Planet Reimagined

NEW FUTURES FELLOWSHIP PROJECT

SDG 17: PARTNERSHIPS FOR THE GOALS

THE ROLE OF URBAN AGRICULTURE IN ADVANCING THE SDGS: A MULTIDISCIPLINARY APPROACH

Contributors: Navaz Bilimoria, Yanaika Denoyelle, and Alexander Nguyen
Fellowship Period: Summer 2020

Project Overview:
This paper explores the multidisciplinary potential of urban agriculture in the United States, employing a four-sphere framework to integrate environmental, social, economic, and political aspects.

Keywords:
Urban Agriculture, Sustainable Development Goals (SDGs), Rooftop Farming

Contact Information:
Planet Reimagined
team@planetreimagined.com
www.planetreimagined.com

I. Introduction

Agriculture is one of the main contributors to greenhouse gas emissions.[1] Yet, the global population growth increases food demand, inevitably leading to agricultural expansion. With climate change posing a serious threat to future food security, it is clear that different approaches should be considered. An alternative to on-field cultivation that has been proposed is urban farming, which can be defined as "all forms of agricultural production (food and non-food products) occurring within or around cities."[2]

The paper gives a comprehensive overview of the diverse ways in which urban agriculture can further sustainable development by reducing the carbon footprint of food.
The aim is to depict how the economic, social, political, and environmental aspects of urban agriculture can be used to further a range of SDGs. However, these benefits can only be achieved when informed by a multidisciplinary analysis that considers these components in localized contexts.

This work focuses on the relationship between urban agriculture, sustainable development, and climate change. This relation relates to a range of United Nations' Sustainable Development Goals (SDGs), as illustrated in FIG. 1. However, it primarily centers around two:

- SDG 11: Sustainable Cities and Communities—"Make cities inclusive, safe, resilient, and sustainable"

[1] J. Poore and T. Nemecek, "Reducing Food's Environmental Impacts through Producers and Consumers," *Science* 360, no. 6392 (June 1, 2018): 987–92, https://doi.org/10.1126/science.aaq0216.
[2] Ross K. Wagstaff and Sam E. Wortman, "Crop Physiological Response across the Chicago Metropolitan Region: Developing Recommendations for Urban and Peri-Urban Farmers in the North Central US," *Renewable Agriculture and Food Systems* 30, no. 1 (February 2015): 8–14, https://doi.org/10.1017/S174217051300046X.

- SDG 13: Climate Action—"Take urgent action to combat climate change and its impacts"

FIG. 1: An overview of the SDGs that urban agriculture can improve and the area of the framework (environmental, political, economic and social) that is relevant. Figure made by the authors.

The first section of this paper will further elaborate on the framework used in relation to urban agriculture. Next, the paper will specifically discuss urban rooftop farming in the United States for the environmental, social, economic, and political spheres. This section will be followed by a more practical case study on lettuce production, to illustrate the importance of considering the four spheres and highlight the potential of lettuce in urban farms. The final sections will bring these findings together, discuss the bigger picture, and outline the next steps.

II. Urban agriculture and the four-sphere framework

For sustainability, the economic, social, and environmental aspects—referred to as the triple bottom line—are very important. However, due to the importance of policies to guide and balance the triple bottom line, O'Connor (2007) proposed a four-sphere framework that additionally considers the politics involved.[3] Recognizing the importance of governance for enabling and guiding sustainable agriculture, this paper's structure will be based on the framework proposed by O'Connor.

In the following sections, the paper provides an overview of the importance of each sphere within the framework for urban agriculture.

1. The environmental sphere and urban agriculture

As mankind's population and use of the world's resources increase, so does the overexploitation and contamination of the environment. As such, environmental sustainability is an important challenge that humanity is facing.[4] Among the environmental pressures society exerts on the environment, the release of large amounts of greenhouse gases leading to climate change is expected to damage the environment in a multitude of ways. Thus, climate change mitigation and adaptation are necessary to achieve environmental sustainability.[5]

---

[3] Martin O'Connor, "The 'Four Spheres' Framework for Sustainability," *Ecological Complexity* 3, no. 4 (December 2006): 285–92, https://doi.org/10.1016/j.ecocom.2007.02.002.
[4] Naveen Kumar Arora, "Environmental Sustainability—Necessary for Survival," *Environmental Sustainability* 1, no. 1 (March 1, 2018): 1–2, https://doi.org/10.1007/s42398-018-0013-3.
[5] Koko Warner et al., "Climate Change, Environmental Degradation and Migration," *Natural Hazards* 55, no. 3 (2010): 689–715; Ove Hoegh-Guldberg et al., "Coral Reefs under Rapid Climate Change and Ocean Acidification," *Science* 318, no. 5857 (2007): 1737–1742; Tamara S. Wilson, Benjamin M. Sleeter, and D. Richard Cameron, "Mediterranean California's Water Use Future under Multiple Scenarios of Developed and Agricultural Land Use Change," ed. David A Lightfoot, *PLOS ONE* 12, no. 10 (October 31, 2017), https://doi.org/10.1371/journal.pone.0187181.

Climate change and the food sector are interconnected. Every step of the food supply system causes GHG emissions. In fact, food is responsible for 26% of global carbon emissions, of which agriculture and associated land use changes represent the largest contribution (see FIG. 2).[6] Urban agriculture has the potential to reduce food's carbon emissions, allowing it to contribute toward climate change mitigation.[7]

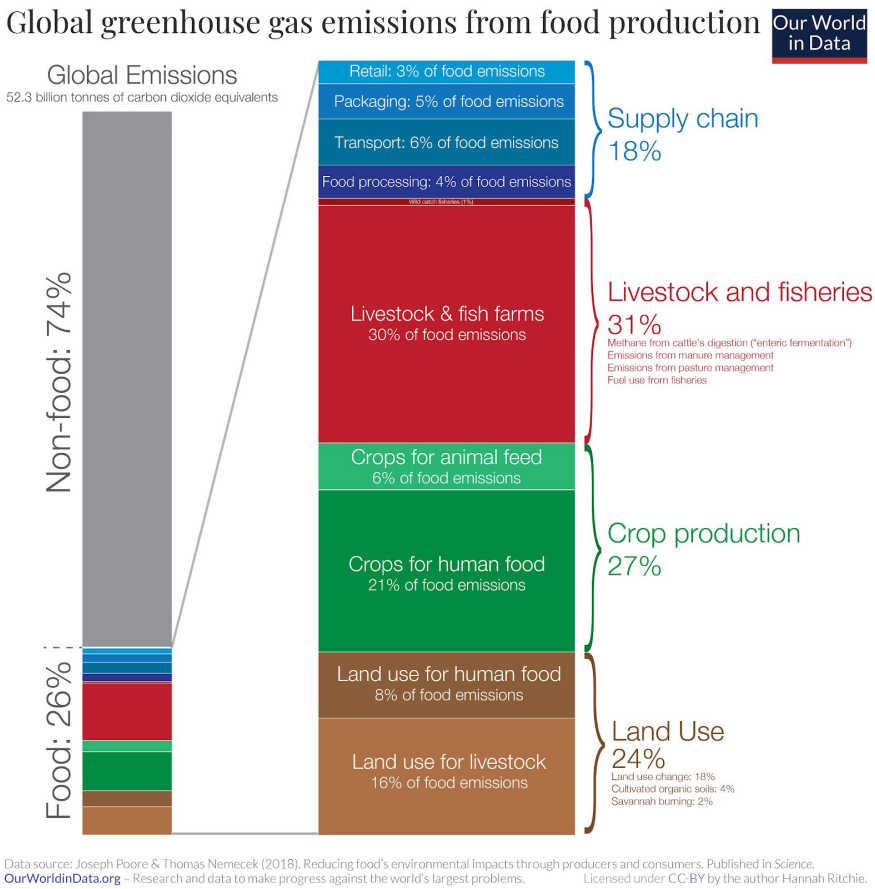

FIG. 2: A breakdown of the carbon emissions from food production.[8]

---

[6] J. Poore and T. Nemecek, "Reducing Food's Environmental Impacts through Producers and Consumers," *Science* 360, no. 6392 (June 1, 2018): 987–92, https://doi.org/10.1126/science.aaq0216.

[7] Kurt Benke and Bruce Tomkins, "Future Food-Production Systems: Vertical Farming and Controlled-Environment Agriculture," *Sustainability: Science, Practice and Policy* 13, no. 1 (January 2017): 13–26, https://doi.org/10.1080/15487733.2017.1394054.

[8] Hannah Ritchie, "Food Production Is Responsible for One-Quarter of the World's Greenhouse Gas Emissions," Our World in Data, June 11, 2019, https://ourworldindata.org/food-ghg-emissions.

While the food system significantly contributes to anthropogenic carbon emissions, agriculture and the food supply chain are also vulnerable to climate change's impacts.[9]

In this context, urban agriculture is of interest to SDG 13: Climate Action. First, urban agriculture can decarbonize the food supply chain, contributing to the mitigation of climate change. Furthermore, benefits such as stormwater management and reduction of the urban heat island effect[10] can help the urban environment adapt to climate change impacts.[11]

Agriculture also negatively impacts the environment in multiple ways. Land use change has negative effects on biodiversity and soil conditions due to changes in the natural habitat. Furthermore, the use of fertilizers is detrimental to water quality.[12] Urban agriculture also provides opportunities to mitigate these environmental pressures.[13] TABLE 1 gives an overview of the SDGs that urban agriculture relates to from an environmental perspective.

---

[9] J. Schmidhuber and F. N. Tubiello, "Global Food Security under Climate Change," *Proceedings of the National Academy of Sciences* 104, no. 50 (December 11, 2007): 19703–8, https://doi.org/10.1073/pnas.0701976104.

[10] "[t]he phenomenon that the urban air temperature is higher than that of the surrounding rural environment." Laura Kleerekoper, Marjolein Van Esch, and Tadeo Baldiri Salcedo, "How to Make a City Climate-Proof, Addressing the Urban Heat Island Effect," *Resources, Conservation and Recycling* 64 (2012): 30–38.

[11] Kurt Benke and Bruce Tomkins, "Future Food-Production Systems: Vertical Farming and Controlled-Environment Agriculture," *Sustainability: Science, Practice and Policy* 13, no. 1 (January 2017): 13–26, https://doi.org/10.1080/15487733.2017.1394054; Guo-yu Qiu et al., "Effects of Evapotranspiration on Mitigation of Urban Temperature by Vegetation and Urban Agriculture," *Journal of Integrative Agriculture* 12, no. 8 (August 1, 2013): 1307–15, https://doi.org/10.1016/S2095-3119(13)60543-2; Brad Bass and Bas Baskaran, "Evaluating Rooftop and Vertical Gardens as an Adaptation Strategy for Urban Areas, Report No NRCC-46737, Edited by National Research Council Canada" (IRC, 2003); Jha Ritesh Kumar et al., "Rooftop Farming: An Alternative to Conventional Farming for Urban Sustainability," *Malaysian Journal of Sustainable Agriculture* 3, no. 1 (2019): 39–43; Yoshiki Harada and Thomas H. Whitlow, "Urban Rooftop Agriculture: Challenges to Science and Practice," *Frontiers in Sustainable Food Systems* 4 (2020), https://doi.org/10.3389/fsufs.2020.00076.

[12] Jonathan A. Foley et al., "Solutions for a Cultivated Planet," *Nature* 478, no. 7369 (October 2011): 337–42, https://doi.org/10.1038/nature10452.

[13] Kathrin Specht et al., "Urban Agriculture of the Future: An Overview of Sustainability Aspects of Food Production in and on Buildings," *Agriculture and Human Values* 31, no. 1 (March 2014): 33–51, https://doi.org/10.1007/s10460-013-9448-4; Robert Taylor et al., "Making Global Cities Sustainable: Urban Rooftop Hydroponics for Diversified Agriculture in Emerging Economies," *OIDA International Journal of Sustainable Development* 5, no. 7 (2012): 11–28; Francesco Orsini et al., "Exploring the Production Capacity of Rooftop Gardens (RTGs) in Urban Agriculture: The Potential Impact on Food and Nutrition Security, Biodiversity and Other Ecosystem Services in the City of Bologna," *Food Security* 6, no. 6 (December 2014): 781–92, https://doi.org/10.1007/s12571-014-0389-6.

TABLE 1: an overview of the SDG targets urban agriculture can contribute to from an environmental perspective. Made by the authors.

SDG	Target	Relation to Urban Agriculture
SDG 1: No Poverty	By 2030, build the resilience of the poor and those in vulnerable situations and reduce their exposure and vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters	Resilience and adaptation can be increased through benefits such as flood risk reduction and reduced urban heat island effect.
SDG 2: Zero Hunger	By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality	Urban agriculture reduces environmental pressures of rural agriculture, especially when sustainable urban agriculture practices are applied. Furthermore, urban agriculture can support urban biodiversity and increase adaptation.
SDG 3: Good Health and Well-Being	By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination	Pollution can be reduced through the use of sustainable urban agriculture practices within the urban context.
SDG 6: Clean Water and Sanitation	By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally	Sustainable urban agriculture practices can reduce water contamination.
	By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity	Urban agriculture practices such as hydroponics have the potential to lower agriculture's water consumption.
	By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes	Urban agriculture prevents on-field impacts and land use change due to agricultural expansion.
SDG 11: Sustainable Cities and Communities	By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations	Urban agriculture may reduce flood risk by delaying stormwater runoff
	By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management	Urban agriculture can reduce the environmental pressures of urban food. Furthermore, urban waste streams can be valorized.
	By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015-2030, holistic disaster risk management at all levels	Urban agriculture can reduce the carbon footprint of food and increase resilience to climate change impacts such as urban heat island effect and floodings.
SDG 13: Climate Action	Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries	Through a reduced food carbon footprint and increased adaptation (see above)
SDG 15: Life on Land	Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species	Urban agriculture can reduce land use change for urban expansion.

2. The social sphere and urban agriculture

Social sustainability is the human dimension of sustainable development, essential to supporting human rights and promoting equal opportunities.[14] The social sphere and urban agriculture have been interwoven throughout history, enhancing community engagement and wellness.[15]

Agriculture was once the foundation of social systems, as food security was a deciding factor for a town's prosperity and advancement.[16] Although nearly 55% of the world's population migrated to urban areas as cities evolved, rural agriculture remained the main source of food production. This long distance between food source and consumer intensified the need to increase accessibility to rapid food production within cities themselves.[17]

Hence, as demographics rise and natural resources dwindle, it is important to create a social framework for future emergency food programs to ensure food security.[18] The United Nations SDG 2: Zero Hunger is aimed at providing food accessibility to the poor and vulnerable segments of society; however urban farming can aid in Target 2.3, to double agricultural production by 2030.

---

[14] Suzanne Vallance, Harvey C. Perkins, and Jennifer E. Dixon, "What Is Social Sustainability? A Clarification of Concepts," *Geoforum*, Themed Issue: Subaltern Geopolitics, 42, no. 3 (June 1, 2011): 342–48, https://doi.org/10.1016/j.geoforum.2011.01.002.

[15] O'Connor, "The 'Four Spheres' Framework for Sustainability."

[16] Alessandra Giannini et al., "Climate Risk and Food Security in Mali: A Historical Perspective on Adaptation," *Earth's Future* 5, no. 2 (2017): 144–57, https://doi.org/10.1002/2016EF000404; Anil K Gupta, "Origin of Agriculture and Domestication of Plants and Animals Linked to Early Holocene Climate Amelioration," *CURRENT SCIENCE* 87, no. 1 (2004): 6.

[17] To reconnect with their food source, a small group of citizens formed on the basis of environmental and social ethos during the 1970s, began urban farming to revitalize unused city spaces and grow food free from pesticides and genetically modified organisms (GMOs).
Emily Toner, Steve Hallet, and Lori Hoagland, "Urban Agriculture: Environmental, Economic, and Social Perspectives," *ResearchGate*, September 2016, https://doi.org/10.1002/9781119281269.ch2.

[18] Emily Toner, Steve Hallet, and Lori Hoagland.

Income disparity and societal segregation have manifested in the form of classism, racism, and educational inequalities within poor urban neighborhoods. These social injustices have highlighted the need to develop urban farms to locally source food at reasonable prices and uplift communities in order to achieve SDG 10: Reduce Inequalities.[19] These initiatives lead to community building, self-sufficiency, higher profitability possibilities, and access to recreational spaces.[20] As such, they work toward SDG 1: No Poverty by improving employment opportunities, and SDG 3: Good Health and Well-Being by increasing access to nutritious food. Furthermore, urban agriculture has the potential to work toward SDG 11: Sustainable Cities and Communities by improving building efficiency, enhancing green spaces, and fostering inclusion and social acceptance.

TABLE 2 gives an overview of all the SDGs that urban agriculture relates to from a social perspective.

[19] Alberto Zezza and Luca Tasciotti, "Urban Agriculture, Poverty, and Food Security: Empirical Evidence from a Sample of Developing Countries," *Food Policy* 35, no. 4 (August 1, 2010): 265–73, https://doi.org/10.1016/j.foodpol.2010.04.007.
[20] Emily Toner, Steve Hallet, and Lori Hoagland, "Urban Agriculture: Environmental, Economic, and Social Perspectives."

TABLE 2: an overview of the SDG targets urban agriculture can contribute to from a Social Perspective. Made by the authors.

SDG	Target	Relation to Urban Agriculture
SDG 1: No Poverty	By 2030, build the resilience of the poor and those in vulnerable situations and reduce their exposure and vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters	Urban agriculture has the possibility of alleviating poverty by providing employment opportunities for poorer segments, people with low skill and formerly incarcerated members of society. Along with income diversification, it also aids lower food cost.
SDG 2: Zero Hunger	By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality	As urban agriculture reduces the distance between source and consumer, it increases food security and accessibility to mass food production.
SDG 3: Good Health and Well-Being	By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination	The biophilic nature of urban agriculture helps promote physical activity and mental well being of different age groups in society.
SDG 4: Quality Education	By 2030, ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship and appreciation of cultural diversity and of culture's contribution to sustainable development	Including urban agriculture in education can be beneficial for young students to learn about the food network and be involved in the community.
SDG 8: Decent Work and Economic Growth	Achieve higher levels of productivity of economies through diversification, technological upgrading and innovation, including through a focus on high value added and labor-intensive sectors	Urban agriculture can create conditions to make it possible for all people to have equal job opportunities and the right to employment.
SDG 10: Reduce Inequalities	By 2030, empower and promote the social, economic and political inclusion of all, irrespective of age, sex, disability, race, ethnicity, origin, religion or economic or other status	Promote sustainable urban practises which are inclusive in nature toward people of different race, class or origin.
SDG 11: Sustainable Cities and Communities	Support positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning	Urban agriculture helps foster sustainable communities to strengthen societies in terms of food security, income generation and social well-being.
	By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities	Urban rooftop farming converts derelict urban spaces into zones of recreation and production that can be accessed by all.
SDG 13: Climate Action	Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning	Urban agriculture can help increase knowledge on food sources and supply chain, and their impacts on climate change. Impact reduction through urban agriculture is also possible in the case of food security in times of food emergencies.

3. The political and economic sphere and urban agriculture

In the traditional ESG framework that measures sustainability impact in business, governance is primarily focused on yielding better corporate returns. With criteria such as board structure, supplier code of conduct, and impact valuation, governance is limited in how it can spread positive societal impact.[21] The focus on economic improvements that pertain to both business and environment ignores the institution of politics. Distinguished by its inclusion of politics, the four-sphere framework works better to define issues, create solutions, and lead the other spheres in urban agriculture.[22]

The government has had a role in the popularization of urban agriculture in the history of the United States as early as World War II.[23] In the 1960s and 1970s, grassroots organizations revitalized urban farms by developing community gardens for low-income communities affected by disinvestment. The resurgence of urban agriculture called for the government to introduce policies to both police and protect urban farmers. Policies known as Right to Farm laws protected peri-urban farms from being classed a "nuisance."[24] To encourage urban agriculture, some cities have updated environmental ordinances to incorporate long-term community gardens. To set aside specific areas for these gardens, advocates of urban agriculture have fought

---

[21] "Exploring the G in ESG: Governance in Greater Detail – Part I," accessed August 12, 2020, https://www.spglobal.com/en/research-insights/articles/exploring-the-g-in-esg-governance-in-greater-detail-part-i.

[22] O'Connor, "The 'Four Spheres' Framework for Sustainability."

[23] Since food was rationed as part of the war effort, American families were encouraged to do their part by growing their own fruits and vegetables in victory gardens. The flair of the victory garden slowly dissipated once the war ended due to its symbolism of wartime hardships.
"Environmental Action and Urban Revitalization : Grown from the Past: A Short History of Community Gardening in the United States," Community of Gardens, accessed August 10, 2020, https://communityofgardens.si.edu/exhibits/show/historycommunitygardens/environmentalaction.

[24] Prior to the enactment of these laws, suburbanites would stage nuisance suits to address noise, water, and odor pollution resulting from farming activities.
Susanne A. Heckler, "A Right to Farm in the City: Providing a Legal Framework for Legitimizing Urban Farming in American Cities," Valparaiso University Law Review 47 (2013 2012): 217.

to formally acknowledge community gardens in local zoning codes that permit them to exist and grow in number.

Grassroots community groups throughout the world have appealed to local city councils to instate securities for urban farmers. Endeavors to build local coalitions and make use of vacant lots have brewed in large U.S. cities like Seattle, Detroit, Cleveland, and others. Urban farm advocates have continued to fight for state and national legislation that would empower community organizations to better take action. However, power is unevenly distributed among the city government, non-profit organizations, and grassroots community groups. There must be a focus on creating middlemen that connect these levels of subgroups with one another so that policy can be directed toward advocating for urban agriculture. Intermediary support is essential to reforming zoning codes, making urban agriculture more accessible, and educating the public. By strengthening national and regional development planning, the impact of middlemen supports SDG 11: Sustainable Cities and Communities.

When local governments attempt to depoliticize the transition to urban agricultural practices, it will be viewed as a "technical solution" with a large opportunity cost, according to planning councils. Despite the multifunctionality of urban agriculture, planners view the city spaces as potential businesses that will stimulate economic growth. Due to this bias, the government has a vested interest in remedying the deeper social inequities that are ingrained in the current urban agricultural system. Gaps in access to political power and material and financial resources determine where urban farms end up being located.[25] The only way to combat

[25] These low-income communities are often prevented from commodifying their own produce. For example, Monsanto, now known as Bayer, has had a large control over the seed industry, trying to strip farmers of autonomy and suing them for patent violations.
Smith, "The Politics of Urban Farming."

these institutions from taking advantage of farmers is to enact policy to popularize and protect urban farmers.

TABLE 3 gives an overview of the SDGs that urban agriculture relates to from an political and economic perspective.

TABLE 3: an overview of the SDG targets urban agriculture can contribute to from a political and economic perspective. Made by the authors.

SDG	**Target**	**Relation to Urban Agriculture**
SDG 8: Decent Work and Economic Growth	Achieve higher levels of productivity of economies through diversification, technological upgrading and innovation, including through a focus on high value added and labor-intensive sectors	Digital urban agriculture has allowed urban farms to economically optimize the growth of crops. There are several cost benefits to reducing distance between farmer and consumer (cut to gas expenses, fresher, more saleable produce, etc.).
SDG 11: Sustainable Cities and Communities	Support positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning	The reformation of zoning codes throughout the United States allow urban agriculture to be more accessible in low-income communities in several U.S. cities. Sustainability coalitions in support of urban farming promote focusing away from viewing rooftop farms as a "technical solution" as opposed to a multifunctional, cost-effective solution.
	By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities	
	By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015-2030, holistic disaster risk management at all levels	
SDG 13: Climate Action	Integrate climate change measures into national policies, strategies and planning	Policies to help mitigate greenhouse gas (GHG) emissions include the promotion of sustainable sourcing, inherent in local urban farms.
SDG 16: Peace, Justice, and Strong Institutions	Ensure responsive, inclusive, participatory and representative decision-making at all levels	Partnerships between different entities (urban agriculture advocates, food justice orgs, planning councils, etc.) should be created. People from marginalized communities where urban farms are created should have a say in the formation of legislation for urban farms.

III. Applying the four-sphere framework to urban rooftop farming

Many benefits of urban agriculture depend on the type of urban agriculture considered. This section of the paper will analyze urban rooftop farms in the United States for each sphere. Urban rooftop farming is a form of agriculture where food is grown on unutilized rooftops. It was chosen as it is interesting to examine in relation to each sphere in the framework. Environmentally, urban rooftop farming has the potential to reduce carbon emissions and environmental pressures with the additional benefit that it does not compete with other land uses such as development.[26] Socially, rooftop farming has the potential of increasing food security and employment opportunities, along with promoting community involvement, healthier lifestyles, and access to spaces of recreation and production.[27] Economically, rooftop farming reduces supply chain costs due to cutting down on transportation. Given all of these benefits of rooftop farming, local policymakers and investing stakeholders will be better equipped to understand the value in protecting and supporting urban agriculture.

In 2016, 70% of commercial urban rooftop farming projects were located in North America, with the trend increasing (see FIG. 3).[28] Within rooftop farming, there are two main types: open-air rooftop farms and rooftop greenhouses.[29] Open-air rooftop farms are usually soil-based while rooftop greenhouses often operate using hydroponics—a soilless growing

---

[26] Susanne Thomaier et al., "Farming in and on Urban Buildings: Present Practice and Specific Novelties of Zero-Acreage Farming (ZFarming)," *Renewable Agriculture and Food Systems* 30, no. 1 (February 2015): 43–54, https://doi.org/10.1017/S1742170514000143; Specht et al., "Urban Agriculture of the Future."
[27] Emily Toner, Steve Hallet, and Lori Hoagland, "Urban Agriculture: Environmental, Economic, and Social Perspectives."
[28] Devi Buehler and Ranka Junge, "Global Trends and Current Status of Commercial Urban Rooftop Farming," *Sustainability* 8, no. 11 (October 29, 2016): 1108, https://doi.org/10.3390/su8111108.
[29] Devi Buehler and Ranka Junge, "Global Trends and Current Status of Commercial Urban Rooftop Farming," *Sustainability* 8, no. 11 (October 29, 2016): 1108, https://doi.org/10.3390/su8111108.

system.[30] Hydroponics are considered very well-suited for rooftops as they are lightweight but enable high yields, making it both environmentally and economically attractive.[31] While hydroponics is more prevalent than soil-based open-air rooftop farms, the latter is also operated on a commercial scale.[32]

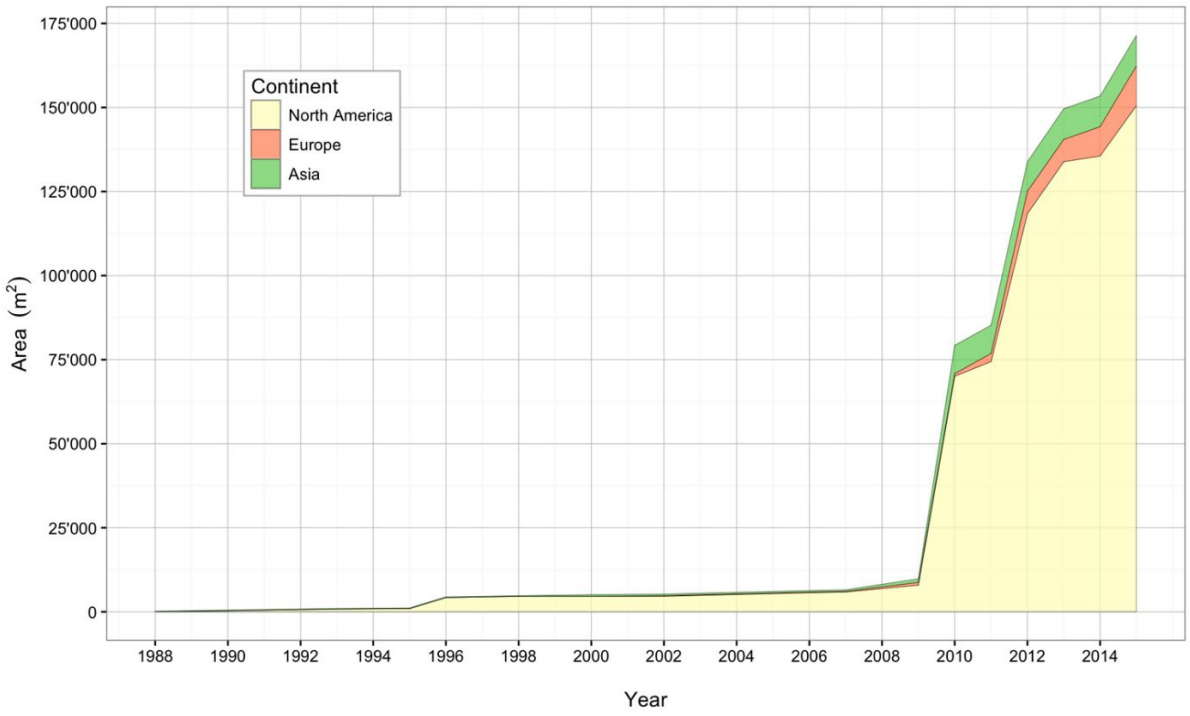

FIG. 3: The area of commercial urban rooftop farms over time for North America, Europe, and Asia.[33]

In the following section, benefits and opportunities that urban rooftop farms offer will be discussed within each sphere in the framework, starting with the environmental sphere.

[30] Buehler and Junge, "Global Trends and Current Status of Commercial Urban Rooftop Farming."
[31] Lim Yinghui Astee and Nirmal T Kishnani, "Building Integrated Agriculture: Utilising Rooftops for Sustainable Food Crop Cultivation in Singapore," *Journal of Green Building* 5, no. 2 (May 1, 2010): 105–13, https://doi.org/10.3992/jgb.5.2.105; Buehler and Junge, "Global Trends and Current Status of Commercial Urban Rooftop Farming"; Kathrin Specht et al., "Urban Agriculture of the Future: An Overview of Sustainability Aspects of Food Production in and on Buildings," *Agriculture and Human Values* 31, no. 1 (March 2014): 33–51, https://doi.org/10.1007/s10460-013-9448-4.
[32] Buehler and Junge, "Global Trends and Current Status of Commercial Urban Rooftop Farming."
[33] Buehler and Junge, "Global Trends and Current Status of Commercial Urban Rooftop Farming."

1. Urban rooftop farming: A discussion of the environmental sustainability sphere

In this section, urban rooftop farming will be discussed in terms of environmental sustainability. While the focus for this sphere is on how urban agriculture can advance climate change mitigation and adaptation, other environmental co-benefits and trade-offs will also be explained. Finally, a few examples of ways to further increase the environmental sustainability of urban rooftop farms will be discussed.

1.1 Climate change mitigation

Urban rooftop farming can reduce carbon emissions related to the food sector, contributing to climate change mitigation. As such, urban agriculture is a useful tool to further SDG 13: Climate Action. While some carbon savings are intrinsic to urban agriculture, overall reductions are only achieved when proper care is taken. A system must tailor its design to the local context, and take measures to identify opportunities to reduce carbon emissions present along the supply chain.

1.1a Intrinsic carbon reductions: Land use change, food waste and transport

Urban rooftop farming will reduce GHG emission along the food supply chain in comparison to rural agriculture in three main ways. First, urban rooftop farming prevents carbon emissions resulting from land use change due to agricultural expansion.[34] Moreover, through a

[34]While 8% of food carbon emissions are a result of land use change, this factor was rarely considered in the examined literature.
Devi Buehler and Ranka Junge, "Global Trends and Current Status of Commercial Urban Rooftop Farming," *Sustainability* 8, no. 11 (October 29, 2016): 1108, https://doi.org/10.3390/su8111108; Specht et al., "Urban Agriculture of the Future"; Michal Kulak, Anil Graves, and Julia Chatterton, "Reducing Greenhouse Gas Emissions

shorter supply chain and pest control in controlled environments, food waste is reduced.[35] Finally, urban agriculture reduces carbon emissions related to transport from the site of production to the point of sale, including savings on required cooling during transport.[36] This idea is referred to as reduced "food miles," a concept that promotes local food. Urban agriculture is often generalized as environmentally friendly because of these reduced food miles. However, reducing transport distances does not necessarily reduce a product's carbon footprint, since larger GHG emissions may take place in other steps of the life cycle.[37] It is then important that the design of the urban farm considers carbon emissions and opportunities to reduce GHG emissions along the supply chain.

1.1b Challenges and opportunities: Production and packaging

The production phase presents challenges and opportunities to lower carbon emissions when compared to the local conventional food supply chain. In favorable climates, crops can grow in open air year-round. Crop production in these open-air urban rooftop farms can be larger

---

with Urban Agriculture: A Life Cycle Assessment Perspective," *Landscape and Urban Planning* 111 (March 2013): 68–78, https://doi.org/10.1016/j.landurbplan.2012.11.007.

[35]Despite this potential, there is limited research focusing specifically on food loss avoidance through urban agriculture.
Taylor et al., "Making Global Cities Sustainable"; Esther Sanyé-Mengual et al., "Environmental Analysis of the Logistics of Agricultural Products from Rooftop Greenhouses in Mediterranean Urban Areas," *Journal of the Science of Food and Agriculture* 93, no. 1 (2013): 100–109; Khadija Benis and Paulo Ferrão, "Potential Mitigation of the Environmental Impacts of Food Systems through Urban and Peri-Urban Agriculture (UPA) – a Life Cycle Assessment Approach," *Journal of Cleaner Production* 140 (January 2017): 784–95, https://doi.org/10.1016/j.jclepro.2016.05.176.

[36] M. Dubbeling, "Cities, Climate Change and Urban Agriculture: The Potential Contributions of Urban and Peri Urban Agriculture and Forestry (UPA/F) to Climate Change Adaptation and Mitigation," in *Proceedings of RUAF-CAH Conference, Almere*, 2011, 19–20; Benjamin Goldstein et al., "Testing the Environmental Performance of Urban Agriculture as a Food Supply in Northern Climates," *Journal of Cleaner Production* 135 (November 2016): 984–94, https://doi.org/10.1016/j.jclepro.2016.07.004; Specht et al., "Urban Agriculture of the Future."

[37] Gareth Edwards-Jones, "Does Eating Local Food Reduce the Environmental Impact of Food Production and Enhance Consumer Health?," *Proceedings of the Nutrition Society* 69, no. 4 (November 2010), https://doi.org/10.1017/S0029665110002004.

or smaller than conventional rural crop production, depending on the local context and the techniques used.[38] In Northern climates, energy-intensive urban rooftop greenhouses are regularly implemented to help achieve high yields. Due to their high energy demand, production in conditioned environments often has a higher carbon footprint than conventional and open-air farming. As such, the fossil fuel percentage in the local grid has a large influence on the carbon footprint of food produced in rooftop greenhouses; powering rooftop greenhouses has been identified as a key opportunity to lower the carbon footprint.[39]

For both open-air and greenhouse rooftop farms, carbon emissions from crop production can be reduced or increased when compared to rural crop production, depending on the techniques used in their local context. It is thus key to design a locally tailored urban rooftop farm to optimize carbon emission savings. For instance, the United States' grid mix is 44% coal on average, but varies between states.[40] Considering this, open-air farms are preferable in states where the climate is favorable. In colder climates, it is worthwhile to consider coupling heated greenhouses to renewable energy sources.

---

[38]Astee and Kishnany (2010) for example assessed an open-air rooftop farm powered by solar energy. Goldstein et al., "Testing the Environmental Performance of Urban Agriculture as a Food Supply in Northern Climates"; Esther Sanyé-Mengual et al., "Techniques and Crops for Efficient Rooftop Gardens in Bologna, Italy," *Agronomy for Sustainable Development* 35, no. 4 (October 2015): 1477–88, https://doi.org/10.1007/s13593-015-0331-0; Kulak, Graves, and Chatterton, "Reducing Greenhouse Gas Emissions with Urban Agriculture"; Lim Yinghui Astee and Nirmal T Kishnani, "Building Integrated Agriculture: Utilising Rooftops for Sustainable Food Crop Cultivation in Singapore," *Journal of Green Building* 5, no. 2 (May 1, 2010): 105–13, https://doi.org/10.3992/jgb.5.2.105.

[39] T. Shiina et al., "Life Cycle Inventory Analysis of Leafy Vegetables Grown in Two Types of Plant Factories," *Acta Horticulturae*, no. 919 (December 2011): 115–22, https://doi.org/10.17660/ActaHortic.2011.919.14; Sofia-Anna Barla, Georgios Salachas, and Konstadinos Abeliotis, "Assessment of the Greenhouse Gas Emissions from Aeroponic Lettuce Cultivation in Greece," *Euro-Mediterranean Journal for Environmental Integration* 5, no. 2 (August 2020): 29, https://doi.org/10.1007/s41207-020-00168-w; Goldstein et al., "Testing the Environmental Performance of Urban Agriculture as a Food Supply in Northern Climates"; Alison Rothwell et al., "Environmental Performance of Local Food: Trade-Offs and Implications for Climate Resilience in a Developed City," *Journal of Cleaner Production* 114 (February 2016): 420–30, https://doi.org/10.1016/j.jclepro.2015.04.096.

[40] Rachel Plawecki et al., "Comparative Carbon Footprint Assessment of Winter Lettuce Production in Two Climatic Zones for Midwestern Market," *Renewable Agriculture and Food Systems* 29, no. 4 (December 2014): 310–18, https://doi.org/10.1017/S1742170513000161.

Another opportunity to reduce the carbon footprint of food produced on an urban rooftop is by minimizing or eliminating packaging.[41] Produce from urban farms can be sold without packaging, arriving fresher and with a longer shelf-life.[42] Alternatively, when the rooftop farm is located in close proximity to the supermarket, reusable packaging can be used.[43]

1.2 Climate change adaptation

Open-air urban rooftop farms can also enhance urban environmental adaptation to climate change in two ways. First, open-air rooftop farms have the potential to delay and reduce stormwater runoff, which can mitigate flood risks and sewer overflows.[44] This opportunity requires that attention is paid to water management and efficiency when designing the farm.[45] Second, open-air farms may create a cooling effect through evapotranspiration.[46] On a larger

---

[41] Additional food packaging used for transport is often induced by retail in order to increase shelf-life but also to make the product more attractive. Packaging leads to carbon emissions through the materials used and emissions from processing the waste.
Rothwell et al., "Environmental Performance of Local Food"; Angela Paxton, "Food Miles," in *Continuous Productive Urban Landscapes: Designing Urban Agriculture for Sustainable Cities*, 2005, 40–46.

[42] Paxton, "Food Miles"; David Sanjuan-Delmás et al., "Improving the Metabolism and Sustainability of Buildings and Cities through Integrated Rooftop Greenhouses (i-RTG)," in *Urban Horticulture* (Springer, 2018), 53–72.

[43] Sanyé-Mengual et al., "Environmental Analysis of the Logistics of Agricultural Products from Rooftop Greenhouses in Mediterranean Urban Areas."

[44] C. Rosenzweig, S. Gaffin, and W. D. Solecki, "Green Roofs in the New York Metropolitan Region: Research Report. A Joint Publication of NASA," *Goddard Institute for Space Studies, Columbia Center for Climate Systems Research of the Earth Institute at Columbia University, and Hunter College, City University of New York*, 2006; Jha Ritesh Kumar et al., "Rooftop Farming: An Alternative to Conventional Farming for Urban Sustainability," *Malaysian Journal of Sustainable Agriculture* 3, no. 1 (2019): 39–43; Harada and Whitlow, "Urban Rooftop Agriculture."

[45] Brooklyn Grange, a rooftop farm in New York, achieves only small stormwater reductions. However, the authors highlighted that stormwater reductions can be achieved in urban rooftop farming when water use efficiency is considered in the design.
Yoshiki Harada et al., "Hydrology of the Brooklyn Grange, an Urban Rooftop Farm," *Urban Ecosystems* 21, no. 4 (August 2018): 673–89, https://doi.org/10.1007/s11252-018-0749-7.

[46] Evapotranspiration is the evaporation of water present on leaves from transpiration. This process uses heat from the surrounding air, effectively cooling it down.
Panagiotis Gkatsopoulos, "A Methodology for Calculating Cooling from Vegetation Evapotranspiration for Use in Urban Space Microclimate Simulations," *Procedia Environmental Sciences* 38 (2017): 477–484.

scale, they could then help reduce the urban heat island effect.[47] By increasing urban adaptation to climate change, urban agriculture can help further SDG 1: No Poverty, SDG 2: Zero Hunger, SDG 11: Sustainable Cities and Communities, and SDG 13: Climate Action, illustrating that the carbon economy influences the broader landscape of sustainability.

1.3 Co-benefits versus trade-offs

While the focus for the environmental sphere is on carbon, there are potential environmental co-benefits of urban rooftop farming when compared to conventional food supply chains. Conventional agricultural production makes use of water, pesticides, fuel, and fertilizer, which lead to environmental impacts such as water depletion, ozone depletion, eutrophication, and acidification. Similarly, fuel use for transport comes with environmental pressures.[48] Urban rooftop farming has the potential to reduce these environmental pressures, the extent to which depends on the growing system used, and on which additional sustainable techniques are applied. One such benefit is the opportunity to reduce water consumption.[49] This opportunity is of particular importance, as crops suited for rooftop farming (e.g., lettuce) have high irrigation

---

[47] Guo-yu Qiu et al., "Effects of Evapotranspiration on Mitigation of Urban Temperature by Vegetation and Urban Agriculture," *Journal of Integrative Agriculture* 12, no. 8 (August 1, 2013): 1307–15, https://doi.org/10.1016/S2095-3119(13)60543-2; Brad Bass and Bas Baskaran, "Evaluating Rooftop and Vertical Gardens as an Adaptation Strategy for Urban Areas, Report No NRCC-46737, Edited by National Research Council Canada" (IRC, 2003); Benjamin Goldstein et al., "Urban versus Conventional Agriculture, Taxonomy of Resource Profiles: A Review," *Agronomy for Sustainable Development* 36, no. 1 (March 2016): 9, https://doi.org/10.1007/s13593-015-0348-4.

[48] Alessandra Fusi et al., "The Environmental Impact of the Production of Fresh Cut Salad: A Case Study in Italy," *The International Journal of Life Cycle Assessment* 21, no. 2 (February 2016): 162–75, https://doi.org/10.1007/s11367-015-1019-z.

[49] Hydroponics can reduce water requirements up to 10% of what is needed in conventional agriculture. Furthermore, transpired water in greenhouses can be recycled. Open-air rooftop farms can reduce water consumption through rainwater collection systems.
Taylor et al., "Making Global Cities Sustainable"; Sanyé-Mengual et al., "Environmental Analysis of the Logistics of Agricultural Products from Rooftop Greenhouses in Mediterranean Urban Areas"; Orsini et al., "Exploring the Production Capacity of Rooftop Gardens (RTGs) in Urban Agriculture"; Specht et al., "Urban Agriculture of the Future."

demands.[50] Furthermore, pollution levels can be decreased, along with resource depletion. For instance, in hydroponics, nutrients are recycled, reducing resource depletion and pollution.[51] Moreover, open-air rooftop farms can benefit biodiversity by (i) relieving environmental pressures that negatively affect biodiversity through on-field farming[52] and (ii) increasing biodiversity in the urban environment[53]. As biodiversity relies on species richness, growing a diverse range of crops is recommended to support urban biodiversity.[54]

While environmental co-benefits have been established, trade-offs between carbon reductions and environmental impacts will also occur.[55] It is then important to consider all

---

[50] Specht et al., "Urban Agriculture of the Future"; Taylor et al., "Making Global Cities Sustainable"; Orsini et al., "Exploring the Production Capacity of Rooftop Gardens (RTGs) in Urban Agriculture"; Yoshiki Harada and Thomas H. Whitlow, "Urban Rooftop Agriculture: Challenges to Science and Practice," *Frontiers in Sustainable Food Systems* 4 (2020), https://doi.org/10.3389/fsufs.2020.00076.

[51] Plawecki et al., "Comparative Carbon Footprint Assessment of Winter Lettuce Production in Two Climatic Zones for Midwestern Market"; Sanyé-Mengual et al., "Environmental Analysis of the Logistics of Agricultural Products from Rooftop Greenhouses in Mediterranean Urban Areas"; Sanyé-Mengual et al., "Techniques and Crops for Efficient Rooftop Gardens in Bologna, Italy"; Taylor et al., "Making Global Cities Sustainable."

[52] More evidence to support these claims is needed.
Harada and Whitlow, "Urban Rooftop Agriculture"; Benjamin Goldstein et al., "Urban versus Conventional Agriculture, Taxonomy of Resource Profiles: A Review," *Agronomy for Sustainable Development* 36, no. 1 (March 2016): 9, https://doi.org/10.1007/s13593-015-0348-4; Barbara Clucas, Israel D. Parker, and Andrea M. Feldpausch-Parker, "A Systematic Review of the Relationship between Urban Agriculture and Biodiversity," *Urban Ecosystems* 21, no. 4 (2018): 635–643; Brenda B. Lin, Stacy M. Philpott, and Shalene Jha, "The Future of Urban Agriculture and Biodiversity-Ecosystem Services: Challenges and next Steps," *Basic and Applied Ecology* 16, no. 3 (2015): 189–201.

[53] Ian Knowd, David Mason, and Andrew Docking, "Urban Agriculture: The New Frontier," *Changing City Structures* 23 (2006); Harada and Whitlow, "Urban Rooftop Agriculture"; Goldstein et al., "Urban versus Conventional Agriculture, Taxonomy of Resource Profiles."

[54] Brenda B. Lin, Stacy M. Philpott, and Shalene Jha, "The Future of Urban Agriculture and Biodiversity-Ecosystem Services: Challenges and next Steps," *Basic and Applied Ecology* 16, no. 3 (2015): 189–201; Janina Borysiak, Andrzej Mizgajski, and Andrew Speak, "Floral Biodiversity of Allotment Gardens and Its Contribution to Urban Green Infrastructure," *Urban Ecosystems* 20, no. 2 (April 1, 2017): 323–35, https://doi.org/10.1007/s11252-016-0595-4.

[55] For example, Sanyé-Mengual et al. (2015) found that soil-based rooftop farming of lettuce had the lowest carbon footprint, when compared to other forms of rooftop farms. However, this form did have a larger water input. Hydroponics on the other hand required less water but had higher carbon emissions.
Goldstein et al., "Testing the Environmental Performance of Urban Agriculture as a Food Supply in Northern Climates"; Sanyé-Mengual et al., "Techniques and Crops for Efficient Rooftop Gardens in Bologna, Italy"; Alison Rothwell et al., "Environmental Performance of Local Food: Trade-Offs and Implications for Climate Resilience in a Developed City," *Journal of Cleaner Production* 114 (February 2016): 420–30, https://doi.org/10.1016/j.jclepro.2015.04.096.

environmental impacts when designing an urban rooftop farm, rather than solely considering GHG emissions, as there will also be trade-offs.[56]

By maximizing environmental benefits, urban agriculture plays a role in achieving multiple SDGs. A sustainable food system is an important element of SDG 2: Zero Hunger and SDG 11: Sustainable Cities and Communities. Furthermore, by decreasing pollution, urban agriculture furthers SDG 3: Good Health and Well-Being, and SDG 6: Clean Water and Sanitation—for which reducing water consumption is also key.

1.4 Opportunities to enhance benefits

There is an opportunity to enhance the discussed benefits of urban rooftop farming through the implementation of non-traditional techniques or designs.

For example, there are alternative practices that allow favorable climate conditions without extensive energy outputs such as hoop houses.[57] Plawecki et al. (2014) compared winter lettuce produced in California and shipped to Michigan to winter lettuce grown in a heated hoop house in Michigan. They showed that producing lettuce in hoop houses significantly lowered the carbon footprint and had environmental co-benefits including reduced eutrophication, acidification, and ecological toxicity.[58]

---

[56] Goldstein et al., "Testing the Environmental Performance of Urban Agriculture as a Food Supply in Northern Climates"; Sanyé-Mengual et al., "Techniques and Crops for Efficient Rooftop Gardens in Bologna, Italy"; Alison Rothwell et al., "Environmental Performance of Local Food: Trade-Offs and Implications for Climate Resilience in a Developed City," *Journal of Cleaner Production* 114 (February 2016): 420–30, https://doi.org/10.1016/j.jclepro.2015.04.096.

[57] Hoop houses, also called unheated greenhouses or high tunnels, are structures that are covered in a polyethylene film, mitigating cold periods through passive heat capture.
Edward E. Carey et al., "Horticultural Crop Production in High Tunnels in the United States: A Snapshot," *HortTechnology* 19, no. 1 (January 1, 2009): 37–43, https://doi.org/10.21273/HORTSCI.19.1.37.

[58] Plawecki et al., "Comparative Carbon Footprint Assessment of Winter Lettuce Production in Two Climatic Zones for Midwestern Market."

Another example of a non-traditional design is the idea of "integrated rooftop greenhouses." This idea seeks to reduce environmental impacts and increase energy efficiency by capitalizing on the symbiosis between the rooftop greenhouse and the building. Residual energy, water, and CO_2-flows will be connected and reused.[59] The integrated rooftop greenhouse can have significantly lower GHG emissions compared to isolated rooftop greenhouses, along with other environmental benefits such as reduced waste and water consumption.[60]

Lastly, the use of agricultural waste or urban food waste as input for the urban farm can further reduce environmental impacts, including the carbon footprint and co-benefits such as acidification and eutrophication potential.[61] This technique reduces the need for fertilizers and valorizes urban waste streams, which further the goals of SDG 11: Sustainable Cities and Communities by improving waste management.

These examples illustrate that the environmental performance of urban rooftop farms can be further increased by implementing high-tech solutions, but also through low-tech practices.

---

[59] While relatively new, one such building is located in Barcelona, Spain, the ICTA-iRTG.
Ana Nadal et al., "Building-Integrated Rooftop Greenhouses: An Energy and Environmental Assessment in the Mediterranean Context," *Applied Energy* 187 (February 2017): 338–51, https://doi.org/10.1016/j.apenergy.2016.11.051.

[60] Esther Sanyé-Mengual et al., "An Environmental and Economic Life Cycle Assessment of Rooftop Greenhouse (RTG) Implementation in Barcelona, Spain. Assessing New Forms of Urban Agriculture from the Greenhouse Structure to the Final Product Level," *The International Journal of Life Cycle Assessment* 20, no. 3 (March 2015): 350–66, https://doi.org/10.1007/s11367-014-0836-9; Sanjuan-Delmás et al., "Improving the Metabolism and Sustainability of Buildings and Cities through Integrated Rooftop Greenhouses (i-RTG)."

[61] On a small scale, waste from the urban rooftop farm can be used as a substrate for the crop. On a larger scale, urban waste streams can also be used.
Georgios Bartzas, Dimitra Zaharaki, and Kostas Komnitsas, "Life Cycle Assessment of Open Field and Greenhouse Cultivation of Lettuce and Barley," *Information Processing in Agriculture* 2, no. 3–4 (October 2015): 191–207, https://doi.org/10.1016/j.inpa.2015.10.001; Ana Manríquez-Altamirano et al., "Analysis of Urban Agriculture Solid Waste in the Frame of Circular Economy: Case Study of Tomato Crop in Integrated Rooftop Greenhouse," *Science of The Total Environment* 734 (September 2020): 139375, https://doi.org/10.1016/j.scitotenv.2020.139375; Baptiste J.-P. Grard et al., "Rooftop Farming on Urban Waste Provides Many Ecosystem Services," *Agronomy for Sustainable Development* 38, no. 1 (February 2018): 2, https://doi.org/10.1007/s13593-017-0474-2.

1.5 Environmental benefits of rooftop farming: Creating and seizing opportunities

This section has illustrated that multiple environmental benefits can be achieved when growing crops on rooftops within the urban area, rather than distant on-field cultivation. First, carbon reductions can be made throughout the life cycle. While reduced transport emissions are inherent to the concept, other carbon savings can only be achieved by intentionally choosing sustainable and context-appropriate practices. Urban rooftop farms can also help the urban environment adapt to climate change, provided these opportunities are recognized and factored in. Furthermore, environmental co-benefits such as reduced water consumption, pollution, and resource depletion can be achieved depending on the techniques used. Trade-offs however will also occur. As a result, when designing an urban rooftop farm, all environmental impacts should be considered, and a design should be chosen that maximizes all benefits.

Thus, in order to advance sustainable development using urban rooftop farms, it is key to carefully design the farm so that opportunities are recognized and seized, by doing thorough research that is tailored to the local context.

2. Urban rooftop farming: A discussion of the social sustainability sphere

Although environmental and economic benefits of urban agriculture can be quantified, this is not directly possible for social benefits. Nonetheless, they are of equal importance. This section will discuss the social benefits of urban agriculture when designed as a space that allows exploration of self expression, gender, and civil disobedience, along with food production and pollution reduction, creating "a new paradigm of community building."[62] As opposed to other kinds of urban agriculture, rooftop farming has a strong emphasis on the social sphere because it creates the opportunity for inclusion in society and a sense of self reliance, where the community members can grow their own food and generate income.

2.1 Food security and accessibility

Climate change threatens food security through the increased occurrences of extreme weather events and the increase of diseases.[63] As carbon emissions and energy consumption continue to increase, it can stress global agriculture systems to where they may begin to decline, leading to famines.[64] Rooftop farming has the potential to provide a constant supply of fresh food as well as a shorter supply chain from source to consumer, which leads to a lesser chance of contamination and spread of disease.[65] However, integrating rooftop farms as a permanent

---

[62] "Exploring The Social Benefits Of Urban Farming In Smart Cities," January 24, 2018, https://leadingcities.org/2018/01/24/exploring-the-social-benefits-of-urban-farming-in-smart-cities/.
[63] Schmidhuber and Tubiello, "Global Food Security under Climate Change."
[64] Lamiaa Abdallah and Tarek El-Shennawy, "Reducing Carbon Dioxide Emissions from Electricity Sector Using Smart Electric Grid Applications," Review Article, Journal of Engineering (Hindawi, April 9, 2013), https://doi.org/10.1155/2013/845051.
[65] Emily Toner, Steve Hallet, and Lori Hoagland, "Urban Agriculture: Environmental, Economic, and Social Perspectives."

component of the urban landscape is a constant debate. While some people consider it to be a hindrance to progress and improper land use, others believe that in a world filled with crisis, it is unwise to be far from a source of food.[66] In light of the current pandemic, the New York Times reported that urban farming has gained much traction, as there is a hesitancy to rely on industrial agriculture.[67] Recognizing the potential benefit of implementing a food network is vital to the progress of food security in U.S. cities.[68] When utilized for urban farming, vacant plots and rooftops turn into generators of overall food security and social well-being.[69]

2.2 Promoting Community Involvement and Employment

A main factor of the social sphere is the unbiased inclusion and employment in all parts of society. SDG 10: Reduced Inequalities aims to provide equal opportunities to people, and SDG 8: Decent Work and Economic Growth, talks about creating conditions to make it possible for all people to have equal job opportunities. This section will discuss how urban rooftop farming promotes community involvement through inclusion of the poor, immigrants, social outsiders, the elderly, and the youth.

---

[66] Emily Toner, Steve Hallet, and Lori Hoagland.

[67] Tejal Rao, "Food Supply Anxiety Brings Back Victory Gardens," *The New York Times*, March 25, 2020, sec. Food, https://www.nytimes.com/2020/03/25/dining/victory-gardens-coronavirus.html.

[68] Brazil's Ministry for Social Development and Fight against Hunger's "Zero Hunger Policy," has wide ranging policies to support urban agriculture as a means to ensure food security in a developing country.
Andrew J. Hamilton et al., "Give Peas a Chance? Urban Agriculture in Developing Countries. A Review," *Agronomy for Sustainable Development* 34, no. 1 (January 1, 2014): 45–73, https://doi.org/10.1007/s13593-013-0155-8; José Graziano da Silva et al., *The Fome Zero (Zero Hunger) Program: The Brazilian Experience*, 2013.

[69] Detroit, for example, has decayed to the extent where it has several vacant plots and buildings, a lacking food network, and high unemployment rates. In order to reduce pressure on rural agriculture, rooftop farming in such slightly lower-income neighborhoods is a good option to enhance food security.
Christine Eigenbrod, Nazim Gruda, "Urban Vegetable for Food Security in Cities. A Review," *ResearchGate*, accessed August 12, 2020, https://www.researchgate.net/publication/271846267_Urban_vegetable_for_food_security_in_cities_A_review.

2.2a Inclusion of marginalized communities

Urban rooftop farming creates new opportunities for inclusion of the urban poor. Social reformists and NGOs provide the urban poor with the opportunity to work on these farms, having a positive psychological effect and providing a sense of belonging in the community. Strategies of urban farming have worked well in developing countries, to alleviate poverty and be a constant source of food and income generation. These strategies highlight the possibility of urban farms being implemented in the United States, to help marginalized communities feel included in society.[70]

Urban agriculture can also increase immigrant inclusion. Immigrants who have come from developing countries typically have lower chances of securing high paying jobs in the United States, and are usually viewed as outsiders. Engaging these immigrants in urban agriculture creates spaces for human interaction. It can be a key pillar for new forms of social involvement between the citizens and immigrants, generating social associations, employment, food, and unity.[71]

Similar to the social benefits of employing people from low-income families or immigrants, urban farming can have a major social impact and be an income generator for the

---

[70] The UN-Habitat Sustainable Cities Program's 2003 initiative of introducing Allotment Gardens for urban poor families to cultivate vegetables in Cagayun de Oro, Philippines, which helped alleviate poverty by providing the opportunity to sell 68% produce on site and the remainder for self consumption.
Robert Holmer and Drescher Axel W., "Empowering Urban Poor Communities through Integrated Vegetable Production in Allotment Gardens: The Case of Cagayan de Oro City, Philippines," *ResearchGate*, May 2006, https://www.researchgate.net/publication/239528437_Empowering_Urban_Poor_Communities_through_Integrated_Vegetable_Production_in_Allotment_Gardens_The_Case_of_Cagayan_de_Oro_City_Philippines.

[71] Urban agriculture initiatives in the downtown area of Barcelona, have created a space of dialogue for neighborhoods with high levels of immigrants, establishing a sense of social inclusion with the locals and reviving abandoned spaces.
"Exploring The Social Benefits Of Urban Farming In Smart Cities."

formerly incarcerated.[72] Employing formerly incarcerated individuals on urban rooftop farms can potentially reduce their employment in carbon-intensive jobs post their term.[73] Additionally, it would be beneficial if menial labor in prisons was replaced with agricultural training. This training would provide food security for the inmates as well as train them during their time in prison, enhancing their ability to work at urban farming organizations once they reenter society and reduce rates of recidivism.[74]

2.2b Involvement of the elderly

Urban agriculture can also benefit the elderly by providing a space to facilitate human interaction, participation in cultivation, and community involvement.[75] Urban farms create a network of communication for the elderly and also help keep them active—physically as well as mentally—which benefits their overall health.[76] Furthermore, urban farming can be a way to create purpose for elders in the community, as modern-day digitalization has led to cases of isolation and a process of individualization.[77] Encouraging senior citizens to change their habits and allot a part of their day to urban farming also indirectly reduces carbon emissions by

---

[72] As per the U.S. Bureau of Justice Statistics, nearly 22% of the world's prisoners are in the United States. This leads to a great number of individuals which once released from prison are usually not accepted back into society due to lack of educational qualifications, social standing, or level of skill and expertise.
"Bureau of Justice Statistics (BJS) - Total Correctional Population," accessed July 18, 2020, https://www.bjs.gov/index.cfm?tid=11&ty=tp.

[73] The formerly incarcerated traditionally pursue jobs in the construction or transport industry, which result in high GHG emissions.
Christy Visher, Sara Debus-Sherrill, and Jennifer Yahner, "Employment after Prison: A Longitudinal Study of Releasees in Three States," October 2008, 9.

[74] Rūta Vaičiūnienė, "Killing Time in Prison: Purposeful Activities and Spare Time in Lithuanian Correctional Facilities," *The Journal of Power Institutions in Post-Soviet Societies. Pipss.Org*, no. Issue 19 (November 15, 2018), https://doi.org/10.4000/pipss.5082.

[75] "Exploring The Social Benefits Of Urban Farming In Smart Cities."

[76] Maria Hofmann and Maryam Javed, "Green Spaces and Mental Health: Does Frequency Of Use Or Proximity Affect Subjective Wellbeing And Perceived Stress?," *ResearchGate*, January 2019, https://doi.org/10.20319/pijss.2019.43.786798.

[77] "Exploring The Social Benefits Of Urban Farming In Smart Cities."

potentially lowering electric consumption.[78] Additionally, growing microgreens requires low physical engagement, thus making it a suitable activity for the elderly.[79] Rooftop farming initiatives atop assisted living facilities and senior citizen homes can be a beneficial solution to regenerate the connectivity with nature and magnify the sense of purpose and inclusion.

2.2c Incorporation in education and skill enhancement

From the educational perspective, it is important for children to know the source of where their food is being grown and obtain the skills for cultivating it. The incorporation of urban agriculture into educational curricula has created a self-reliance by which students can learn to sustain their own needs.[80] Many countries have recognized this potential, leading to school boards and health agencies beginning to work with farms and cooperatives to bring local food into educational institutions, in order to instill characteristics of community solidarity, social skills, and self-esteem.[81] Not only do schools value locally-grown food, but they desire educational opportunities for young students to learn about local food distribution in the

---

[78] The U.S. Bureau of Labor Statistics states, an average senior citizen spends nearly 5 hours a day watching television post retirement. Reducing electricity usage, would in turn reduce the atmospheric carbon as currently 40% of global CO_2 emissions is a result of electricity generation.
Abdallah and El-Shennawy, "Reducing Carbon Dioxide Emissions from Electricity Sector Using Smart Electric Grid Applications"; "American Time Use Survey: Charts by Topic: Leisure and Sports Activities," December 20, 2016, https://www.bls.gov/tus/charts/leisure.htm.

[79] Francesco Orsini et al., "Farmers-to-Consumers: An Example of Sustainable Soilless Horticulture in Urban and Peri-Urban Areas," *ResearchGate*, January 2009, https://doi.org/10.17660/ActaHortic.2009.809.21.

[80] Carolyn Dimitri, Lydia Oberholtzer, and Andy Pressman, "Urban Agriculture: Connecting Producers with Consumers," ed. Fabio Verneau and Professor Christopher J, *British Food Journal* 118, no. 3 (March 7, 2016): 603–17, https://doi.org/10.1108/BFJ-06-2015-0200.

[81] For example, the local government in Montevideo has incorporated agriculture as a compulsory component of primary school education.
Alain Santandreu et al., "Urban Agriculture in Montevideo and Rosario: A Response to Crisis or a Stable Component of the Urban Landscape?," June 2009, 2; JoAnne Berkenkamp, "Making the Farm / School Connection: Opportunities and Barriers to Greater Use of Locally-Grown Produce in Public Schools," *Leopold Center Pubs and Papers* 153 (2006): 33.

community. Field trips to rooftop gardens like the Five Borough Farm project in New York are attractive opportunities for young students to learn more about environmental sustainability.[82]

Aside from socially benefiting the youth, schools and universities in cities that host rooftop gardens might be able to perform research on the further environmental, social, and economic consequences of urban agriculture. The generated data can help strengthen the case for rooftop gardens.

2.3 Improving Physical and Mental Health

Health is a vital element of the social sphere, and urban farming can work toward SDG 3: Good Health and Well-Being by promoting nutrient-rich food, physical activity, and mental wellness. Physical engagement in farming activities such as walking, sowing, weeding, watering, and harvesting can aid in reducing the high obesity rates and the future health complications which they precede.[83] On the spectrum of malnutrition, on one end obesity is rampant in developed countries while at the other end, undernourishment is a major problem in developing

---

[82] The Five Borough Farm project in New York emphasizes community development as one of their major goals. They have developed innovative programs of engagement such as Youth Empowerment, Youth Leadership Training, paid internships for students, classes and workshops on food and nutrition. The project also promotes environmental consciousness through low carbon strategies, rainwater harvesting, and composting.
Nevin Cohen and Kristin Reynolds, "Five Borough Farm: Seeding the Future of Urban Agriculture in New York City," July 2012, https://www.academia.edu/18958897/Five_Borough_Farm_Seeding_the_Future_of_Urban_Agriculture_in_New_York_City.

[83] Obesity rates are extremely high in the United States due to high energy diets rich in refined fats and carbohydrates.
Andrew M. Prentice, "The Emerging Epidemic of Obesity in Developing Countries," *International Journal of Epidemiology* 35, no. 1 (February 1, 2006): 93–99, https://doi.org/10.1093/ije/dyi272; Hamilton et al., "Give Peas a Chance?"

countries that face food scarcity.[84] In order to eradicate malnutrition and maintain universally good health, it is important to have access to high-quality fresh vegetables at affordable prices.[85]

Mental health is also benefited as psychologists believe the biophilic nature of urban farming has a therapeutic effect on urban dwellers, aiding stress reduction.[86] A common solution to de-stress or rejuvenate is going to the countryside, resulting in unaccounted transportation carbon. This carbon can be eliminated with the popularization of urban rooftop gardens, more easily accessible spaces of recreation.[87]

2.4 Building Efficiency and Energy Symbiosis

Other than having a direct impact on the community, rooftop farming can be beneficial to the built environment as well. In apartment buildings, the top-most floors heat up excessively in summer and lose heat rapidly in winter due to an exposed roof. These changes in heat increase the demand on cooling and heating in the respective seasons, increasing the energy consumption to nearly double that which is normally consumed.[88] Rooftop greenhouses have the potential to decrease the energy demand of buildings as the greenhouse creates an insulating layer between the roof and the environment.[89] The life expectancy of the roof is also increased, as the rooftop

---

[84] The World Health Organization's statistics on malnutrition state that "approximately 462 million adults worldwide were underweight, while 1.9 billion were either overweight or obese."
Hamilton et al., "Give Peas a Chance?"; "Fact Sheets - Malnutrition," April 1, 2020, https://www.who.int/news-room/fact-sheets/detail/malnutrition.

[85] Francesco Orsini et al., "Farmers-to-Consumers."

[86] Marion Tharrey et al., "Does Participating in Community Gardens Promote Sustainable Lifestyles in Urban Settings? Design and Protocol of the JArDinS Study," *BMC Public Health* 19, no. 1 (May 17, 2019): 589, https://doi.org/10.1186/s12889-019-6815-0.

[87] Maria Hofmann and Maryam Javed, "Green Spaces and Mental Health."

[88] Asmat Ismail, Muna Hanim Abdul Samad, and Abdul Malek Abdul Rahman, "Literature Review On Green Roof Technology: A Way To Improve Thermal Performance And Energy Consumption In Building," *ResearchGate*, June 2008.

[89] Goldstein et al., "Testing the Environmental Performance of Urban Agriculture as a Food Supply in Northern Climates."

farming protects the roof material from climatic elements and weathering. Furthermore, optimizing unused roof space through rooftop gardens and farming enhances the property value and quality of living. This space provides an additional amenity to the residents along with improving the air quality and providing acoustic insulation, resulting in social, economic, and health benefits.

2.5 Rooftop farming: The potential social benefits

This section has illustrated the potential social benefits obtained from rooftop farming in contrast to traditional farming practices.While locally grown food increases the trust in food sources and strengthens food security, there are several other environmental and economic factors to be considered to achieve a sustainable practice. Furthermore, community involvement varies in different societies, hence it is not possible to achieve the same levels of social inclusion even if the farming strategies and policies are along the same lines. Further research is required to show the importance of the role of the contributor in urban farming and prove that it can be a tool to promote community unity.

Lastly, further benefits include improving health, increasing accessibility to green spaces, and reducing building energy consumption. These positive social externalities thus enhance the overall well-being of people who participate in urban farming.

3. Urban rooftop farming: A discussion of the political and economic sustainability spheres

According to the World Bank, cities produce about 70% of GHG emissions and urban populations continue to grow. It is important to note that 90% of this growth takes place in developed countries.[90] As such, it has become more critical than ever to mitigate climate change by advancing sustainable cities in developed countries like the United States. Integration of climate change measures in local and national policies is a target for SDG 13: Climate Change. Opportunities for further integration of these measures lie in the lack of policies protecting urban agriculture. Underutilized land use in cities have been transformed into urban farms that address food insecurity.

One target of SDG 11: Sustainable Cities and Communities is to provide universal access to safe green spaces like urban farms for marginalized communities, whose low-income areas often experience food insecurity. However, the restrictive red tape of traditional policy prevents urban agriculture from developing well. As opposed to more drastic measures such as implementing vertical farms, supporting rooftop farms in cities will allow investors and policymakers to see the benefits of urban agriculture. In order to better shape rooftop farms as an attractive option for policymakers, it is necessary to pursue a similar interest to the United Nations' SDG 16: Peace, Justice, and Strong Institutions. A key goal of this SDG is to support responsive, participatory decision-making at all levels, which enforces accountability. By creating partnerships between different entities as well as including people from different economic, social and religious backgrounds, this goal can be achieved.

[90] "Urban-Agriculture-Magazine-No.-25-RUAF-10-Years.Pdf," accessed September 2, 2020, https://ruaf.org/assets/2019/11/Urban-Agriculture-Magazine-no.-25-RUAF-10-years.pdf.

In this section, an emphasis on SDG 11: Sustainable Cities and Communities and SDG 16: Peace, Justice, and Strong Institutions will be used to capture an effective form of preparation for portraying rooftop farms as a worthwhile option for policymakers to consider. First, the major risk of urban farms being classified as gentrification will be deconstructed and explored as a positive for policy support. Then, symbiotic partnerships with different stakeholders will be analyzed in order to establish a sustainable funding system for rooftop farms. Finally, more technical economic advantages of rooftop farms will complement the value of these partnerships.

3.1 Gentrification

Among the many risks inherent in pursuing rooftop agriculture is gentrification. Economic and cultural gentrification pressures are vital factors in urban integration because the potential transformation of neighborhoods impacts local policymaking. Stakeholders often fear two main risks associated with rooftop agriculture: (i) the high complexity of rooftop farm technology and (ii) the notion that large enterprises will overtake these historically grassroots-based initiatives.[91] Many stakeholders in the industry are hesitant to accept complex technologies such as soilless growing into their communities. The high costs of these technologies also concern citizens because they associate these designer solutions with the help of corrupt individuals and enterprises. Moreover, for-profit entrepreneurs who establish rooftop greenhouses are often at risk of using a model that more resembles an unsustainable company.

[91] Specht and Sanyé-Mengual, "Risks in Urban Rooftop Agriculture."

Instead of these entrepreneurs spearheading the rooftop farms, there must be a requirement to have NGOs or private initiatives managing these socially-driven projects. Solicitation of input from food justice-oriented organizations and from the disadvantaged communities themselves should then be encouraged in order to prevent displacement.[92] These NGOs and food justice-oriented organizations are key to lobby for affordable housing that includes access to rooftop gardens. A diverse set of individuals composing a task force of middlemen would better be able to connect NGOs, grassroots organizations, local city council members, and state legislators and communicate these demands.[93]

Private initiatives like NGOs will ensure that the urban farms will be as inclusive as possible, especially considering those who benefit from urban agriculture the most should be able to access it most easily. However, there is a growing trend in the urban agriculture space that could be classified as gentrification— the digitization of practices[94] that attempts to advance the goal of SDG 8: Decent Work and Economic Growth by economically optimizing crop growth with technological innovation. Candid discussions with Denver citizens revealed that people find digital urban agriculture to be less socially acceptable.[95] High-tech solutions and the misconception that they will instantly improve digital literacy create a sense of discomfort for those without the skill sets and training to handle the technology. It is thus important that urban farm supporters do not ignore the deep structural inequalities present in these neighborhoods.

---

[92] Horst, McClintock, and Hoey, "The Intersection of Planning, Urban Agriculture, and Food Justice."

[93] In a case study of community gardening in the California Central Coast, racial tensions associated with capitalist urbanizations lead to inefficient resource management. Conflicts over theft of harvest by outsiders demonstrated agonism embedded in the community.
Egerer and Fairbairn, "Gated Gardens."

[94] One example of this digitization of urban farming is automation exhibition feedback that provides custom farm plans based on weather, soil, pest, and crop data in near-real time.
Trendov, Varas, and Zeng, "Digital Technologies in Agriculture and Rural Areas."

[95] Carolan, "'Urban Farming Is Going High Tech.'"

In addition, as the popularity and success of urban and peri-urban farms grow, rural farms find it difficult to transition into these digital agricultural practices. There exists an even wider disparity between those operating urban and rural agriculture in the digital literacy necessary for high-tech solutions. This difference overtly challenges the simultaneous growth of both sectors. On the other hand, the rise of digital and urban agriculture provides an opportunity for rural agriculture to develop this essential digital literacy and improve food security, profitability, and sustainability. A joint partnership between both urban and rural farms, along with a smooth transition into innovative supplements, is crucial to promote rooftop farms and support SDG 16.

After understanding the perception of rooftop farming through the eyes of the community, it is then important to organize this information in a way that appeals to local, state, and national policymakers. Even though the high-tech features of digital urban farm technologies are attractive investments, the drastic change in automation diminishes the human-centric nature of the initiative. Policymakers willing to sacrifice tradition will be more amenable to steady steps in the transition to urban farming, as long as this solution precludes gentrification. However, as gentrification becomes more of a hot-button issue, people continue to grow weary of the power of large enterprises looking to profit off of neighborhoods. As such, the perception of large enterprises as money-grubbing behemoths can and should be amended to fit a more collaborative narrative.

3.2 Partnerships with large enterprises

The goal for smallholding growers is to appear worthy of support from policymakers. These policymakers have the power to update environmental ordinances and zoning laws that

reinforce urban agriculture at large. Planners value the commercial farm because of the opportunity cost of hosting a lucrative business in lieu of an urban rooftop farm. As opposed to vertical farms or community farms that take up valuable real estate, rooftop farms are able to take advantage of largely unused space. However, city officials still view them as technical solutions and necessitate that the potential multifunctionality of the rooftop farms are used to their best capabilities.[96] Thus, to better incentivize rooftop farming, advocates should regard these areas as commercial farms rather than mere community gardens.

When examining rooftop farms as commercial farms, it is important to plan for them to be competitive in a market so that they can be seen as lucrative businesses. However, a major obstacle is the high-start up cost of setting up the infrastructure. To be competitive among other produce sellers, rooftop agriculture should set a standard in operating under optimal conditions achieved through various expensive technologies. While agri-lenders may pass the first step of initial funding, they must also sustain growth and stimulate opportunities for success within the disadvantaged communities. Disregarding areas with thriving farmers' markets, local growers find it difficult to advertise their food to wholesale distributors. "Buy local" campaigns have proven successful, since the influence of culinary trends has led to changes in the modern consumer's food choices.[97]

---

[96] Andrew Butt and Elizabeth Taylor, "Smells like Politics: Planning and the Inconvenient Politics of Intensive Peri-Urban Agriculture," *Geographical Research* 56, no. 2 (2018): 206–18, https://doi.org/10.1111/1745-5871.12266.

[97] There are many responses to this challenge, which include: foundations providing seed-grants; farming businesses donating their wares, tool banks renting their equipment for a fee, and governments funding redevelopment plans that bestow micro-credit to growers connected to NGOs.
Brown and Carter, "Urban Agriculture and Community Food Security in the United States."

3.2a Different stakeholders

As the public becomes more inclined to support locally-grown produce, stakeholders of urban agriculture should leverage this behavior into public-private partnerships. Through the advertisement of a symbiotic relationship between urban farms and large enterprises, rooftop gardens may be able to sustain a large revenue stream and be able to afford the cost and upkeep of high-tech machinery. While there are central hubs for U.S. urban farmers such as Urban Farming that showcase different gardens, these contacts are primarily for the urban farmers to network.[98] The focus of this form of organization must pivot to seeking relationships with large enterprises such as supermarkets, restaurants, and well-regarded policymakers.

In the case of supermarkets, the Slow Food movement[99] has accelerated the creed of "Good, Clean, and Fair." This lifestyle of pursuing "slow food" consists of consuming local, sustainable foods. Backed by political lobbying, the processed food industry has appropriated food in the past, fostering a distrust among consumers in regards to institutional labels. Civic-minded individuals are thus more likely to prefer natural foods in the market that are not made "pretty" with waxes and oils, which also cause soil and water contamination. If supermarkets create policies for sustainably sourcing from rooftop farms, these supermarkets can reestablish their reputation among consumers. The United States' biggest traditional supermarket chain Kroger has recently reinvigorated its fresh food offerings from urban farms.[100] Meanwhile

---

[98] "Urban Farming :: Welcome To Urban Farming!," accessed August 25, 2020, https://www.urbanfarming.org/welcome.html.

[99] Chaudhury and Albinsson, "Citizen-Consumer Oriented Practices in Naturalistic Foodways."

[100] Urban-grown vegetables like lettuce and kale sell for no more than Kroger's existing storebrand organic produce, and increase Kroger's environmental credibility.
Deena Shanker and Matthew Boyle, "Kroger Brings Farming to Its Stores in Push to Get Greener (and Sell More Kale)," *Bloomberg.Com*, November 19, 2019, https://www.bloomberg.com/news/articles/2019-11-19/urban-farming-coming-to-kroger-grocery-stores-seattle-first.

the rooftop farms become more well-known, along with receiving more funds to maintain the operations of the farms.

Restaurants in particular would be major beneficiaries when investing in urban rooftop farms. With respect to the urban quality of life, food desertification has negatively impacted the protection of communities' food sovereignty.[101] To actively shape the food system, supporters of food sovereignty must engage with urban agriculture for the sake of public health. For example, several city leaders in New York City, Chicago, and Detroit have enacted a trans fat ban to address the obesity problem in the United States. Mandates that create a partnership between restaurants and rooftop farms would be able to combat malnutrition and bring light to this overall issue of food sovereignty, placing the power to sustainably farm into the people's hands.

3.2b The Green New Deal

Since 2018, more attention has been placed on the advancement of the Green New Deal. Though there are people who believe the Green New Deal should move away from carbon-intensive industrial agriculture, rooftop farming should not be categorized as such.[102] In this clean energy transition from a world so fossil fuel-reliant, strong policies in support of rooftop farms are necessary to alleviate the potential hazard of companies abusing the environment for profit. The Green New Deal beseeches large enterprises to move their money away from environmentally harmful investments in an economically sustainable fashion. Better

---

[101] Food sovereignty is the right to healthy and culturally appropriate foods. It is different from food security in that the former ensures the right to use and manage lands, waters, seeds, etc. that belong to the producers.
Hashim, "Reversing Food Desertification."

[102] The Green New Deal is a worldwide program aiming to realistically bring down CO2 emissions in the next few decade.
"Green New Deal Must Transform Our Food System to Save Our Climate," Friends of the Earth, February 15, 2019, https://foe.org/blog/green-new-deal-must-transform-food-system-save-climate/.

marketing of the inherently economic benefits of pursuing initiatives like urban agriculture will afford these stakeholders the drive to buy into the Green New Deal.[103]

3.3 Technical economic benefits

Since urban products are distributed through very short marketing chains, there exist several economic advantages to the proximity of production to consumers. A reduction in transportation costs due to the proximity of farm to market contributes to a low price differential for peri-urban vegetables. As a result of this proximity, producers cannot cheat on product quality since vegetables arrive earlier and thus fresher. Freshness allows urban farms to competitively differentiate themselves from rural agriculture. A guarantee of freshness is cited as a revered criterion for vegetable choice because of the consumers' perception of a more nutritious value and the idea of indirectly giving to the local community.[104]

Furthermore, less transportation needed to move produce means there are fewer emissions being released into the atmosphere. Based on a 2017 study on food supply chains, if urban farms were to follow a hub-and-spoke model, then these emissions may be optimized.[105] In this model, a limited number of delivery vehicles are assigned to a central hub that branches out into spokes of customer zones. With the flexibility to be associated with any type of building from an abandoned warehouse to a university research center, the rooftop farm serves as a great central hub. If regulated correctly, the location of each farm can better serve communities, specifically, marginalized populations, in need of fresh fruits and vegetables. The framework of

[103] Pollin, "Advancing a Viable Global Climate Stabilization Project."
[104] Van Veenhuizen, "Cities Farming for the Future."
[105] Musavi and Bozorgi-Amiri, "A Multi-Objective Sustainable Hub Location-Scheduling Problem for Perishable Food Supply Chain."

the hub and spokes works well with perishable foods because this freshness is pivotal in the choice of the consumer. In one experiment by Harold Rohm et. al (2017), focus groups revealed that it is difficult to motivate consumers to purchase and consume suboptimal foods.[106] Enabling the hub-and-spoke model would effectively prevent much suboptimality and thus represents an economic benefit.

However, if an urban farm seeks to succeed as market farming without reliance on grants, there must be careful consideration of the local context and what is grown. These factors will ultimately enhance the market success of an urban farm and complement the non-market benefits of urban agriculture when compared to rural agriculture. To reconcile the costs of creating and maintaining urban farms, it is crucial to take into consideration the power of corporations. Businesses in cities will want to partake in rooftop farming, particularly if they are interested in getting their buildings LEED-certified. Not only does the reputation of businesses get better once the buildings become greener, there may be federal tax incentives, provided a high performance in energy efficiency.[107] In New York City, the Green Roof Tax Abatement Program has provided up to $100,000, and the Green Infrastructure Grant Program has funded $6 million of green roofs on privately owned property.[108]

---

[106] Suboptimal foods have slight imperfections in color, texture, and size. These otherwise standard produce items are often unnecessarily thrown out, contributing to the 30% of vegetables and fruits discarded solely due to aesthetic imperfections.
Harald Rohm et al., "Consumers in a Sustainable Food Supply Chain (COSUS): Understanding Consumer Behavior to Encourage Food Waste Reduction," *Foods* 6, no. 12 (December 2017): 104, https://doi.org/10.3390/foods6120104.

[107] Pearson, "Tax and Government Incentives Promoting Sustainable Development in Oregon | Stoel Rives LLP."

[108] "Wayback Machine," September 7, 2015, https://web.archive.org/web/20150907122543/http://www.nyc.gov/html/dob/downloads/pdf/green_roof_tax_abatement_info.pdf; "NYC DEP - Green Infrastructure Grant Program," March 15, 2014, https://web.archive.org/web/20140315174323/https://a826-web01.nyc.gov/GIGrant/.

As expounded upon in this section, urban agriculture provides several opportunities for economic growth in distributors. To better define how to streamline success in rooftop farms, policymakers should consider all of the facts. While the risks of financial failure can easily be avoided, they must be clearly defined along with opportunities for growth.

3.4 Completing the framework

Given the many environmental and social benefits of rooftop farms, a discussion of the economic and political sphere will complete the framework. These two spheres arise in the obstacles of implementing policy and showcasing economic incentives in support of urban farms. Only by being politically-backed and financially stable will rooftop farms be able to thrive and positively affect society and the environment.

Several economic benefits, particularly that of reduced transportation costs, make rooftop farms an attractive investment. These economic benefits serve well for encouraging more policy for urban farms. And as seen in this section, there are plenty of risks detract from urban agriculture's reputation among policymakers. For example, high-tech solutions have the ability to gentrify neighborhoods and cause a rift between rural and urban farms. However, they present an opening for forging a smoother transition into integrating the multifunctional urban farm into low-income areas in order to advance SDG 11: Sustainable Cities and Communities.

Conversations with members of the marginalized communities advance SDG 16: Peace, Justice, and Strong Institutions because there is currently a weak connection among the stakeholders of urban agriculture. Urban farm advocates, food justice organizations, local policymakers, supermarkets, restaurants, and others must create a coalition that researches data

which compiles social, environmental, and economic reasons as to why rooftop farms are a sustainable investment. If this coalition can actively collaborate, then further steps toward integrating all four spheres can be achieved, followed by state and national legislation supporting urban farms.

IV. Case study: Urban rooftop lettuce production in the United States

Complementing the discussion on the varied uses of urban rooftop farms, this case study on lettuce will illustrate the value of a multidisciplinary analysis. It will be highlighted that lettuce is an interesting crop to produce on urban rooftop farms, given its versatile benefits.

1. The lettuce life cycle

Lettuce is an interesting crop to consider for urban rooftop farms, as it is well-suited for hydroponics due to its high yield and light weight.[109] It is also a popular vegetable; crisphead lettuce and romaine lettuce combined are the third-most consumed vegetable in the United States at 25 pounds per capita.[110] Moreover, the amount of information available in regards to lettuce makes it a valuable case study.

When analyzing a specific crop, challenges and opportunities can be determined along the life cycle for each of the four spheres. The different life stages of lettuce are shown in FIG. 4.

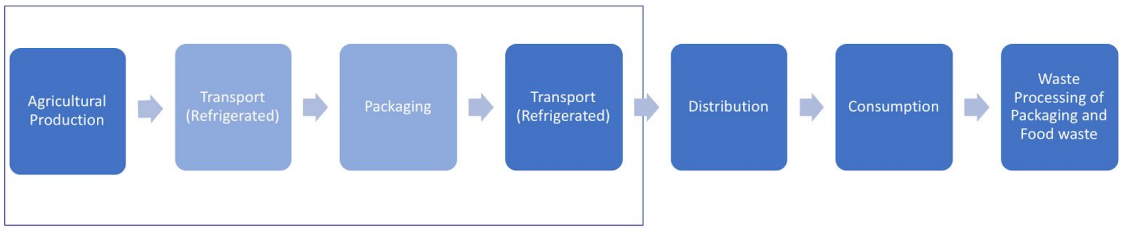

FIG. 4: The different phases in the lettuce life cycle. The stages in light blue are often neglected in literature, and the stages that are framed are those more often discussed in literature. Figure made by the authors.

[109] Yoshiki Harada and Thomas H. Whitlow, "Urban Rooftop Agriculture: Challenges to Science and Practice," *Frontiers in Sustainable Food Systems* 4 (2020), https://doi.org/10.3389/fsufs.2020.00076; Robert Taylor et al., "Making Global Cities Sustainable: Urban Rooftop Hydroponics for Diversified Agriculture in Emerging Economies," *OIDA International Journal of Sustainable Development* 5, no. 7 (2012): 11–28; Buehler and Junge, "Global Trends and Current Status of Commercial Urban Rooftop Farming"; Kubi Ackerman, E. Dahlgren, and X. Xu, "Sustainable Urban Agriculture: Confirming Viable Scenarios for Production," *New York: NYSERDA*, 2013.
[110] USDA ERS, "USDA ERS - Food Availability (Per Capita) Data System," Data Products, 2020, https://www.ers.usda.gov/data-products/food-availability-per-capita-data-system/.

2. Carbon savings

The stages represented in FIG. 4 are the same for conventional farming and urban farming. For each of these steps, there are inputs (e.g., fertilizers, pesticides, energy) and associated emissions, among which are GHG emissions. Depending on the cultivation method, the number and types of inputs will vary resulting in differing environmental impacts. Lettuce is an interesting crop to illustrate the nuance of carbon savings. 98% of lettuce in the United States is grown in Arizona and California, where the favorable climate allows the growth of winter lettuce on-field. Thus, decentralized lettuce production can lead to fewer transport emissions.[111]

However, when research compares GHG emissions from urban rooftop lettuce to rural lettuce, it usually considers both transport and production, highlighting that food miles alone do not necessarily lead to a reduced carbon footprint. Indeed, Muñoz, Hospido, and Plassman (2008) found that winter lettuce imported to the United Kingdom from Spain was associated with fewer GHG emissions than winter lettuce produced in a greenhouse within the United Kingdom, due to greenhouses' high energy use.[112] Often, lettuce produced on urban rooftop greenhouses, as required to achieve high yields in colder climates, had a larger carbon footprint.[113] The research highlights the need to seize opportunities; when powered by renewables, urban rooftop production of lettuce did lower the overall carbon footprint.[114]

---

[111] Plawecki et al., "Comparative Carbon Footprint Assessment of Winter Lettuce Production in Two Climatic Zones for Midwestern Market."
[112] Iván Muñoz, Almudena Hospido, and Katharina Plassmann, "Life Cycle Assessment (LCA) of Domestic vs. Imported Vegetables. Case Studies on Broccoli, Salad Crops and Green Beans," 2008, 47.
[113] Shiina et al., "Life Cycle Inventory Analysis of Leafy Vegetables Grown in Two Types of Plant Factories"; Goldstein et al., "Testing the Environmental Performance of Urban Agriculture as a Food Supply in Northern Climates"; Barla, Salachas, and Abeliotis, "Assessment of the Greenhouse Gas Emissions from Aeroponic Lettuce Cultivation in Greece."
[114] Rothwell et al., "Environmental Performance of Local Food"; Goldstein et al., "Testing the Environmental Performance of Urban Agriculture as a Food Supply in Northern Climates."

3. Health benefits and concerns

The high content of minerals, antioxidants, and vitamins in lettuce makes it an interesting crop to analyze for urban rooftop farming. The varieties of lettuce being grown matters, as cultivation and consumption of more nutritious kinds of lettuce can aid in eradicating malnutrition. Currently, crisphead lettuce is the most popular and widely available in the United States, but is low in minerals, vitamins, and bioactive compounds compared to more nutritious leafy lettuce groups like Butterhead or Romaine, which are not easily available.[115] Prior to planning the urban farm, thorough analysis and research on nutrient content of different varieties within a vegetable category can promote overall health of that community.

However, lettuce also comes with several challenges. Even though lettuce shares similar statistics to other crops popular for urban farming, lettuce is seldom favored due to the perception that urban leafy vegetables are highly susceptible to contamination.[116] In an article by Dala-Paula et al. (2018) detailing the presence of cadmium, copper, and lead in lettuce grown from hydroponics in industrial areas, a clear solution is proposed. While atmospheric deposition pollutes the plant leaves, the act of thoroughly washing the lettuce with water will largely reduce metal contamination (e.g., 73% for lead).[117] Dispelling the stereotype that lettuce is unsafe will

---

[115] Moo Jung Kim et al., "Nutritional Value, Bioactive Compounds and Health Benefits of Lettuce (Lactuca Sativa L.)," *Journal of Food Composition and Analysis* 49 (June 1, 2016): 19–34, https://doi.org/10.1016/j.jfca.2016.03.004; Jennifer Di Noia, "Defining Powerhouse Fruits and Vegetables: A Nutrient Density Approach," *Preventing Chronic Disease* 11 (2014), https://doi.org/10.5888/pcd11.130390.

[116] In the past, tomatoes have been a more popular commodity than lettuce among urban farmers. This is in part due to how tomatoes require minimal hectares to tend to, reduce a large number of emissions, and perform well in consumer demand.
Kulak, Graves, and Chatterton, "Reducing Greenhouse Gas Emissions with Urban Agriculture."

[117] Bruno M. Dala-Paula et al., "Cadmium, Copper and Lead Levels in Different Cultivars of Lettuce and Soil from Urban Agriculture," *Environmental Pollution* 242 (November 1, 2018): 383–89, https://doi.org/10.1016/j.envpol.2018.04.101.

allow lettuce to be seen as competitive urban produce. Once farmers are educated on this solution, the economic and social opportunities to capitalize on lettuce would be substantial.

4. Supply chain and economic value

Besides food contamination, there are other risks perceived with growing lettuce in rooftop farms. In a study by Suyono et al. (2019) analyzing the supply chain management of organic lettuce, two models are proposed: Model 1 (producers → suppliers → market) and Model 2 (producers → market).[118] Because the trading volume in Model 1 was higher than in Model 2, the marketing margin implied that urban agriculture was only more technically efficient than economically efficient. The longer marketing channel present in rooftop farms forces farmers to be responsible for all of the supplier responsibilities (e.g., harvesting, packing, risk coverage). And although the cost of lettuce production varies depending on the location, harvesting and handling the leafy vegetable is a costly, labor-intensive process.

Despite this apparent lack of economic efficiency, the study overlooks some universal economic benefits to shorter supply chains in lettuce production. According to a different study by Managa et al. (2018), significant weight loss of crisphead lettuce (45%) appeared at the retail shelf stage in longer supply chains.[119] This difference negatively affects saleable weight, and ultimately the success of the farmer. With rooftop farms cutting out suppliers, farmers will reap much more comparable economic benefits with high-quality lettuce that inherently avoids the

[118] Suyono et al., "Evaluation of Supply Chain Management Model of Organic Lettuce Produced in Rural Areas."
[119] Rusty browning, stem discoloration, and wilting due to the extended number of days in storage and transport weaken the economic value of the lettuce. Cumulative loss at the retail shelf on Day 2 for these vegetables was 53%. Millicent G. Managa et al., "Impact of Transportation, Storage, and Retail Shelf Conditions on Lettuce Quality and Phytonutrients Losses in the Supply Chain," *Food Science & Nutrition* 6, no. 6 (2018): 1527–36, https://doi.org/10.1002/fsn3.685.

long distance of rurally grown lettuce. Especially if NGOs are able to procure the high-functioning technology that ensures better access to high-quality lettuce, rooftop farms can financially thrive.

Lettuce production is already highly suitable for communities based on the simplicity of its growing practice and quick generation of income. To ensure the high demand of lettuce is met with a continuous supply, the production needs to be programmed as cycles. As it is a short duration crop, it can be grown and harvested in several 28 day cycles.[120] The briefness of the cycle ensures a steady source of income throughout the year for urban lettuce producers.

On the whole, this case study shows that lettuce is a worthwhile crop to grow on urban rooftop farms. It also illustrates that there are benefits and challenges across the four spheres that need to analyzed and accounted for to ensure a successful project.

[120] Francesco Orsini et al., "Farmers-to-Consumers."

V. Bringing the four spheres together

In seeking a comprehensive solution, this section integrates all four spheres of the paper as they pertain to urban agriculture. After reviewing the multidisciplinary implementation of rooftop farming, it will be necessary to discuss how to zoom out and scale this initiative.

1. The multidimensional benefits of urban rooftop farms in the United States

In section III and IV, the range of possible benefits of urban rooftop farming in the environmental, social, economic, and political spheres were discussed. These benefits are summarized in FIG. 5 on the next page.

However, these sections have also highlighted that such benefits can only be achieved when preceded by a multidimensional analysis that aims to recognize and maximize benefits in each sphere. Care should be taken to avoid scenarios where the carbon footprint is significantly increased or detrimental environmental trade-offs occur. Hence, when designing an urban rooftop farm, all environmental impacts must be considered and weighed. Furthermore, it must be determined how to incorporate high-tech solutions to rooftop farms, to avoid community outrage over gentrification. While applications of digital urban farming can better economically succeed through optimized data, rooftop gardens in marginalized communities must remain highly accessible. The mission of both relieving these target groups of food insecurity, GHG emissions, and stakeholder anguish cannot be disregarded.

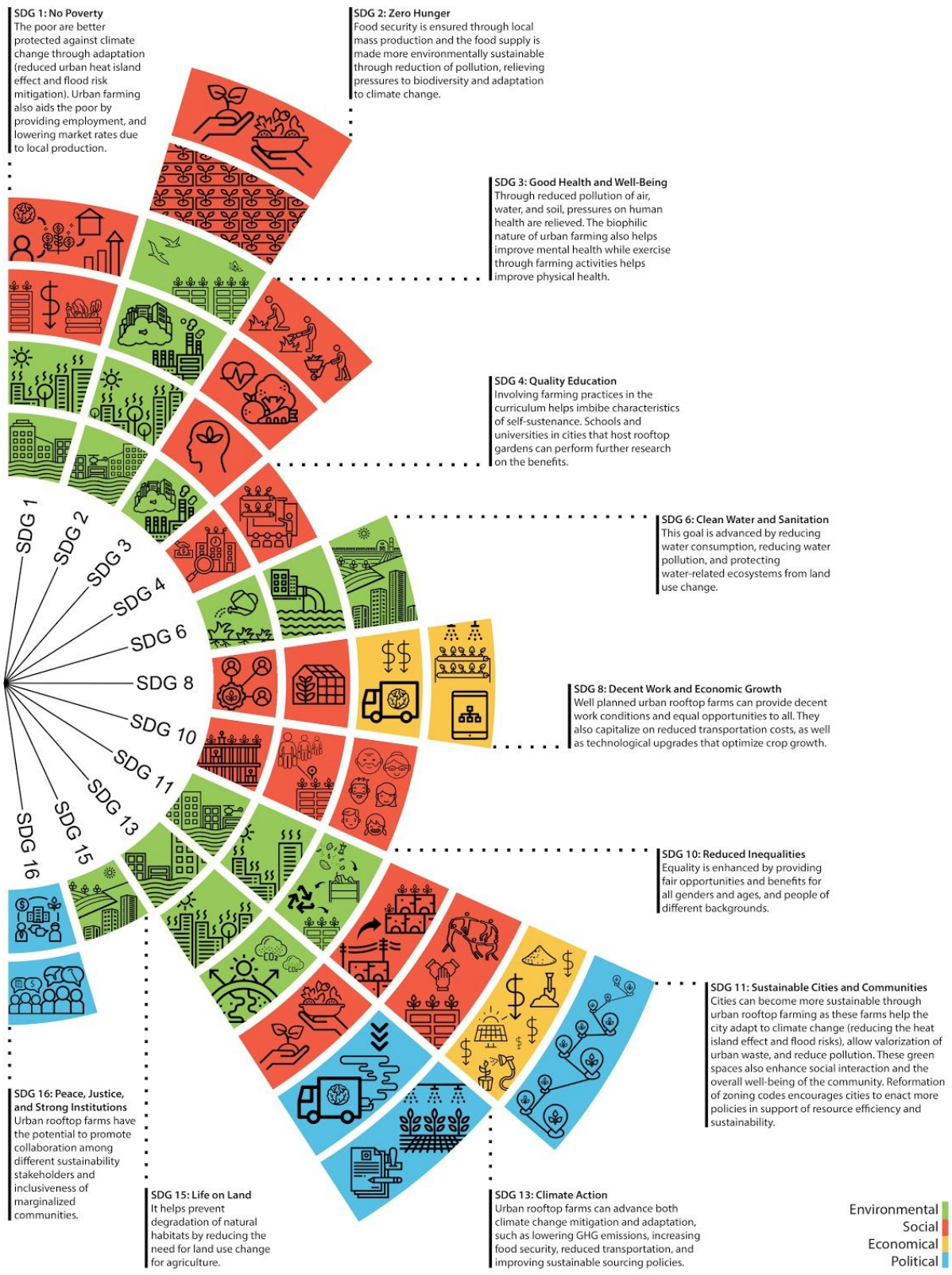

FIG. 5: A representation of the benefits of urban rooftop farms as they pertain to the four spheres and relate to the SDGs. Figure made by the authors.

2. Scaling rooftop farming

In this section, the findings of this paper will be extrapolated to other forms of urban agriculture, multiple crops, other countries and larger scales. At scale, urban agriculture can amount to larger benefits across all four spheres.

2.1 Other forms of urban agriculture

There is a wide diversity of forms of urban agriculture, and TABLE. 4 summarizes some of the well-known forms. Each form of urban agriculture comes with its unique set of benefits, opportunities, and challenges. For example, while vertical farms can achieve higher yields, maintaining them requires a high financial cost and sacrifice of social inclusion benefits, especially compared to rooftop gardens. However, there is an opportunity to decrease heat and overall costs associated with energy to offset these maintenance fees.[121]

TABLE. 5: Description of some common forms of urban agriculture. Adapted by the author.[122]

Type of Urban Agriculture	**Description**
Community Garden	Non-commercial areas where communities cultivate the area as a collective group.
Allotment Garden	Non-commercial areas which are subdivided in parcels that are cultivated individually.
Private Garden	Private areas around the house or property which are used for cultivation.
Rooftop Farms	The area on top of the rooftop is (partly) used for cultivation.
Vertical Farms	Cultivation takes place in high-rise buildings through a controlled environment.

[121] Fatemeh Kalantari et al., "Opportunities and Challenges in Sustainability of Vertical Farming: A Review," *Journal of Landscape Ecology* 11, no. 1 (January 1, 2018): 35–60, https://doi.org/10.1515/jlecol-2017-0016.
[122] Lin, Philpott, and Jha, "The Future of Urban Agriculture and Biodiversity-Ecosystem Services"; Kalantari et al., "Opportunities and Challenges in Sustainability of Vertical Farming."

The key point is that any urban agriculture project should consider the full range of benefits and impacts through a multidisciplinary analysis before commiting to a project design. This paper recommends urban rooftop farming as a nascent point to further the case for urban agriculture, as it enables such a wide range of benefits.

2.2 Other crops

While the case study in Section IV focused on lettuce, there are many benefits to including a range of crops in an urban farm. Considering multiple crops and techniques can maximize environmental benefits, by designing a system with the highest yield and lowest environmental pressures and trade-offs for a specific local context.[123] It is also important to evaluate the cultural aspect of food, as food plays a pivotal role in society. The crops included in urban farming should be in sync with the food habits of different communities.[124] Hence, an analysis that considers challenges and opportunities for considered crops in the local context including each of the four spheres will enable a better informed initial design.

---

[123] Martí Rufí-Salís et al., "Identifying Eco-Efficient Year-Round Crop Combinations for Rooftop Greenhouse Agriculture," *The International Journal of Life Cycle Assessment* 25, no. 3 (March 2020): 564–76, https://doi.org/10.1007/s11367-019-01724-5; Kulak, Graves, and Chatterton, "Reducing Greenhouse Gas Emissions with Urban Agriculture"; Orsini et al., "Exploring the Production Capacity of Rooftop Gardens (RTGs) in Urban Agriculture"; Sanyé-Mengual et al., "Techniques and Crops for Efficient Rooftop Gardens in Bologna, Italy."

[124] For example, in the United Kingdom, polytunnel tomatoes and zucchini have the greatest assumed yield in urban farms compared to other organic produce and have thrived there.
Kulak, Graves, and Chatterton, "Reducing Greenhouse Gas Emissions with Urban Agriculture."

2.3 Other countries

In order to assess the potential environmental impact reductions and trade-offs for an urban farm design, the local context should always be considered. Factors such as the local energy mix and conventional produce life cycle are key to identifying where and how in the supply chain environmental benefits can be achieved. Additionally, other developed countries outside of the United States have had similar levels of experience in urban agriculture. For example, in Glasgow, United Kingdom, a series of initiatives in the 2010s were introduced by the Glasgow city council.[125] With varying levels of industrial air quality, land space, consumer behavior, social needs, etc., these factors reinforce how the advocacy of urban farm policies should be approached on a case-by-case basis.

3. Next steps

First, multiple gaps in the literature were identified. More research with empirical evidence is needed to strengthen claims on reduced GHG emissions through the prevention of land use change and food waste, benefits to biodiversity, community engagement, and practical relationships with businesses. While there is much general research into the lifecycle of urban produce, there are not as many strategic analyses of incorporating urban agriculture in individual cities and communities. Not only should there be more efforts to collect data that demonstrate this great potential of urban agriculture, these benefits must be accompanied by social

[125] These initiatives include: 1) a candid discussion with the Glasgow Local Food Network, a coalition of organizations interested in the topic of sustainable food planning, and 2) the release of "paused" development sites and vacant lots for community use.
James T. White and Christopher Bunn, "Growing in Glasgow: Innovative Practices and Emerging Policy Pathways for Urban Agriculture," *Land Use Policy* 68 (November 1, 2017): 334–44, https://doi.org/10.1016/j.landusepol.2017.07.056.

advantages. The multifunctionality of urban agriculture is often overlooked when it is in fact the key toward advancing its implementation. The presentation of this customized research of benefits, along with the economic offsets of urban agriculture, bodes well for convincing key stakeholders to invest their time and money. A focus on appealing individualized research to incentivize local policymakers for support is an important first step.

Therein lies the opportunity for urban farming advocates. In order to achieve a system where the multidimensional benefits of urban rooftop farms are maximized, it is recommended that a coalition of important local stakeholders be created. As it currently stands, organizations such as the American Association of Urban Farmers provide ample resources for urban farmers interested in networking with one another; websites and blogs such as Urban Farming educate on urban agriculture's multidimensional benefits and globally identify urban farms.[126]

However, if these interest groups intend to better realize the growth and reach of sustainable rooftop farms, then they must first build strong coalitions of key localized stakeholders (food justice organizations, social workers, NGOs, etc.) to invest their time and money into urban rooftop farms. As explained in Section III, the creation of urban rooftop farms requires a careful approach that considers risks common in the environmental, social, political, and economic spheres. By incorporating the subject matter experts of all peripheral spaces in this coalition, then demands of local policymakers can be better efficiently communicated. In U.S. cities like New York City, Seattle, and Detroit where urban agriculture has thrived, coalitions can more easily accelerate. If the United States can bring attention to urban agriculture on the local level, then state and national legislation protecting land use for urban farms will follow.

---

[126] "American Association Of Urban Farmers Group," AgFuse - Agricultural Social Network, accessed August 25, 2020, https://agfuse.com/group/AAUF; "Urban Farming :: Welcome To Urban Farming!"

VI. Conclusion

The paper discussed the multidisciplinary range of benefits that makes urban agriculture a valuable tool to advance the United Nations' SDGs. The use of a four-sphere framework including the environmental, social, economic, and political aspects highlighted the extent of this range, specifically with the case of urban rooftop farming.

The key to maximizing these benefits across all four spheres is by preceding urban agriculture projects with a thorough multidisciplinary analysis tailored to the local context. This analysis should be used to identify challenges, and create and seize opportunities. The value of such an analysis was demonstrated by highlighting benefits and challenges in a case study of growing lettuce in urban rooftop farms. When appropriate care is taken, urban agriculture can, and should, be a useful tool in furthering progress on the United Nations' SDGs.

To allow urban farming to promote the full range of its benefits, more research backed by empirical evidence should be conducted in all four spheres. However, as an immediate action item, this paper recommends the formation of coalitions of localized stakeholders in U.S. cities where urban rooftop farms thrive. These collaborative groups are more capable of understanding nuances in the members' respective fields and demanding more equitable local policy for urban agriculture. Thus, with their simple design, multidisciplinary benefits, and accessibility, urban rooftop farms are the key starting point to invigorating the urban agriculture movement.

Bibliography

Abdallah, Lamiaa, and Tarek El-Shennawy. "Reducing Carbon Dioxide Emissions from Electricity Sector Using Smart Electric Grid Applications." Review Article. Journal of Engineering. Hindawi, April 9, 2013. https://doi.org/10.1155/2013/845051.

AgFuse - Agricultural Social Network. "American Association Of Urban Farmers Group." Accessed August 25, 2020. https://agfuse.com/group/AAUF.

"American Time Use Survey: Charts by Topic: Leisure and Sports Activities," December 20, 2016. https://www.bls.gov/tus/charts/leisure.htm.

Arora, Naveen Kumar. "Environmental Sustainability—Necessary for Survival." *Environmental Sustainability* 1, no. 1 (March 1, 2018): 1–2. https://doi.org/10.1007/s42398-018-0013-3.

Asmat Ismail, Muna Hanim Abdul Samad, and Abdul Malek Abdul Rahman. "Literature Review On Green Roof Technology: A Way To Improve Thermal Performance And Energy Consumption In Building." *ResearchGate*, June 2008.

Astee, Lim Yinghui, and Nirmal T Kishnani. "Building Integrated Agriculture: Utilising Rooftops for Sustainable Food Crop Cultivation in Singapore." *Journal of Green Building* 5, no. 2 (May 1, 2010): 105–13. https://doi.org/10.3992/jgb.5.2.105.

Barla, Sofia-Anna, Georgios Salachas, and Konstadinos Abeliotis. "Assessment of the Greenhouse Gas Emissions from Aeroponic Lettuce Cultivation in Greece." *Euro-Mediterranean Journal for Environmental Integration* 5, no. 2 (August 2020): 29. https://doi.org/10.1007/s41207-020-00168-w.

Bartzas, Georgios, Dimitra Zaharaki, and Kostas Komnitsas. "Life Cycle Assessment of Open Field and Greenhouse Cultivation of Lettuce and Barley." *Information Processing in Agriculture* 2, no. 3–4 (October 2015): 191–207. https://doi.org/10.1016/j.inpa.2015.10.001.

Bass, Brad, and Bas Baskaran. "Evaluating Rooftop and Vertical Gardens as an Adaptation Strategy for Urban Areas, Report No NRCC-46737, Edited by National Research Council Canada." IRC, 2003.

Benis, Khadija, and Paulo Ferrão. "Potential Mitigation of the Environmental Impacts of Food Systems through Urban and Peri-Urban Agriculture (UPA) – a Life Cycle Assessment Approach." *Journal of Cleaner Production* 140 (January 2017): 784–95. https://doi.org/10.1016/j.jclepro.2016.05.176.

Benke, Kurt, and Bruce Tomkins. "Future Food-Production Systems: Vertical Farming and Controlled-Environment Agriculture." *Sustainability: Science, Practice and Policy* 13, no. 1 (January 2017): 13–26. https://doi.org/10.1080/15487733.2017.1394054.

Berkenkamp, JoAnne. "Making the Farm / School Connection: Opportunities and Barriers to Greater Use of Locally-Grown Produce in Public Schools." *Leopold Center Pubs and Papers* 153 (2006): 33.

Buehler, Devi, and Ranka Junge. "Global Trends and Current Status of Commercial Urban Rooftop Farming." *Sustainability* 8, no. 11 (October 29, 2016): 1108. https://doi.org/10.3390/su8111108.

"Bureau of Justice Statistics (BJS) - Total Correctional Population." Accessed July 18, 2020. https://www.bjs.gov/index.cfm?tid=11&ty=tp.

Butt, Andrew, and Elizabeth Taylor. "Smells like Politics: Planning and the Inconvenient Politics of Intensive Peri-Urban Agriculture." *Geographical Research* 56, no. 2 (2018): 206–18. https://doi.org/10.1111/1745-5871.12266.

Carey, Edward E., Lewis Jett, William J. Lamont, Terrance T. Nennich, Michael D. Orzolek, and Kimberly A. Williams. "Horticultural Crop Production in High Tunnels in the United States: A Snapshot." *HortTechnology* 19, no. 1 (January 1, 2009): 37–43. https://doi.org/10.21273/HORTSCI.19.1.37.

Christine Eigenbrod, Nazim Gruda. "Urban Vegetable for Food Security in Cities. A Review." *ResearchGate*. Accessed August 12, 2020. https://www.researchgate.net/publication/271846267_Urban_vegetable_for_food_security_in_cities_A_review.

Clucas, Barbara, Israel D. Parker, and Andrea M. Feldpausch-Parker. "A Systematic Review of the Relationship between Urban Agriculture and Biodiversity." *Urban Ecosystems* 21, no. 4 (2018): 635–643.

Cohen, Nevin, and Kristin Reynolds. "Five Borough Farm: Seeding the Future of Urban Agriculture in New York City," July 2012. https://www.academia.edu/18958897/Five_Borough_Farm_Seeding_the_Future_of_Urban_Agriculture_in_New_York_City.

Dala-Paula, Bruno M., Flávia B. Custódio, Eliana A. N. Knupp, Helena E. L. Palmieri, José Bento B. Silva, and Maria Beatriz A. Glória. "Cadmium, Copper and Lead Levels in Different Cultivars of Lettuce and Soil from Urban Agriculture." *Environmental Pollution* 242 (November 1, 2018): 383–89. https://doi.org/10.1016/j.envpol.2018.04.101.

Dimitri, Carolyn, Lydia Oberholtzer, and Andy Pressman. "Urban Agriculture: Connecting Producers with Consumers." Edited by Fabio Verneau and Professor Christopher J. *British Food Journal* 118, no. 3 (March 7, 2016): 603–17. https://doi.org/10.1108/BFJ-06-2015-0200.

Dubbeling, M. "Cities, Climate Change and Urban Agriculture: The Potential Contributions of Urban and Peri Urban Agriculture and Forestry (UPA/F) to Climate Change Adaptation and Mitigation." In *Proceedings of RUAF-CAH Conference, Almere*, 19–20, 2011.

Edwards-Jones, Gareth. "Does Eating Local Food Reduce the Environmental Impact of Food Production and Enhance Consumer Health?" *Proceedings of the Nutrition Society* 69, no. 4 (November 2010): 582–91. https://doi.org/10.1017/S0029665110002004.

Emily Toner, Steve Hallet, and Lori Hoagland. "Urban Agriculture: Environmental, Economic, and Social Perspectives." *ResearchGate*, September 2016. https://doi.org/10.1002/9781119281269.ch2.

"Exploring the G in ESG: Governance in Greater Detail – Part I." Accessed August 12, 2020. https://www.spglobal.com/en/research-insights/articles/exploring-the-g-in-esg-governance-in-greater-detail-part-i.

"Exploring The Social Benefits Of Urban Farming In Smart Cities," January 24, 2018. https://leadingcities.org/2018/01/24/exploring-the-social-benefits-of-urban-farming-in-smart-cities/.

"Fact Sheets - Malnutrition," April 1, 2020. https://www.who.int/news-room/fact-sheets/detail/malnutrition.

Foley, Jonathan A., Navin Ramankutty, Kate A. Brauman, Emily S. Cassidy, James S. Gerber, Matt Johnston, Nathaniel D. Mueller, et al. "Solutions for a Cultivated Planet." *Nature* 478, no. 7369 (October 2011): 337–42. https://doi.org/10.1038/nature10452.

Francesco Orsini, Nicola Michelon, F. Scocozza, and Giorgio Gianquinto. "Farmers-to-Consumers: An Example of Sustainable Soilless Horticulture in Urban and Peri-Urban Areas." *ResearchGate*, January 2009. https://doi.org/10.17660/ActaHortic.2009.809.21.

Giannini, Alessandra, P. Krishna Krishnamurthy, Rémi Cousin, Naouar Labidi, and Richard J. Choularton. "Climate Risk and Food Security in Mali: A Historical Perspective on Adaptation." *Earth's Future* 5, no. 2 (2017): 144–57. https://doi.org/10.1002/2016EF000404.

Gkatsopoulos, Panagiotis. "A Methodology for Calculating Cooling from Vegetation Evapotranspiration for Use in Urban Space Microclimate Simulations." *Procedia Environmental Sciences* 38 (2017): 477–484.

Goldstein, Benjamin, Michael Hauschild, John Fernández, and Morten Birkved. "Testing the Environmental Performance of Urban Agriculture as a Food Supply in Northern Climates." *Journal of Cleaner Production* 135 (November 2016): 984–94. https://doi.org/10.1016/j.jclepro.2016.07.004.

———. "Urban versus Conventional Agriculture, Taxonomy of Resource Profiles: A Review." *Agronomy for Sustainable Development* 36, no. 1 (March 2016): 9. https://doi.org/10.1007/s13593-015-0348-4.

Grard, Baptiste J.-P., Claire Chenu, Nastaran Manouchehri, Sabine Houot, Nathalie Frascaria-Lacoste, and Christine Aubry. "Rooftop Farming on Urban Waste Provides Many Ecosystem Services." *Agronomy for Sustainable Development* 38, no. 1 (February 2018): 2. https://doi.org/10.1007/s13593-017-0474-2.

Friends of the Earth. "Green New Deal Must Transform Our Food System to Save Our Climate," February 15, 2019. https://foe.org/blog/green-new-deal-must-transform-food-system-save-climate/.

Gupta, Anil K. "Origin of Agriculture and Domestication of Plants and Animals Linked to Early Holocene Climate Amelioration." *CURRENT SCIENCE* 87, no. 1 (2004): 6.

Hamilton, Andrew J., Kristal Burry, Hoi-Fei Mok, S. Fiona Barker, James R. Grove, and Virginia G. Williamson. "Give Peas a Chance? Urban Agriculture in Developing Countries. A Review." *Agronomy for Sustainable Development* 34, no. 1 (January 1, 2014): 45–73. https://doi.org/10.1007/s13593-013-0155-8.

Harada, Yoshiki, and Thomas H. Whitlow. "Urban Rooftop Agriculture: Challenges to Science and Practice." *Frontiers in Sustainable Food Systems* 4 (2020). https://doi.org/10.3389/fsufs.2020.00076.

Hoegh-Guldberg, Ove, Peter J. Mumby, Anthony J. Hooten, Robert S. Steneck, Paul Greenfield, Edgardo Gomez, C. Drew Harvell, Peter F. Sale, Alasdair J. Edwards, and Ken Caldeira. "Coral Reefs under Rapid Climate Change and Ocean Acidification." *Science* 318, no. 5857 (2007): 1737–1742.

Holmer, Robert, and Drescher Axel W. “Empowering Urban Poor Communities through Integrated Vegetable Production in Allotment Gardens: The Case of Cagayan de Oro City, Philippines.” *ResearchGate*, May 2006. https://www.researchgate.net/publication/239528437_Empowering_Urban_Poor_Communities_through_Integrated_Vegetable_Production_in_Allotment_Gardens_The_Case_of_Cagayan_de_Oro_City_Philippines.

Kalantari, Fatemeh, Osman Mohd Tahir, Raheleh Akbari Joni, and Ezaz Fatemi. “Opportunities and Challenges in Sustainability of Vertical Farming: A Review.” *Journal of Landscape Ecology* 11, no. 1 (January 1, 2018): 35–60. https://doi.org/10.1515/jlecol-2017-0016.

Kim, Moo Jung, Youyoun Moon, Janet C. Tou, Beiquan Mou, and Nicole L. Waterland. “Nutritional Value, Bioactive Compounds and Health Benefits of Lettuce (Lactuca Sativa L.).” *Journal of Food Composition and Analysis* 49 (June 1, 2016): 19–34. https://doi.org/10.1016/j.jfca.2016.03.004.

Kleerekoper, Laura, Marjolein Van Esch, and Tadeo Baldiri Salcedo. “How to Make a City Climate-Proof, Addressing the Urban Heat Island Effect.” *Resources, Conservation and Recycling* 64 (2012): 30–38.

Kulak, Michal, Anil Graves, and Julia Chatterton. “Reducing Greenhouse Gas Emissions with Urban Agriculture: A Life Cycle Assessment Perspective.” *Landscape and Urban Planning* 111 (March 2013): 68–78. https://doi.org/10.1016/j.landurbplan.2012.11.007.

Kumar, Jha Ritesh, Bhattarai Natasha, K. C. Suraj, Shrestha Arjun Kumar, and Kadariya Manahar. “Rooftop Farming: An Alternative to Conventional Farming for Urban Sustainability.” *Malaysian Journal of Sustainable Agriculture* 3, no. 1 (2019): 39–43.

Lin, Brenda B., Stacy M. Philpott, and Shalene Jha. “The Future of Urban Agriculture and Biodiversity-Ecosystem Services: Challenges and next Steps.” *Basic and Applied Ecology* 16, no. 3 (2015): 189–201.

Managa, Millicent G., Peter P. Tinyani, Grany M. Senyolo, Puffy Soundy, Yasmina Sultanbawa, and Dharini Sivakumar. “Impact of Transportation, Storage, and Retail Shelf Conditions on Lettuce Quality and Phytonutrients Losses in the Supply Chain.” *Food Science & Nutrition* 6, no. 6 (2018): 1527–36. https://doi.org/10.1002/fsn3.685.

Manríquez-Altamirano, Ana, Jorge Sierra-Pérez, Pere Muñoz, and Xavier Gabarrell. “Analysis of Urban Agriculture Solid Waste in the Frame of Circular Economy: Case Study of Tomato Crop in Integrated Rooftop Greenhouse.” *Science of The Total Environment* 734 (September 2020): 139375. https://doi.org/10.1016/j.scitotenv.2020.139375.

Maria Hofmann, and Maryam Javed. “Green Spaces and Mental Health: Does Frequency Of Use Or Proximity Affect Subjective Wellbeing And Perceived Stress?” *ResearchGate*, January 2019. https://doi.org/10.20319/pijss.2019.43.786798.

Muñoz, Iván, Almudena Hospido, and Katharina Plassmann. “Life Cycle Assessment (LCA) of Domestic vs. Imported Vegetables. Case Studies on Broccoli, Salad Crops and Green Beans,” 2008, 47.

Nadal, Ana, Pere Llorach-Massana, Eva Cuerva, Elisa López-Capel, Juan Ignacio Montero, Alejandro Josa, Joan Rieradevall, and Mohammad Royapoor. “Building-Integrated Rooftop Greenhouses: An Energy and Environmental Assessment in the Mediterranean Context.” *Applied Energy* 187 (February 2017): 338–51. https://doi.org/10.1016/j.apenergy.2016.11.051.

Noia, Jennifer Di. "Defining Powerhouse Fruits and Vegetables: A Nutrient Density Approach." *Preventing Chronic Disease* 11 (2014). https://doi.org/10.5888/pcd11.130390.

"NYC DEP - Green Infrastructure Grant Program," March 15, 2014. https://web.archive.org/web/20140315174323/https://a826-web01.nyc.gov/GIGrant/.

O'Connor, Martin. "The 'Four Spheres' Framework for Sustainability." *Ecological Complexity* 3, no. 4 (December 2006): 285–92. https://doi.org/10.1016/j.ecocom.2007.02.002.

Orsini, Francesco, Daniela Gasperi, Livia Marchetti, Chiara Piovene, Stefano Draghetti, Solange Ramazzotti, Giovanni Bazzocchi, and Giorgio Gianquinto. "Exploring the Production Capacity of Rooftop Gardens (RTGs) in Urban Agriculture: The Potential Impact on Food and Nutrition Security, Biodiversity and Other Ecosystem Services in the City of Bologna." *Food Security* 6, no. 6 (December 2014): 781–92. https://doi.org/10.1007/s12571-014-0389-6.

Paxton, Angela. "Food Miles." In *Continuous Productive Urban Landscapes: Designing Urban Agriculture for Sustainable Cities*, 40–46, 2005.

Plawecki, Rachel, Rich Pirog, Adam Montri, and Michael W. Hamm. "Comparative Carbon Footprint Assessment of Winter Lettuce Production in Two Climatic Zones for Midwestern Market." *Renewable Agriculture and Food Systems* 29, no. 4 (December 2014): 310–18. https://doi.org/10.1017/S1742170513000161.

Poore, J., and T. Nemecek. "Reducing Food's Environmental Impacts through Producers and Consumers." *Science* 360, no. 6392 (June 1, 2018): 987–92. https://doi.org/10.1126/science.aaq0216.

Prentice, Andrew M. "The Emerging Epidemic of Obesity in Developing Countries." *International Journal of Epidemiology* 35, no. 1 (February 1, 2006): 93–99. https://doi.org/10.1093/ije/dyi272.

Qiu, Guo-yu, Hong-yong Li, Qing-tao Zhang, Wan Chen, Xiao-jian Liang, and Xiang-ze Li. "Effects of Evapotranspiration on Mitigation of Urban Temperature by Vegetation and Urban Agriculture." *Journal of Integrative Agriculture* 12, no. 8 (August 1, 2013): 1307–15. https://doi.org/10.1016/S2095-3119(13)60543-2.

Rao, Tejal. "Food Supply Anxiety Brings Back Victory Gardens." *The New York Times*, March 25, 2020, sec. Food. https://www.nytimes.com/2020/03/25/dining/victory-gardens-coronavirus.html.

Ritchie, Hannah. "Food Production Is Responsible for One-Quarter of the World's Greenhouse Gas Emissions." Our World in Data, June 11, 2019. https://ourworldindata.org/food-ghg-emissions.

Rohm, Harald, Marije Oostindjer, Jessica Aschemann-Witzel, Claudia Symmank, Valérie L. Almli, Ilona E. De Hooge, Anne Normann, and Kostas Karantininis. "Consumers in a Sustainable Food Supply Chain (COSUS): Understanding Consumer Behavior to Encourage Food Waste Reduction." *Foods* 6, no. 12 (December 2017): 104. https://doi.org/10.3390/foods6120104.

Rothwell, Alison, Brad Ridoutt, Girija Page, and William Bellotti. "Environmental Performance of Local Food: Trade-Offs and Implications for Climate Resilience in a Developed City." *Journal of Cleaner Production* 114 (February 2016): 420–30. https://doi.org/10.1016/j.jclepro.2015.04.096.

Rufí-Salís, Martí, Anna Petit-Boix, Gara Villalba, Mireia Ercilla-Montserrat, David Sanjuan-Delmás, Felipe Parada, Verónica Arcas, Joan Muñoz-Liesa, and Xavier Gabarrell. "Identifying Eco-Efficient Year-Round Crop Combinations for Rooftop Greenhouse Agriculture." *The International Journal of Life Cycle Assessment* 25, no. 3 (March 2020): 564–76. https://doi.org/10.1007/s11367-019-01724-5.

Sanjuan-Delmás, David, Pere Llorach-Massana, Ana Nadal, Esther Sanyé-Mengual, Anna Petit-Boix, Mireia Ercilla-Montserrat, Eva Cuerva, Maria Rosa Rovira, Alejandro Josa, and Pere Muñoz. "Improving the Metabolism and Sustainability of Buildings and Cities through Integrated Rooftop Greenhouses (i-RTG)." In *Urban Horticulture*, 53–72. Springer, 2018.

Santandreu, Alain, Alberto Gómez Perazzoli, Raúl Terrile, and Mariana Ponce. "Urban Agriculture in Montevideo and Rosario: A Response to Crisis or a Stable Component of the Urban Landscape?," June 2009, 2.

Sanyé-Mengual, Esther, Ileana Cerón-Palma, Jordi Oliver-Solà, Juan Ignacio Montero, and Joan Rieradevall. "Environmental Analysis of the Logistics of Agricultural Products from Rooftop Greenhouses in Mediterranean Urban Areas." *Journal of the Science of Food and Agriculture* 93, no. 1 (2013): 100–109.

Sanyé-Mengual, Esther, Jordi Oliver-Solà, Juan Ignacio Montero, and Joan Rieradevall. "An Environmental and Economic Life Cycle Assessment of Rooftop Greenhouse (RTG) Implementation in Barcelona, Spain. Assessing New Forms of Urban Agriculture from the Greenhouse Structure to the Final Product Level." *The International Journal of Life Cycle Assessment* 20, no. 3 (March 2015): 350–66. https://doi.org/10.1007/s11367-014-0836-9.

Sanyé-Mengual, Esther, Francesco Orsini, Jordi Oliver-Solà, Joan Rieradevall, Juan Ignacio Montero, and Giorgio Gianquinto. "Techniques and Crops for Efficient Rooftop Gardens in Bologna, Italy." *Agronomy for Sustainable Development* 35, no. 4 (October 2015): 1477–88. https://doi.org/10.1007/s13593-015-0331-0.

Schmidhuber, J., and F. N. Tubiello. "Global Food Security under Climate Change." *Proceedings of the National Academy of Sciences* 104, no. 50 (December 11, 2007): 19703–8. https://doi.org/10.1073/pnas.0701976104.

Shanker, Deena, and Matthew Boyle. "Kroger Brings Farming to Its Stores in Push to Get Greener (and Sell More Kale)." *Bloomberg.Com*, November 19, 2019. https://www.bloomberg.com/news/articles/2019-11-19/urban-farming-coming-to-kroger-grocery-stores-seattle-first.

Shiina, T., D. Hosokawa, P. Roy, N. Nakamura, M. Thammawong, and T. Orikasa. "Life Cycle Inventory Analysis of Leafy Vegetables Grown in Two Types of Plant Factories." *Acta Horticulturae*, no. 919 (December 2011): 115–22. https://doi.org/10.17660/ActaHortic.2011.919.14.

Silva, José Graziano da, Mauro Eduardo Del Grossi, Caio Galvão de França, and Luiz Marcos Vasconcelos. *The Fome Zero (Zero Hunger) Program: The Brazilian Experience*, 2013.

Specht, Kathrin, Rosemarie Siebert, Ina Hartmann, Ulf B. Freisinger, Magdalena Sawicka, Armin Werner, Susanne Thomaier, Dietrich Henckel, Heike Walk, and Axel Dierich. "Urban Agriculture of the Future: An Overview of Sustainability Aspects of Food Production in and on Buildings." *Agriculture and Human Values* 31, no. 1 (March 2014): 33–51. https://doi.org/10.1007/s10460-013-9448-4.

Taylor, Robert, J. S. Carandang, C. Alexander, and J. S. Calleja. “Making Global Cities Sustainable: Urban Rooftop Hydroponics for Diversified Agriculture in Emerging Economies.” *OIDA International Journal of Sustainable Development* 5, no. 7 (2012): 11–28.

Thomaier, Susanne, Kathrin Specht, Dietrich Henckel, Axel Dierich, Rosemarie Siebert, Ulf B. Freisinger, and Magdalena Sawicka. “Farming in and on Urban Buildings: Present Practice and Specific Novelties of Zero-Acreage Farming (ZFarming).” *Renewable Agriculture and Food Systems* 30, no. 1 (February 2015): 43–54. https://doi.org/10.1017/S1742170514000143.

“Urban Farming :: Welcome To Urban Farming!” Accessed August 25, 2020. https://www.urbanfarming.org/welcome.html.

“Urban-Agriculture-Magazine-No.-25-RUAF-10-Years.Pdf.” Accessed September 2, 2020. https://ruaf.org/assets/2019/11/Urban-Agriculture-Magazine-no.-25-RUAF-10-years.pdf.

USDA ERS. “USDA ERS - Food Availability (Per Capita) Data System.” Data Products, 2020. https://www.ers.usda.gov/data-products/food-availability-per-capita-data-system/.

Vaičiūnienė, Rūta. “Killing Time in Prison: Purposeful Activities and Spare Time in Lithuanian Correctional Facilities.” *The Journal of Power Institutions in Post-Soviet Societies. Pipss.Org*, no. Issue 19 (November 15, 2018). https://doi.org/10.4000/pipss.5082.

Vallance, Suzanne, Harvey C. Perkins, and Jennifer E. Dixon. “What Is Social Sustainability? A Clarification of Concepts.” *Geoforum*, Themed Issue: Subaltern Geopolitics, 42, no. 3 (June 1, 2011): 342–48. https://doi.org/10.1016/j.geoforum.2011.01.002.

Visher, Christy, Sara Debus-Sherrill, and Jennifer Yahner. “Employment after Prison: A Longitudinal Study of Releasees in Three States,” October 2008, 9.

Warner, Koko, Mohamed Hamza, Anthony Oliver-Smith, Fabrice Renaud, and Alex Julca. “Climate Change, Environmental Degradation and Migration.” *Natural Hazards* 55, no. 3 (2010): 689–715.

“Wayback Machine,” September 7, 2015. https://web.archive.org/web/20150907122543/http://www.nyc.gov/html/dob/downloads/pdf/green_roof_tax_abatement_info.pdf.

White, James T., and Christopher Bunn. “Growing in Glasgow: Innovative Practices and Emerging Policy Pathways for Urban Agriculture.” *Land Use Policy* 68 (November 1, 2017): 334–44. https://doi.org/10.1016/j.landusepol.2017.07.056.

Wilson, Tamara S., Benjamin M. Sleeter, and D. Richard Cameron. “Mediterranean California’s Water Use Future under Multiple Scenarios of Developed and Agricultural Land Use Change.” Edited by David A Lightfoot. *PLOS ONE* 12, no. 10 (October 31, 2017). https://doi.org/10.1371/journal.pone.0187181.

Zezza, Alberto, and Luca Tasciotti. “Urban Agriculture, Poverty, and Food Security: Empirical Evidence from a Sample of Developing Countries.” *Food Policy* 35, no. 4 (August 1, 2010): 265–73. https://doi.org/10.1016/j.foodpol.2010.04.007.