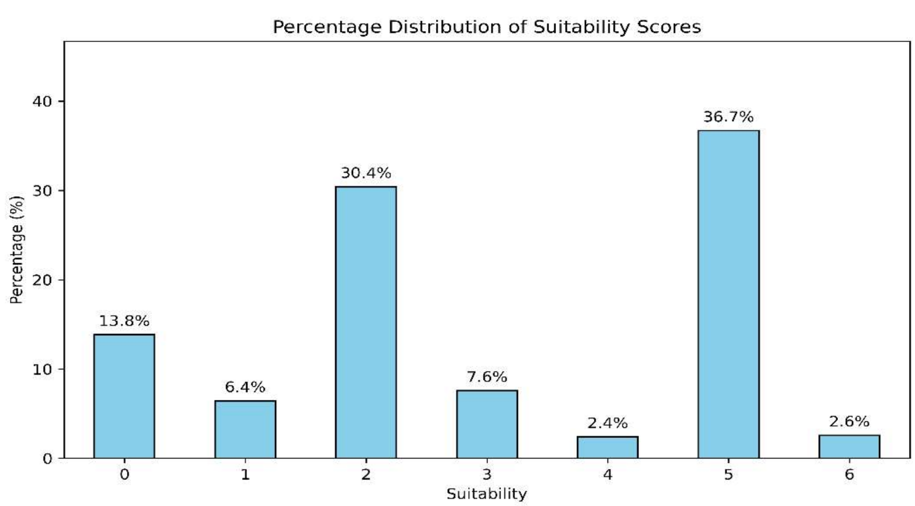

Fig 3. Percentage Distribution of Suitability Scores in Hunts Point

Policy Recommendation:

Based on the findings of this study, policy recommendations should prioritize incentivizing the adoption of rooftop urban agriculture through targeted financial support and regulatory reforms. This includes expanding and promoting rebate programs and tax incentives that offset the high upfront costs of green roof installation and maintenance, such as offering rebates proportional to installation expenses rather than fixed amounts per square foot. Additionally, zoning policies should be updated to facilitate urban farming by easing restrictions and encouraging the integration of agricultural infrastructure in commercial and industrial buildings. To ensure equitable access and broad impact, city-owned buildings should lead by example through mandatory green roof installations or retrofits where feasible. Finally, implementing stormwater runoff fees based on impervious roof area can further motivate building owners to adopt green roofs, aligning environmental benefits with economic incentives and supporting New York City's sustainability and food resilience goals.

Discussion

The GIS model developed in this study provides a comprehensive and innovative framework for assessing rooftop urban agriculture potential, with a focused application on Hunts Point, Bronx. By integrating multiple spatial criteria—such as zoning, building characteristics, structural capacity, slope, and solar radiation—the model offers a robust and replicable approach to identifying suitable rooftops for urban farming. This localized case study highlights the untapped agricultural capacity within densely urbanized neighborhoods, demonstrating how Hunts Point can serve as a model for resilient and sustainable food production in other urban areas. The approach not only aids planners and building owners in making data-driven decisions but also positions New

York City, starting with neighborhoods like Hunts Point, as a potential leader in pioneering rooftop agriculture that addresses food security, environmental sustainability, and urban resilience.

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