HJTAS
Holistic: Journal of Tropical Agriculture Sciences
HJTAS 2(1): 31-45
ISSN 3025-4272

Urban agriculture as ecosystem services provider: A review

Assyifa Fauzia [1]*, Evi Frimawaty [1], Hadi Susilo Arifin [2]
[1] *School of Environmental Science, Universitas Indonesia, Central Jakarta 10430, Indonesia;*
[2] *Natural Resources and Environmental Management, IPB University, Bogor 16129, Indonesia.*
*Correspondence: assyifa.fauzia21@ui.ac.id

ABSTRACT
Background: Urban agriculture's role in mitigating the urban environment deterioration as ecosystem services provider. Urban agriculture adds various functions to different landscape scales, providing numerous benefits if managed correctly. This paper aims to study the role of urban agriculture as ecosystem services provider in mitigating urban environment deterioration. **Method:** The method that will be used in this article is literature review from articles related to urban agriculture and ecosystem services from provisioning, regulating, services, and culture. The review is compiled from urban agriculture's function as ecosystem services provider, such as biodiversity conservation, microclimate regulation, aesthetic function, and food production. **Result:** In essence, urban agriculture is a diverse and vital solution for cities, and it takes various forms, from private gardens to community plots, addressing challenges like limited public funding and promoting greening initiatives. Urban agriculture plays a key role in biodiversity conservation, contributing to enhanced environmental benefits and the preservation of local habitats. Another crucial role in regulating the complex dynamics of the urban microclimate, offering ecological benefits such as reduced Urban Heat Island effects, wind protection, and pollutant absorption. Beyond its ecological impact, urban agriculture adds aesthetic value to urban spaces, creating visually appealing landscapes and promoting cultural integration. Moreover, it serves as a multifaceted strategy for sustainable urban development, addressing food security, resilience, and well-being. **Conclusion:** Amidst challenges, such as the threat to urban biodiversity and the need for proper green space management, urban agriculture emerges as a holistic approach, contributing to the visual, cultural, and environmental fabric of cities. **Novelty/Originality of this article:** This study offers a new perspective on urban agriculture as a multifunctional solution to address urban environmental degradation. By integrating agriculture into the urban landscape, the study reveals the transformative potential for creating greener, more resilient and sustainable cities.

KEYWORDS: urban agriculture; ecosystem services; biodiversity; microclimate; aesthetic; food production

1. Introduction

Urban areas are home to more than half of the world's population (52%) and by 2050, two out of three people are likely to be urban dwellers, the majority of whom will grow up in developing countries (Miller & Spoolman, 2016). Population growth in urban areas has become a cause of environmental problems. Sustainable development is a middle ground that supports development that follows the sustainability of the landscape ecology. Urban planners in the future will face hurdles in choosing to protect green cities, urban economic growth, and social justice. (Setiowati et al., 2019). The assemblage of people in urban areas facilitates cooperation to improve the efficiency of economic production and increases the demand for accessible public facilities and services. Urbanization has become a trend in

Cite This Article:
Fauzia, A., Frimawaty, E., & Arifin, H. S. (2024). Urban agriculture as ecosystem services provider: A review. *Holistic: Journal of Tropical Agriculture Sciences*, 2(1), 31-45. https://doi.org/10.61511/hjtas.v2i1.2024.785

human development, however the increasing concentration of the population in urban areas also brings a series of problems, such as the continuous erosion of rural land at the edge of urban areas, the decrease of arable land, the increased distance of consumers from food production sites, and environmental pollution (Zheng & Chou, 2023). In addition to these urban issues, the longstanding global problems of a growing population, food shortages, supply security, and climate change have been the world's key concerns in this century (Baker et al., 2023; Nikologianni et al., 2022; Tacoli, 2017).

An environmentally sound development pattern that prioritizes natural resources as a component of the environmental order, the processing of a natural resource can produce a man-made environment so that various natural functions are taken over by man-made natural functions, and natural resources can be processed for various purposes (Yayasan Keanekaragaman Hayati Indonesia, 2020). Inadequate resource management in urban areas results in benefits abatement of residing in cities. The absence of accessible tools and strategies that could alleviate poverty might be a contributing factor to the significant surge in urban poverty. The emergence of urban agriculture overall and urban horticulture specifically stands out as a primary approach that is organically being embraced in developing nations to tackle urban poverty and enhance the welfare of urban residents (Orsini et al., 2013).

Urban agriculture or urban farming can be defined as the process of producing foodstuffs and other end products on land and other types of spaces located in urban areas (FAO & RUAF, 2022). Urban agriculture as a real concept has only come into general use recently and began to be established in 1990. Urban agriculture is largely about using and improving local resources that address the changing needs of local populations while providing services for multiple purposes and functions. Urban agriculture has ecological and social benefits as it can be a solution to turn vacant land into useful use and an affordable and flexible solution for people's financial situation (Cahya, 2016). The presence of urban agriculture not only provides positive value to meet food needs, but also practical value that can affect the ecological and social sustainability of an urban area. Urban agriculture practices carried out with environmentally friendly methods have many benefits (Fauzi et al., 2016).

Urban agriculture contributes to the multifunctionality of several landscape scales, offering multiple benefits to society if appropriately managed. However, since the functions depend on the underlying conditions and landscape parameters, verifying synergies and trade-offs with other functions is necessary to target green infrastructure multifunctionality in urban agriculture (Korkou et al., 2023). Urban agriculture plays a role for the ecology by reducing pollution in the supply chain of goods, facilitating recycling and energy synergy for sustainable food production, serving as a model of good agricultural practice (De Bon et al., 2009; FAO & RUAF, 2022; Kumar et al., 2023; Valley & Wittman, 2019) and acting as a buffer area in urban settings through the regulation of microclimates and the urban heat island effect (Eom et al., 2012; Octarino, 2023; Sharifi & Lehmann, 2015). Urban agriculture also naturally creates water cycles to mitigate the threat of floods (Ebissa & Desta, 2022), contributes to the conservation of green open spaces in urban areas (Rogus & Dimitri, 2015; Sarjan et al., 2022), and preserves biodiversity (Carrus et al., 2015; Lin et al., 2015; Orsini et al., 2013; Royer et al., 2023).

This paper will mainly discuss the overview of urban agriculture's role as ecosystem services provider in mitigating urban environments deterioration. As ecosystem services providers, here in this paper will divide the ecosystem services based on the urban agriculture roles that were mostly found across the article from 2015 to 2023. This can be done as a result of from the year 2015 until 2021 there were rapid developments from the number of articles published related to urban agriculture, for instance in 2020 there were 79 articles related to urban agriculture published (Yan et al., 2022). However, the writer added the time span to 2023 to improve the number of articles gathered. The ecosystem services that were provided by urban agriculture that will be discussed in this article are biodiversity conservation, regulation of microclimates, soil and water conservation, and food production in the urban area. All in all, the paper gives conclusions and suggestions for future research.

2. Methods

The method employed in this article involves conducting a comprehensive literature review focusing on articles related to urban agriculture and ecosystem services across various dimensions, including provisioning, regulating, and cultural services. The review encompasses urban agriculture's role as a provider of ecosystem services, such as biodiversity conservation, microclimate regulation, aesthetic enhancement, and food production. This approach involves analyzing and synthesizing existing research findings and insights to gain a comprehensive understanding of the relationship between urban agriculture and ecosystem services.

The literature search is meticulously curated to encompass various aspects of urban agriculture's function as an ecosystem services provider, such as biodiversity conservation, microclimate regulation, aesthetic enhancement, and food production. By synthesizing insights from diverse sources, this review aims to offer a comprehensive examination of the relationship between urban agriculture and ecosystem services.

3. Results and Discussion

Ecosystem services, derived from natural resources, play a vital role in sustaining life on the planet and are crucial for enhancing human well-being and global economic operations. Instances of these services include chemical cycles, natural pest management, and the innate purification of air and water (Miller & Spoolman, 2018). The idea of ecosystem services serves to convey society's reliance on ecological life support systems and to promote a greater interest in the preservation of biodiversity. Agriculture functions as both a generator and beneficiary of ecosystem services, as it produces and relies on ecosystem assistance primarily facilitated by human intervention (Halperin et al., 2023). Urban agriculture offers a wide scope of benefits, but the author will divide it based on 4 kinds of ecosystem services, they are supporting biodiversity conservation, food production as in provisioning, microclimate regulation as in regulating, and aesthetics function as in culture.

3.1 Biodiversity conservation

Urban environments, historically overlooked in efforts to preserve biodiversity, are now recognized for their substantial potential to support diverse ecosystems and contribute to ecological processes. Despite this potential, the burgeoning anthropogenic pressures and expanding urban areas pose a threat to urban biodiversity (Royer et al., 2023). In this scenario, urban agriculture emerges as a promising refuge capable of safeguarding urban biodiversity. The integration of urban agriculture with green spaces forms a vital ecological network within cities, essential for enhancing resilience and conserving biodiversity (Korkou et al., 2023; Nicholas et al., 2023; Nigussie et al., 2021; Royer et al., 2023; Speak et al., 2015).

The assessment examination of regulating and supporting services of urban agriculture played a role in the preservation of local biodiversity and habitats (Chen et al., 2023). Biodiversity's foundational role in ecosystem services is crucial, considering it serves as the origin of these services. Enhanced local biodiversity is regarded as a significant environmental advantage of urban agriculture (UA). Measurement for farm-scale biodiversity impacts, such as species richness, habitat fragmentation, habitat vulnerability, or indicators of land use intensity, becomes more relevant in assessing these benefits (Dorr et al., 2023a). Farmers may choose to embrace methods that support biodiversity due to their environmental concerns, while policymakers may enact safety regulations to enhance public health (Piso et al., 2019). Home garden is a source of various forms of food and traditional medicine, a place of worship, supporting biodiversity, and aesthetic functions (Saroinsong et al., 2021). Urban agriculture is advocated for its numerous potential advantages, such as enhancing the greenery of the city and fostering biodiversity. Fresh Roots highlights the capacity of urban farms to establish agro-biodiversity in urban environments, supporting pollinators and offering opportunities for urban residents to reconnect with the natural world (Valley & Wittman, 2019).

Urban agriculture offers a diverse array of advantages. Research has showcased its favorable effects on ecosystems, encompassing enhancements in biodiversity, more effective stormwater infiltration, mitigation of the urban heat island effect, and a reduction in greenhouse gas emissions by minimizing the distance between consumers and producers (Kumar et al., 2023). In urban areas, the biodiversity and ecosystem services provided by urban agriculture can improve food security, air quality, and the regulation of water resources for cities. The biodiversity and species abundance in Beijing exhibited variation based on proximity to the city, transitioning from ornamental plants to those meeting edible demand levels. These patterns were correlated with decreased income, diminished food security, and a decline in suburban food security (Zheng & Chou, 2023).

Urban land holds potential as an informal element of urban green infrastructure. Edible schools, grounded in biodiversity, have the potential to deepen children's connection to nature and enhance their comprehension of the opportunities and challenges related to food production and policies aimed at improving diets (Fischer et al., 2019). Enhanced biodiversity can result from replacing taxonomically depauperate lawns with more diverse gardens, which have the potential to offer crucial ecological resources like flowers according to a research in Sydney, Australia (Mcdougall et al., 2020). Research in New York, USA conducts a program evaluation that assists in recording specific outcomes, spanning from the effectiveness of youth employment programs to the impact of the farm on biodiversity (Cohen & Reynolds, 2015).

In urban settings, the biodiversity and ecosystem services provided by urban agriculture can improve food security, air quality, and the regulation of water resources for cities (Zheng & Chou, 2023). The varied composition of vegetation can lead to elevated levels of biodiversity compared to other green spaces in the city (Tapia et al., 2021). Green roofs and vertical walls not only help decrease heating and cooling needs but also enhance air quality, contributing to increased biodiversity and ecosystem services. Understanding the availability of green areas that can be harmonized with urban agriculture becomes essential to prevent the mismanagement of these spaces and the loss of biodiversity (Bennedetti et al., 2023).

3.2 Microclimate regulation

Urban artificial temperature increase affects the urban microclimates in different layers of the atmosphere, including the surface layer (buildings and land surfaces), the canopy layer (below the canopy of trees or in human scale) and the boundary layer (up to 1500 meters above the ground surface). These three layers of urban microclimates are tangled in complex climatic systems, while local air circulation in the built environment can moderate the Urban Heat Island (UHI) effect by mixing the air in each layer with other adjacent layers (Dorr et al., 2023a; Sharifi & Lehmann, 2015). Main ecological benefits range widely, one of them is regulating ecosystem services for local microclimate reduction of urban heat island effects, wind protection, sequestration of CO2 and other pollutants (Marini et al., 2023). Considering the potential impact, urban agriculture as in a garden increases vegetation toward regulating temperatures, there could be big implications on energy use and comfort levels for urban communities. Additionally, gardens located in areas unsuitable for buildings or established as buffer zones along rail corridors and highways, may be helpful in balancing the urban microclimate (Lin et al., 2015).

Evergreen trees are highly beneficial because they potentially provide multiple ecosystem services, related to leaf area index, year-round. A review of 115 tree research papers found carbon storage, air quality improvement, microclimate modification and energy savings (from cooling) to be the four most reported, with noise reduction, biodiversity/habitat creation and flood amelioration being lesser reported ones (Speak et al., 2015). The use of shade trees has generally been found to improve resilience to climate change through regulation of microclimate (Baker et al., 2023). The scale of the farm that Napawan (2015) observed in San Francisco, USA varied microclimates for growing a range of crops at multiple scales, including multiple fruit trees, groves, row crops, herbs, and edible groundcovers. Interstitial space in urban agriculture is generally referred to as a microclimate modifier that improves the comfort level of the surrounding environment. The space has a high potential to mitigate high temperature, channel breezes, and adjust the degree of humidity inside the house. The interstitial space serves as a social gathering place and a source of airflow and creates thermal comfort for the user. Thus, the interstitial space is a cool air reservoir, mostly in hot climates. This helps to maintain a low temperature in the interstitial and surrounding areas (Mari et al., 2022).

Urban agriculture contributes to pollution control by repurposing urban organic waste, establishing green belts, and enhancing the urban microclimate (Kumar et al., 2023). Urban agriculture's function in regulating ecosystem services can be seen in fixing carbon and combatting increasing levels of greenhouse gases (Chen et al., 2023). The System and sustainable Approach to virTuous interaction of Urban and Rural LaNdscapes (SATURN) project explored by Nikologianni et al. (2022) to find resilience at a city scale might be achieved and the issues of landscape fragmentation, governance and land management can be addressed resulting in a sustainable future. The SATURN project is based on a collaboration between three cities of very different scales and contexts, those of Gothenburg in western Sweden, Trento in northern Italy, and Birmingham in the United Kingdom and focused on which urban farming can become an important tool to mitigate or adapt to climate change in urban environments by exploring how the three major cities of SATURN deal with these concepts.

Octarino (2023) observed the effectiveness of urban agriculture in maintaining the microclimate quality at District of Tompeyan Yogyakarta using ENVI-MET simulation and showed that there is an increase in the thermal comfort index in the areas with vegetation, although it has not yet reached the ideal value and represents the role of vegetation in urban heat island mitigation to provide a comfortable and sustainable environment and suggest microclimate to be the foundation for local spatial planning recommendations. Xu & Fricker (2023) conduct research in Singapore and found the food growing structures in urban agriculture provide shading for microclimate mitigation, as vegetation shading can effectively reduce solar heat gain; the rainfall collected in the stormwater infrastructure can be supplied for food production, while the growing plants provide vegetation shading for cooling the microclimate; and stormwater infrastructure in connection with urban agriculture can increase drainage capacity, offer accessible community spaces, improve green features, and create comfortable microclimates.

The study in District of Kotabaru Yogyakarta conducted by Adityo (2016) using Envi-MET system to understand the existing landscaping affected the thermal conditions and empirical measurement to show the microclimate condition based on data measured in field observation and found that the design of the vegetation landscape could improve the urban thermal conditions and affects the wind speed in the urban areas. Saroinsong et al. (2021) studied urban agriculture in a form of home garden in 3 Indonesia's cities, such as Tomohon, Solo, and Denpasar, and found that urban agriculture benefits in a home garden can be a source ameliorating the microclimate.

3.3 Aesthetic function

The aesthetic dimension is related to the positive visual image of the garden and its relation to buildings. Hence, nature could play a significant role in improving the aesthetic and unique quality of interstitial spaces. Nature not only improves the microclimate but also creates a pleasant environment (Mari et al., 2022). Aside from its ecological and economic importance, biodiversity in urban agriculture has always been aesthetically pleasing. The urban agriculture garden as an element of the urban structure thus can give aesthetic values (Tapia et al., 2021). Rooftop farming is considered as urban agriculture and Bihari et al. (2022) found that rooftop vegetable farming enhances the aesthetic value of the urban environment and Bhattarai & Adhikari (2023) in Nepal found that urban agriculture consisting of edible landscapes can also be an aesthetic public space. Most of the respondents of a research in the City of Hyderabad, India observed by Kumari & Shirisha (2022) were using containers unutilized container at home or from their vehicles (tyres) and with their creative ideas they recycled and broken things into reusable grow containers and added aesthetic elements to beautify their garden in a cost-effective manner.

Many of the issues raised by urban farmers in Greater Melbourne of Australia require systematic intervention rather than piecemeal regulation. The role of farming in urban agriculture can be re-evaluated through alternative models of agriculture, from the new functions of peri-urban agriculture that can provide recreational and aesthetic integration by hybridisation and gentrification (Spataru et al., 2020). Home gardens, as urban agriculture edible landscapes based on community empowerment, have the potential to improve health, education, recreation, and aesthetic functions as well as enhancing social status, income, and connectivity thus becoming a sustainable and resilient strategy for urban development (Zheng & Chou, 2023). Urban agriculture provides benefits for urban dwellers in health and emotion by giving urban farmers happiness from having fun, joy, aesthetic pleasure, and satisfaction after practicing urban agriculture (Wadumestrige Dona et al., 2021). Peri-urban agriculture in Bangkok that was observed by Likitswat & Sahavacharin (2022) identified cultural function in aesthetic values and preserving cultural landscape.

Speak et al. (2015) conducted research in allotment gardens located in Poznan of Poland and Manchester of England, resulting in ponds that were common in both Manchester and Poznan allotment garden, however, in Poznan the ponds were more for aesthetic purposes than for biodiversity or rainwater storage. The ponds in Manchester allotments were less well manicured and they appear to play a much more ecological role, e.g., providing a habitat for frogs, which help control garden pest populations. Audate et al. (2022) observes urban agriculture in two deprived neighborhoods in Haiti, and the local inhabitants' active involvement in the process has allowed them to shape the gardens. Representatives from both associations have left it to the participants to determine the size of the garden and the amount of effort to be invested. Participants learn to adapt the project to existing conditions and the local culture. This aligns with place-making principles and with the fact that motivations to garden in the city are diverse and heterogeneous. Sereenonchai & Arunrat (2023) stated that home gardeners in Toronto of Canada apart from self-satisfaction, access to fresh food, education, environmental awareness, and aesthetics also played a crucial role.

Integrated urban agriculture in Magelang of Indonesia contributes to overall urban circularity metabolism and urban aesthetics and positively impacts household income because the products come from not only one sector but several sectors that are integrated into an agricultural system (Nugroho et al., 2023). Social factors from urban agriculture, such as a greater value being placed on aesthetic or recreational uses of land than on productivity also play a part in the limited uptake of the practice in Sydney of Australia (Mcdougall et al., 2020). Intensive farm agricultural production often decreases the highly aesthetic agricultural landscape and its naturalness, as a result Chen et al. (2023) considered that through multifunctional management and improvement of green infrastructures toward public access, such trade-offs can be mitigated. On the one hand, the agricultural landscape held significant cultural values including aesthetic appreciation, sense of place and local ecological integrity.

Tomohon of Indonesia known as The City of Flowers, along with city programs and outreach by women's community organization (PKK) influence the use of the home garden in Tomohon City. The local regulation is in line with local community custom and culture (Minahasa ethnic) to manage the front of the home garden by considering aesthetic aspects such as flowering ornamental plants, not only for the family but also for guests and surrounding people pleasure (Saroinsong et al., 2021). Urban agriculture in Canada is increasingly used as a strategy to improve food environments and the aesthetic of urban areas in different socioeconomic contexts and other factors to be the driving motives of home gardeners, include access to fresh food, education, environmental awareness, and aesthetics, in addition to the self-satisfaction motivation (Audate et al., 2021).

3.4 Urban area food production

Food production within urban environments could be part of the solution as urban agriculture allows food to be grown on land that may not otherwise be put to a productive use and, as the majority of the global population now reside in cities, it can allow for food production closer to where it will be ultimately consumed (Mcdougall et al., 2020). Urban agriculture can contribute to household food security in developing countries and has also played a role in improving national food security in developed countries in times of crisis during the 20th century (Poulsen et al., 2015). Diversification in mixed agriculture systems can buffer against the risks climate change poses to food production systems through increased livelihood resilience, food security, and multiple ecosystem services. Urban integrated systems can reconnect urban residents with food production, improve food security for low-income communities (Baker et al., 2023). As the lack of suitable land areas for food production is a frequent issue faced by entrepreneurs and the private sector in the city area, the government of Malaysia may need to create Permanent Food Production Parks (TKPM) in urban areas, as has previously been done in rural areas. The TKPM will provide permanent sites for food production, especially fruits and vegetables (Murdad et al., 2022).

Improving a community's localized food production in urban agriculture may contribute to resilience through providing healthy food after a natural disaster and filling the nutrition gap created by long-term reliance on emergency rations. Vancouver of Canada has been quite proactive developing several policies to address issues of food insecurity and local food production, the city developed the Vancouver Food Strategy, a high-level, yet detailed policy that treats food systems as part of a broader set of priorities (Slater & Birchall, 2022). Implementing food, energy, and water production systems on urban rooftops can potentially help cities become more self-sufficient but depends on the city's urban morphology, as Toboso-Chavero et al. (2022) observed the supply potential and impacts of four roof mosaic scenarios for different urban forms in Cerdanyola of Barcelona and found that housing estates has the highest level of vegetable self-sufficiency. Accommodating urban gardening and food production in cities requires negotiating between various interests wielding differential levels of power to defend their claims to urban space, as observed by Barthel et al. (2015) in the case of the Stockholm National Urban Park illustrates four important roles that urban environmental movements can play in protecting green space that can be used for food production and gardening, or protecting space for generating ecosystem services of importance for such activities.

Actual values of food production, protein supply, and dietary energy supply adequacy are three proxies for food security (Saboori et al., 2023). Fischer et al. (2019) observed schools which are critical for environmental education, and there is a long tradition of schools serving as sites of food production and consumption that are linked to "biodiverse edible schools", result shown that edible school garden in Berlin of Germany helps students understand food production and improving their diet. Shao et al. (2022) stated that food production is getting more and more pressure to meet the demand with the increasing recognition of urban agriculture in industrial cities, family food production is becoming an increasingly attractive topic. The promotion of food production is one of the driving forces for the innovative forms of urban agriculture, as part of the food production process, the main foods produced are fresh vegetables and fruits. Dorr et al. (2023b) observed urban agriculture in California, and suggest for policy makers, the environmental performance of different farmscan profile which urban agriculture type to promote based on different objectives: if food production is the goal, for example, to improve food security of a city, then medium-tech farms or professional farms similar to the ones we included can optimize growing food with lower impacts per kilogram and if food production is less important than education or social benefits, then low-tech farms are better to minimize impacts per m2 per year regardless of how much food is grown.

Singapore's 'smart food city' modes of governance assume consideration to be given both to modern technologies and innovative methods of food production being deployed in the city as well as to social and civil forms of innovation, in line with the traditions of the urban food system and also investments in roof farming can be an opportunity for the development of local food production (Gorna & Gorny, 2021). Research in Bandung of Indonesia showed that the members of women's farmer group are involved in various production activities such as seeding, maintenance, hydroponic management for making herbal medicinal products derived from medicinal plants from the garden they plant and develop the creativity of housewives in carrying out agricultural production activities and making processed products from food crops (Safitri et al., 2021). Urban agriculture in Singapore contributed to job creation by having both full- and part-time employees, and to local food production by selling their produce to one retailer and on-premises once a week, these impacts were often meager (Nicholas et al., 2023). Valley & Wittman (2019) have done a research in Vancouver of Canada and concluded by calling attention to issues of food literacy, equity, and inclusion within municipal food system policy and planning, and the opportunity to frame support for urban farming as a mechanism to orient urban citizens towards issues of peri-urban.

Decentralized urban agriculture integrated with underutilized spaces is a sustainable way to enhance local food production and utilizing the rainfall collected in canals for food production contributes to water conservation, which is highly imperative to sustainable vertical farming are reasons as a result of 90% of Singapore's consumer food is imported, motivating local food production to achieve 30% food self-sufficiency by 2030 (Xu & Fricker, 2023). The trade-off between food production and wildlife habitat fuels the long-standing debate between the conservation strategies around land- sharing versus land-sparing. Land-sharing involves using methods like wildlife-friendly farming to support wildlife and food production on the same land. On the other hand, a land-sparing approach would devote land to high-yield agriculture on a smaller area and separately, devote land for biodiversity protection (Halperin et al., 2023). Urban agriculture, particularly innovative and disruptive solutions, is seen as having the potential to contribute to more resilient and sustainable cities and food systems and strengthen local food production during and after the COVID-19 pandemic. Urban agriculture can be an efficient approach to promote the integrated development of urban and rural areas by breaking geographical and institutional barriers and by promoting cooperation between urban and rural areas in terms of technologies, capital, and talent (Yan et al., 2022).

4. Conclusions

Urban agriculture is characterized as a sector operating within or near urban areas, utilizing local resources and providing essential services to the same urban community. The forms of urban agriculture vary widely across different countries, influenced by contextual settings, stakeholder involvement, land surfaces, tools employed, production goals, and distribution methods. Common forms include private gardens, community gardens, green open spaces, and urban farm allotments. Urban agriculture is often viewed as a compensatory use of unwanted land, contributing to greening initiatives and community responses to limited public funding. The link between nature and community involvement, emphasizing the positive impact of community gardens on residents' sense of belonging and social interaction. Challenges such as time constraints for participation are acknowledged, with integrated farming systems suggested as an alternative approach to promote urban agriculture. Urban agriculture is seen as expanding the availability of green areas in urban settings, utilizing diverse spaces like school grounds, rooftops, and riverbanks. This practice contributes to reintroducing natural elements into built environments and engaging local communities with nature.

Urban environments, often overlooked in biodiversity conservation efforts, are increasingly acknowledged for their potential to support diverse ecosystems. However, expanding urban areas poses a threat to urban biodiversity. Urban agriculture emerges as a promising solution, forming a vital ecological network when integrated with green spaces. The assessment of urban agriculture's regulating and supporting services plays a crucial role in preserving local biodiversity and habitats. Enhanced biodiversity is recognized as a significant environmental advantage of urban agriculture, contributing to various aspects such as species richness, habitat fragmentation, and land use intensity indicators. Various studies across different regions highlight the potential of urban agriculture to deepen connections with nature, improve diets, and enhance ecological resources. The varied composition of vegetation, including green roofs and vertical walls, contributes to increased biodiversity and ecosystem services, emphasizing the importance of proper management of green spaces in urban areas. Overall, urban agriculture stands as a multifaceted solution with the potential to foster biodiversity conservation, ecological resilience, and sustainable urban living.

The urban microclimate is intricately influenced by temperature variations in different atmospheric layers, including the surface, canopy, and boundary layers. Urban agriculture, particularly in gardens, plays a significant role in mitigating the Urban Heat Island (UHI) effect and regulating local microclimates. This ecological benefit encompasses reductions in urban heat island effects, wind protection, CO_2 sequestration, and pollutant absorption. Trees, especially evergreen ones, contribute to multiple ecosystem services, such as carbon storage, air quality improvement, and microclimate modification. Interstitial spaces in urban agriculture act as microclimate modifiers, enhancing comfort levels and serving as cool air reservoirs, particularly in hot climates. Additionally, urban agriculture addresses pollution control by repurposing organic waste and creating green belts. Urban agriculture structures contribute to microclimate mitigation, offering shading, stormwater management, and enhanced drainage capacity. Overall, urban agriculture emerges as a multifaceted solution that not only supports food production but also significantly contributes to creating sustainable and comfortable urban environments by regulating microclimates.

The aesthetic function of urban agriculture emerges as a pivotal aspect, contributing not only to the visual appeal of interstitial spaces but also to the overall quality of urban environments. Nature, integrated into these spaces, enhances microclimates, fostering a comfortable atmosphere. Biodiversity within urban agriculture gardens adds an aesthetic value to the urban structure, exemplified by rooftop farming and edible landscapes. Home gardens, especially those based on community empowerment, offer multifaceted improvements, including health, education, recreation, and aesthetic functions. The role of farming in urban agriculture goes beyond mere productivity; it integrates with alternative models, providing recreational and aesthetic integration in peri-urban areas. The diverse benefits of urban agriculture, such as happiness derived from fun, joy, and aesthetic pleasure, contribute to the well-being of urban dwellers. Overall, urban agriculture emerges as a holistic strategy, not only promoting sustainability and resilience but also enhancing the aesthetic and cultural fabric of urban spaces.

Urban agriculture emerges as a multifaceted solution to address various challenges related to food production, security, and sustainable urban development. The diversification of agriculture systems within urban settings not only contributes to livelihood resilience but also integrates multiple ecosystem services, fostering a more sustainable and resilient urban environment. Moreover, urban agriculture has proven to be a valuable tool in disaster recovery, providing healthy food and bridging nutrition gaps after natural disasters. The integration of food production enhances environmental education and dietary practices. Balancing the trade-offs between food production and wildlife habitat, the debate between land-sharing and land-sparing strategies highlights the need for innovative solutions like urban agriculture to create resilient and sustainable urban food systems. The potential of urban agriculture to contribute to resilient and sustainable cities is particularly evident in its capacity to adapt and thrive, even in the face of challenges such as the COVID-19 pandemic.

Acknowledgement

The authors would like to express sincere gratitude to the reviewers for valuable insights and constructive feedback, which have significantly contributed to the improvement of this manuscript.

Author Contribution

All authors contributed equally to the research, drafting, and revision of the manuscript. All have approved the final version for submission.

Funding

Not available.

Ethical Review Board Statement

Not available.

Informed Consent Statement

Not available.

Data Availability Statement

Not available.

Conflicts of Interest

The authors declare no conflict of interest.

Open Access

References

Adityo. (2016). Peningkatan Kenyamanan Termal Koridor Jalan Melalui Desain Tata Vegetasi Berbasis Simulasi. *Arsitektur Komposisi*, *11*(3), 159–168. https://doi.org/10.24002/jars.v11i3.1189

Audate, P. P., Cloutier, G., & Lebel, A. (2021). The motivations of urban agriculture practitioners in deprived neighborhoods: A comparative study of Montreal and Quito. *Urban Forestry and Urban Greening*, *62*(November 2020). https://doi.org/10.1016/j.ufug.2021.127171

Audate, P. P., Cloutier, G., & Lebel, A. (2022). Role of urban agriculture in the space-to-place transformation: Case study in two deprived neighborhoods, Haiti. *Cities*, *127*(April). https://doi.org/10.1016/j.cities.2022.103726

Baker, E., Bezner Kerr, R., Deryng, D., Farrell, A., Gurney-Smith, H., & Thornton, P. (2023). Mixed farming systems: potentials and barriers for climate change adaptation in food systems. *Current Opinion in Environmental Sustainability*, *62*(July 2022), 101270.

https://doi.org/10.1016/j.cosust.2023.101270

Barthel, S., Parker, J., & Ernstson, H. (2015). Food and Green Space in Cities: A Resilience Lens on Gardens and Urban Environmental Movements. *Urban Studies*, *52*(7), 1321–1338. https://doi.org/10.1177/0042098012472744

Bennedetti, L. V., de Almeida Sinisgalli, P. A., Ferreira, M. L., & Lemes de Oliveira, F. (2023). Challenges to Promote Sustainability in Urban Agriculture Models: A Review. *International Journal of Environmental Research and Public Health*, *20*(3). https://doi.org/10.3390/ijerph20032110

Bhattarai, K., & Adhikari, A. P. (2023). *Promoting Urban Farming for Creating Sustainable Cities in Nepal*. *January*, 1–25. https://doi.org/10.20944/preprints202301.0142.v1

Bihari, C., Ahamad, S., & Saha, S. (2022). *Rooftop Vegetable Farming in Urban Areas*. *04*(06), 226–228. https://doi.org/10.1115/1.4062545

Cahya, D. L. (2016). Analysis of Urban Agriculture Sustainability in Metropolitan Jakarta (Case Study: Urban Agriculture in Duri Kosambi). *Procedia - Social and Behavioral Sciences*, *227*(November 2015), 95–100. https://doi.org/10.1016/j.sbspro.2016.06.048

Carrus, G., Scopelliti, M., Lafortezza, R., Colangelo, G., Ferrini, F., Salbitano, F., Agrimi, M., Portoghesi, L., Semenzato, P., & Sanesi, G. (2015). Go greener, feel better? The positive effects of biodiversity on the well-being of individuals visiting urban and peri-urban green areas. *Landscape and Urban Planning*, *134*, 221–228. https://doi.org/10.1016/j.landurbplan.2014.10.022

Chandra, A. J., & Diehl, J. A. (2019). Urban agriculture, food security, and development policies in Jakarta: A case study of farming communities at Kalideres – Cengkareng district, West Jakarta. *Land Use Policy*, *89*(October), 104211. https://doi.org/10.1016/j.landusepol.2019.104211

Chen, S., Chen, H., Yang, R., & Ye, Y. (2023). Linking social-ecological management and ecosystem service bundles: Lessons from a peri-urban agriculture landscape. *Land Use Policy*, *131*(April), 106697. https://doi.org/10.1016/j.landusepol.2023.106697

Cohen, N., & Reynolds, K. (2015). Resource needs for a socially just and sustainable urban agriculture system: Lessons from New York City. *Renewable Agriculture and Food Systems*, *30*(1), 103–114. https://doi.org/10.1017/S1742170514000210

De Bon, H., Parrot, L., & Moustier, P. (2009). Sustainable urban agriculture in developing countries: A review. *Sustainable Agriculture*, *30*, 619–633. https://doi.org/10.1007/978-90-481-2666-8_38

Dorr, E., Goldstein, B., Aubry, C., Gabrielle, B., & Horvath, A. (2023a). Best practices for consistent and reliable life cycle assessments of urban agriculture. *Journal of Cleaner Production*, *419*(April), 138010. https://doi.org/10.1016/j.jclepro.2023.138010

Dorr, E., Goldstein, B., Aubry, C., Gabrielle, B., & Horvath, A. (2023b). Life cycle assessment of eight urban farms and community gardens in France and California. *Resources, Conservation and Recycling*, *192*(February), 106921. https://doi.org/10.1016/j.resconrec.2023.106921

Ebissa, G., & Desta, H. (2022). Review of urban agriculture as a strategy for building a water resilient city. *City and Environment Interactions*, *14*(March), 100081. https://doi.org/10.1016/j.cacint.2022.100081

Eom, K.-C., Jung, P.-K., Park, S.-H., Yoo, S.-Y., & Kim, T.-W. (2012). Evaluation of the Effect of Urban-agriculture on Urban Heat Island Mitigation. *Korean Journal of Soil Science and Fertilizer*, *45*(5), 848–852. https://doi.org/10.7745/kjssf.2012.45.5.848

FAO & RUAF. (2022). Urban and peri-urban agriculture sourcebook. In *Urban and peri-urban agriculture sourcebook*. FAO. https://doi.org/10.4060/cb9722en

Fauzi, A. R., Ichniarsyah, A. N., & Agustin, H. (2016). Urban Agriculture : Urgency, Role, and Best Practice. *Jurnal Agroteknologi*, *10*(01), 49–62. https://doi.org/10.19184/j-agt.v10i01.4339

Fischer, L. K., Brinkmeyer, D., Karle, S. J., Cremer, K., Huttner, E., Seebauer, M., Nowikow, U., Schütze, B., Voigt, P., Völker, S., & Kowarik, I. (2019). Biodiverse edible schools: Linking healthy food, school gardens and local urban biodiversity. *Urban Forestry and Urban*

Greening, *40*(February 2018), 35–43. https://doi.org/10.1016/j.ufug.2018.02.015

Gorna, A., & Gorny, K. (2021). Singapore vs. the 'Singapore of Africa'—Different Approaches to Managing Urban Agriculture. *Land*, *10*(987), 1–28. https://doi.org/10.3390/land10090987

Gulyas, B. Z., & Edmondson, J. L. (2021). Increasing city resilience through urban agriculture: Challenges and solutions in the global north. *Sustainability (Switzerland)*, *13*(3), 1–19. https://doi.org/10.3390/su13031465

Halperin, S., Castro, A. J., Quintas-Soriano, C., & Brandt, J. S. (2023). Assessing high quality agricultural lands through the ecosystem services lens: Insights from a rapidly urbanizing agricultural region in the western United States. *Agriculture, Ecosystems and Environment*, *349*(March), 108435. https://doi.org/10.1016/j.agee.2023.108435

Korkou, M., Tarigan, A. K. M., & Hanslin, H. M. (2023). The multifunctionality concept in urban green infrastructure planning: A systematic literature review. *Urban Forestry and Urban Greening*, *85*, 127975. https://doi.org/10.1016/j.ufug.2023.127975

Kumar, A., Mangla, S. K., & Kumar, P. (2023). An integrated literature review on sustainable food supply chains: Exploring research themes and future directions. *Science of the Total Environment*, *821*(February), 104878. https://doi.org/10.1016/j.scitotenv.2022.153411

Kumari, V., & Shirisha, J. (2022). Urban Farming Practices Among the Urbanites of Hyderabad, Telangana. *Journal of Community Mobilization and Sustainable Development*, *2*(Seminar Special Issue), 295–300. https://www.manage.gov.in/publications/resArticles/veenita/Mobilization-2022-23.pdf

Likitswat, F., & Sahavacharin, A. (2022). Landscape Change Analysis: Ecosystem Services in the Peri-urban Agriculture of Bangkok. *Journal of Architectural/Planning Research and Studies (JARS)*, *20*(2), 25–38. https://doi.org/10.56261/jars.v20i2.249694

Lin, B. B., Philpott, S. M., & Jha, S. (2015). The future of urban agriculture and biodiversity-ecosystem services: Challenges and next steps. *Basic and Applied Ecology*, *16*(3), 189–201. https://doi.org/10.1016/j.baae.2015.01.005

Mabon, L., Shih, W. Y., & Jou, S. C. (2022). Integration of knowledge systems in urban farming initiatives: insight from Taipei Garden City. *Sustainability Science*, *18*(2), 857–875. https://doi.org/10.1007/s11625-022-01196-x

Mari, T., Ameerah, P. B., Gunasagaran, S., Veronica, N., & Kuppusamy, S. (2022). Urban Farming As Sustainable Strategy To Revive Interstitials in Community Housing. *Journal of Engineering Science and Technology*, *17*(January), 279–291. https://expert.taylors.edu.my/file/rems/publication/100149_10704_1.pdf

Marini, M., Caro, D., & Thomsen, M. (2023). Investigating local policy instruments for different types of urban agriculture in four European cities: A case study analysis on the use and effectiveness of the applied policy instruments. *Land Use Policy*, *131*(April), 106695. https://doi.org/10.1016/j.landusepol.2023.106695

Mcdougall, R., Rader, R., & Kristiansen, P. (2020). Urban agriculture could provide 15% of food supply to Sydney, Australia, under expanded land use scenarios. *Land Use Policy*, *94*(March), 104554. https://doi.org/10.1016/j.landusepol.2020.104554

Miller, G. T., & Spoolman, S. E. (2016). *Environmental Science* (Fifteenth). Cengage Learning.

Miller, G. T., & Spoolman, S. E. (2018). *Living in Environment* (Nineteenth). Cengage Learning.

Murdad, R., Muhiddin, M., Osman, W. H., Tajidin, N. E., Haida, Z., Awang, A., & Jalloh, M. B. (2022). Ensuring Urban Food Security in Malaysia during the COVID-19 Pandemic—Is Urban Farming the Answer? A Review. *Sustainability (Switzerland)*, *14*(7). https://doi.org/10.3390/su14074155

Napawan, N. C. (2015). Production places: Evaluating communally-managed urban farms as public space. *Landscape Journal*, *34*(1), 37–56. https://doi.org/10.3368/lj.34.1.37

Nicholas, S. O., Groot, S., & Harré, N. (2023). Understanding urban agriculture in context: environmental, social, and psychological benefits of agriculture in Singapore. *Local Environment*, *28*(11), 1446–1462. https://doi.org/10.1080/13549839.2023.2238721

Nigussie, S., Liu, L., & Yeshitela, K. (2021). Towards improving food security in urban and peri-urban areas in Ethiopia through map analysis for planning. *Urban Forestry and Urban Greening*, *58*(May 2020), 126967. https://doi.org/10.1016/j.ufug.2020.126967

Nikologianni, A., Betta, A., Andreola, M., Pianegonda, A., Battistel, G. A., Ternell, A., & Gretter, A. (2022). Urban Farming Models, Ecosystems and Climate Change Adaptation in Urban Environments: The Case of SATURN Pan European Programme. *Athens Journal of Sciences*, *9*(1), 9–24. https://doi.org/10.30958/ajs.9-1-1

Nugroho, R. W., Kusnandar, & Sutrisno, J. (2023). Urban Farming Development Strategy to Achieve Sustainable Agriculture in Magelang, Indonesia. *International Journal on Advanced Science, Engineering and Information Technology*, *13*(1), 289–296. https://doi.org/10.18517/ijaseit.13.1.17162

Octarino, C. N. (2023). Efektivitas Pertanian Perkotaan (Urban Farming) dalam Mitigasi Urban Heat Island di Kawasan Perkotaan. *ATRIUM: Jurnal Arsitektur*, *8*(3), 189–198. https://doi.org/10.21460/atrium.v8i3.200

Orsini, F., Kahane, R., Nono-Womdim, R., & Gianquinto, G. (2013). Urban agriculture in the developing world: A review. *Agronomy for Sustainable Development*, *33*(4), 695–720. https://doi.org/10.1007/s13593-013-0143-z

Piso, Z., Goralnik, L., Libarkin, J. C., & Lopez, M. C. (2019). Types of Urban agricultural stakeholders and their understandings of governance. *Ecology and Society*, *24*(2). https://doi.org/10.5751/ES-10650-240218

Popoola, A., Wahab, B., Magidimisha-Chipungu, H., & Chipungu, L. (2022). Integration of Urban Farming into City Infrastructure Development. *CSID Journal of Infrastructure Development*, *5*(1), 4. https://doi.org/10.32783/csid-jid.v5i1.148

Poulsen, M. N., McNab, P. R., Clayton, M. L., & Neff, R. A. (2015). A systematic review of urban agriculture and food security impacts in low-income countries. *Food Policy*, *55*, 131–146. https://doi.org/10.1016/j.foodpol.2015.07.002

Rogus, S., & Dimitri, C. (2015). Agriculture in urban and peri-urban areas in the United States: Highlights from the census of agriculture. *Renewable Agriculture and Food Systems*, *30*(1), 64–78. https://doi.org/10.1017/S1742170514000040

Royer, H., Yengue, J. L., & Bech, N. (2023). Urban agriculture and its biodiversity: What is it and what lives in it? *Agriculture, Ecosystems and Environment*, *346*(January), 108342. https://doi.org/10.1016/j.agee.2023.108342

Saboori, B., Alhattali, N. A., & Gibreel, T. (2023). Agricultural products diversification-food security nexus in the GCC countries; introducing a new index. *Journal of Agriculture and Food Research*, *12*(December 2022), 100592. https://doi.org/10.1016/j.jafr.2023.100592

Safitri, K. I., Abdoellah, O. S., & Gunawan, B. (2021). Urban Farming as Women Empowerment: Case Study Sa'uyunan Sarijadi Women's Farmer Group in Bandung City. *E3S Web of Conferences*, *249*. https://doi.org/10.1051/e3sconf/202124901007

Sarjan, M., Fauzi, M. T., & Thei, R. S. P. (2022). Introduction of Integrated Pest Management Practices in Urban Farming in Mataram City During the Covid-19 Pandemic. *Unram Journal of Community Service*, *3*(3), 85–91. https://doi.org/10.29303/ujcs.v3i3.192

Saroinsong, F. B., Ismail, Y., Gravitiani, E., & Sumantra, K. (2021). Utilization of Home Gardens as a Community Empowerment-Based Edible Landscape to Combat Stunting. *IOP Conference Series: Earth and Environmental Science*, *940*(1). https://doi.org/10.1088/1755-1315/940/1/012093

Sereenonchai, S., & Arunrat, N. (2023). Urban Agriculture in Thailand: Adoption Factors and Communication Guidelines to Promote Long-Term Practice. *International Journal of Environmental Research and Public Health*, *20*(1), 1–22. https://doi.org/10.3390/ijerph20010001

Setiowati, R., Hasibuan, H. S., Koestoer, R. H., & Harmain, R. (2019). Planning for Urban Green Area and Its Importance for Sustainability: The Case of Jakarta. *IOP Conference Series: Earth and Environmental Science*, *328*(1). https://doi.org/10.1088/1755-1315/328/1/012027

Shao, Y., Zhou, Z., Chen, H., Zhang, F., Cui, Y., & Zhou, Z. (2022). The potential of urban family vertical farming: A pilot study of Shanghai. *Sustainable Production and Consumption*, *34*(October), 586–599. https://doi.org/10.1016/j.spc.2022.10.011

Sharifi, E., & Lehmann, S. (2015). Correlation analysis of surface temperature of rooftops, streetscapes and urban heat island effect: Case study of central Sydney. *Journal of Urban and Environmental Engineering*, *9*(1), 3–11. https://doi.org/10.4090/juee.2015.v9n1.003011

Slater, T., & Birchall, S. J. (2022). Growing resilient: The potential of urban agriculture for increasing food security and improving earthquake recovery. *Cities*, *131*(June), 103930. https://doi.org/10.1016/j.cities.2022.103930

Spataru, A., Faggian, R., & Docking, A. (2020). Principles of multifunctional agriculture for supporting agriculture in metropolitan peri-urban areas: The case of Greater Melbourne, Australia. *Journal of Rural Studies*, *74*(October 2019), 34–44. https://doi.org/10.1016/j.jrurstud.2019.11.009

Speak, A. F., Mizgajski, A., & Borysiak, J. (2015). Allotment gardens and parks: Provision of ecosystem services with an emphasis on biodiversity. *Urban Forestry and Urban Greening*, *14*(4), 772–781. https://doi.org/10.1016/j.ufug.2015.07.007

Tacoli, C. (2017). Urban poverty , food security and climate change Policy pointers. *International Institute for Environment and Development*, *2013*, 5. http://www.jstor.org/stable/resrep01511

Tapia, C., Randall, L., Wang, S., & Aguiar Borges, L. (2021). Monitoring the contribution of urban agriculture to urban sustainability: an indicator-based framework. *Sustainable Cities and Society*, *74*, 103130. https://doi.org/10.1016/j.scs.2021.103130

Toboso-Chavero, S., Montealegre, A. L., García-Pérez, S., Sierra-Pérez, J., Muñoz-Liesa, J., Gabarrell Durany, X., Villalba, G., & Madrid-López, C. (2022). The potential of local food, energy, and water production systems on urban rooftops considering consumption patterns and urban morphology. *Sustainable Cities and Society*, *95*(April). https://doi.org/10.1016/j.scs.2023.104599

Valley, W., & Wittman, H. (2019). Beyond feeding the city: The multifunctionality of urban farming in Vancouver, BC. *City, Culture and Society*, *16*(September 2017), 36–44. https://doi.org/10.1016/j.ccs.2018.03.004

Wadumestrige Dona, C. G., Mohan, G., & Fukushi, K. (2021). Promoting urban agriculture and its opportunities and challenges—a global review. *Sustainability (Switzerland)*, *13*(17). https://doi.org/10.3390/su13179609

Xu, M., & Fricker, P. (2023). Urban Agriculture: Climate-Responsive Design Strategies for Blue Infrastructure in the Context of Singapore. *Journal of Digital Landscape Architecture*, *2023*(8), 292–300. https://doi.org/10.14627/537740031

Yan, D., Liu, L., Liu, X., & Zhang, M. (2022). Global Trends in Urban Agriculture Research: A Pathway toward Urban Resilience and Sustainability. *Land*, *11*(1), 1–17. https://doi.org/10.3390/land11010117

Yayasan Keanekaragaman Hayati Indonesia. (2020). Sustainable Development: Pembangunan Berkelanjutan: Towards Indonesia Takeoff 2045. In *90 Tahun Prof. Emil Salim, Pembangunan Berkelanjutan: Menuju Indonesia Tinggal Landas 2045*.

Zheng, Z. W., & Chou, R. J. (2023). The impact and future of edible landscapes on sustainable urban development: A systematic review of the literature. *Urban Forestry and Urban Greening*, *84*(April), 127930. https://doi.org/10.1016/j.ufug.2023.127930

Biographies of Authors

Assyifa Fauzia, School of Environmental Science, Universitas Indonesia, Central Jakarta, 10430, Indonesia.

- Email: assyifa.fauzia21@ui.ac.id
- ORCID: N/A
- Web of Science ResearcherID: N/A
- Scopus Author ID: N/A
- Homepage: N/A

Evi Frimawaty, School of Environmental Science, Universitas Indonesia, Central Jakarta, 10430, Indonesia.

- Email: evi.frimawaty11@ui.ac.id
- ORCID: 0000-0002-9016-4062
- Web of Science ResearcherID: N/A
- Scopus Author ID: 8128517300
- Homepage: https://sinta.kemdikbud.go.id/authors/profile/6719988

Hadi Susilo Arifin, Natural Resources and Environmental Management, IPB University, Bogor, 16129, Indonesia.

- Email: hsarifin@apps.ipb.ac.id
- ORCID: 0000-0002-8338-274X
- Web of Science ResearcherID: N/A
- Scopus Author ID: 15080540000
- Homepage: https://sinta.kemdikbud.go.id/authors/profile/5976974