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Urban farming and the nexus of economic growth and environmental sustainability in coastal cities, Indonesia

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ABSTRACT

This study investigates the contribution of urban farming to economic growth and environmental sustainability in Kendari City, a coastal urban area in Southeast Sulawesi, Indonesia. The research adopts a quantitative descriptive approach, analyzing the role of urban farming within the gross domestic regional product (GDRP), specifically in the agriculture, forestry, and fisheries sectors, alongside its environmental performance. Using the Asian green city index (AGCI) framework, the study evaluates energy consumption, CO_2 emissions, and air quality indicators (NO_2, SO_2, and PM_{10}). Findings reveal that urban farming is the third-highest contributor to the city's GDRP, accounting for 10.66% of the total economic output, emphasizing its significant role in supporting local economies and food security. Despite this, the overall growth of the sector remains fluctuating, and its direct economic impact is underreported. In terms of environmental performance, Kendari's per capita energy use (1,121 kWh/person) and CO_2 emissions (316,560 tons) exceed AGCI thresholds, categorizing the city as "below average" in sustainability. However, air quality indicators remain within acceptable limits, contributing to an "average" environmental performance score of 43.46%. The findings point to the need for policy reform to position urban farming not only as an economic sector but also as a tool for climate mitigation. Enhanced integration of urban farming into coastal city planning can significantly contribute to achieving the sustainable development goals and advancing low-carbon urban development agendas.

Keywords: urban farming, economic growth, environmental sustainability, coastal cities, GDRP

INTRODUCTION

The intersection between urban economic growth and environmental sustainability remains a pressing issue in global development agendas. Balancing these goals poses a significant challenge, as urban expansion and economic acceleration are closely tied to increasing resource consumption and environmental degradation. Urbanization, particularly in coastal areas, intensifies these pressures. According to Hasddin et al. (2022a), Gu et al. (2021), Boni et al. (2023), more than two-thirds of the global population currently reside in cities, while the World Economic Forum (2019) estimates that by 2050, approximately 800 million people will inhabit coastal cities. These dynamics render urban environments, especially in coastal zones, more vulnerable to the combined pressures of climate change, population density, and infrastructure demands. This makes the pursuit of integrated solutions such as those framed by the sustainable development goals (SDGs) critical in addressing the nexus between economic growth and ecological resilience in rapidly urbanizing regions.

Several studies (Hegazy, 2021; Ragheb & EL-Ashmawy, 2020; Rahim et al., 2023) have shown that urban development often prioritizes economic growth at the expense of environmental health, leading to increased CO_2 emissions and deteriorating air quality. In response, sustainable urban development strategies have emerged, emphasizing the alignment of economic, social, and environmental objectives, as codified in the SDGs (Hasddin et al., 2023; Rostin et al., 2023). The SDGs framework urges cities to pursue inclusive, integrative, and resilient development pathways. Local economies are encouraged to foster decent employment, green productivity, and urban resilience through collaborative, multisectoral engagement (Ali et al., 2020; Hegazy, 2014, 2020).

Despite the expanding discourse on sustainable cities, specific studies targeting coastal urban systems remain limited. Coastal cities in Africa and Asia particularly those with low elevation have witnessed disproportionate population growth (Barragan & de-Andres, 2015; MacManus et al., 2021). By 2020, over 300 million people were residing in areas less than two meters above sea level, with Southeast Asia accounting for a significant share (Hooijer & Vernimmen, 2021). Moreover, more than 570 coastal cities globally face the imminent risk of sea-level rise (World Economic Forum, 2019), compounded by environmental threats from unmanaged urban growth (Jonkman & Vrijling, 2008; Zaki & Hegazy, 2023). These realities necessitate urgent, locally adaptive strategies to promote environmental integrity while maintaining economic momentum, aligning with the overarching principles of sustainable development, particularly in the context of coastal urban regions where ecological fragility and socioeconomic pressures intersect.

Conceptual models such as the green economy, blue economy, green cities, and eco-cities have emerged as responses to these challenges. The Asian green city index (AGCI) provides a comprehensive assessment framework, encompassing energy use, CO_2 emissions, waste management, air quality, and governance (AGCI, 2011; Hasddin et al., 2022a, 2022b; Rostin et al., 2023). However, achieving these benchmarks requires integrative innovations one of which is urban farming. These models also provide operational pathways for achieving the SDGs, particularly SDG11, SDG12, and SDG13, through integrated environmental, economic, and spatial strategies.

Urban farming is increasingly recognized as a localized, low-impact economic activity with multifaceted sustainability benefits, particularly in supporting sustainable urban food systems, strengthening local economies, and enhancing environmental resilience. It encompasses crop cultivation, aquaculture, and/or small-scale livestock raising within urban areas, typically using limited spaces such as backyards, rooftops, and marginal land (Giyarsih et al., 2024; Nasruddin et al., 2022). Empirical evidence shows its potential to improve household nutrition, reduce living costs, and contribute to environmental health by enhancing urban greenery and absorbing pollutants (Maulana et al., 2023; Nelson et al., 2023).

Importantly, urban farming distinct from the broader agriculture, forestry, and fisheries (AFF) sectors captured in gross domestic regional product (GDRP) accounting represents a sub-sectoral, community-based practice that is often informal and under-institutionalized. Its contributions are rarely disaggregated in regional economic data, which can obscure its policy significance. While categorized administratively under agriculture, urban farming typically operates on a micro-scale and integrates economic, ecological, and social dimensions in ways that conventional rural agriculture does not.

Theoretically, urban farming aligns with urban metabolism and circular economic frameworks. It utilizes otherwise wasted resources organic waste, idle land, household water and transforms them into productive inputs, reducing ecological footprints and enhancing sustainability (Carolan, 2020; Mabon et al., 2023). Additionally, it supports localized food systems, shortens supply chains, and fosters food sovereignty, particularly relevant in times of crisis such as pandemics or supply shocks.

Nonetheless, urban farming faces structural limitations in many cities, including Kendari. These include constrained land availability due to densification, limited access to resources and capital, lack of technical assistance, and weak institutional support (Acquah et al., 2020; Salim et al., 2019; Saputro et al., 2020). In many cases, existing urban land use policies prioritize industrial and commercial functions, leaving limited space for green or productive areas. Furthermore, societal perceptions of farming as a rural or subsistence activity often undermine its legitimacy as an urban livelihood strategy.

Yet, as some studies, Alwi et al. (2024) and Bindarto et al. (2024), suggest strengthening urban farming is crucial to address urban food insecurity and chronic undernutrition, particularly in low-income communities. Nasruddin et al. (2022) reported that in 2022, over 15 million people in Indonesia faced severe food insecurity, with urban populations consuming less than 90% of the recommended daily intake. Urban farming can mitigate this by providing accessible, nutritious food, especially in areas underserved by traditional food distribution systems.

Kendari City, a growing coastal city in Eastern Indonesia, has demonstrated positive trends in economic performance, with its economy growing from 3% in 2018 to 4% in 2023. Urban farming activities though not yet institutionalized have supported community livelihoods and food access. However, their contributions are often masked by aggregation into the wider agriculture sector. Existing practices remain largely recreational or supplemental and are not yet integrated into broader economic planning (Amir & Saidin, 2020). Government intervention remains limited, with support restricted to input assistance (seeds, composters) rather than enabling infrastructure or policy integration.

There is a clear policy gap: urban farming is absent from the formal urban development and environmental policy agenda, despite its cross-cutting relevance. Local governments often lack standardized mechanisms for measuring their impact on GDRP, employment, emissions, or health outcomes. Consequently, its potential as a climate adaptation and mitigation tool remains untapped.

Previous studies in Kendari (Balaka et al., 2023; Boni et al., 2023), have addressed agricultural land use and air quality, yet few have explored the intersection between urban farming, economic output, and environmental indicators such as energy and emissions. This study fills that gap. It aims to

(1) analyze the economic contribution of urban farming within the AFF component of GDRP while clarifying its distinct role, and

(2) assess Kendari's sustainability performance in relation to energy use, CO_2 emissions, and air quality based on AGCI criteria.

These dual objectives reflect the study's novelty and relevance, offering empirical insights into the underappreciated role of urban farming as a sustainable development instrument in coastal city contexts.

Figure 1. Location of Kendari City, Southeast Sulawesi Province, Indonesia (Source: Author's Layout Results 2024, data sourced from the Geospatial Information Agency which is publicly accessible)

MATERIALS AND METHODS

This research was conducted in Kendari City, the capital of Southeast Sulawesi Province, Indonesia, which is geographically positioned along the coastal area of Kendari Bay (see **Figure 1**). The study site was purposively selected due to Kendari's classification as a coastal city undergoing rapid urban expansion and increasing environmental pressure, making it a relevant case for examining urban sustainability.

Kendari is also the capital city of Southeast Sulawesi Province and has been experiencing urban agglomeration due to population growth. In 2019, the population of Kendari was recorded at 392,830 inhabitants, and by 2023, it was estimated to have increased to around 404,232 inhabitants.

The research utilized a descriptive quantitative approach to analyze the role of urban farming in Kendari's regional economy and environmental conditions based on quantitative data. The focus variables analyzed include urban farming, economic growth in the agricultural sector, and the sustainable city concept. Urban farming is assessed based on the area of agricultural land in Kendari (hectares). In 2023, the total area of agricultural land utilized in Kendari City was 6,820.85 hectares, equivalent to 25% of the city's total land area, which is 27,176 hectares (271.76 km^2). Economic growth is evaluated based on the GDRP structure, which comprises 17 sectors, one of which is agriculture (including forestry and fisheries). The sustainable city aspect is examined through environmental factors, specifically:

(a) energy and CO_2 and

(b) air quality.

The operational variables are detailed in **Table 1**.

The research data comprise both secondary and primary sources. Secondary data for the economic analysis were obtained from the Central Bureau of Statistics in Kendari City, including regional economic indicators, energy consumption, CO_2 emissions, and air quality. Quantitative environmental data were sourced from the Kendari City Environmental Agency and the Southeast Sulawesi Provincial Environmental Agency. Specifically, air quality data were collected using the air quality monitoring system (AQMS) through real-time monitoring conducted by the authorized environmental agency. Primary data were gathered through field observations to assess qualitative aspects of energy consumption, CO_2 emissions, and air quality.

Following data collection, a weighting analysis was carried out for each indicator. The assessment of quantitative environmental aspects–specifically energy consumption, CO_2

Table 1. Research focus (AGCI, 2011; Boni et al., 2023; Hasddin et al., 2022a, 2023; Pace et al., 2016; Rostin et al., 2023)

Variable	Analysis indicator	Unit
1. Regional economy	Economic growth in GDRP and growth in each sector	IDR and %
2. Urban farming's economic role	The contribution of urban farming through the performance of the agricultural sector (including forestry and fisheries) in the economy	IDR and %
3. Urban farming	Area	Hectares (ha)
4. Energy and CO_2	a. Quantitative	
	Energy consumption per capita	kWh/person
	CO_2 emissions	Tons
	a. Qualitative	
	Clean energy policy	%
	Policies and implementation related to climate change mitigation	%
	Renewable energy policies and plans	%
5. Air quality	a. Quantitative	b
	Daily NO_2 levels	μg/Nm^3/day
	Daily SO_2 levels	μg/Nm^3/day
	Daily PM_{10} levels	μg/Nm^3/day
	a. Qualitative	c
	Policies for maintaining clean air quality	%

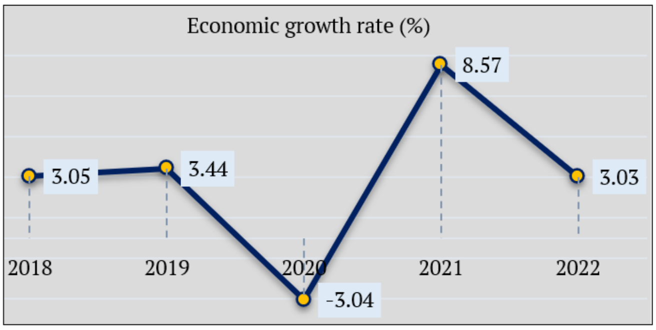

Figure 2. Economic growth of Kendari City 2018-2022 (Central Statistics Agency Kendari City, 2023)

emissions, and air quality–was conducted using Eq. (1) (Boni et al., 2023):

$$Weight\ (\%) = \left(1 - \frac{Obtained\ Value}{Environmental\ quality\ standar\ value}\right) xWeight(25\%). \quad (1)$$

For quantitative evaluation of the sustainability of a city based on energy use, CO_2 emissions, and air quality, the calculation is as follows (Boni et al., 2023):

$$Value\ Weight\ (\%) = \left(\frac{Total\ score}{Highest\ Score}\right) xWeight(\%). \quad (2)$$

The AGCI classifies the sustainability of cities into five categories: 81-100% as "well above average"; 61-80% as "above average"; 41-60% as "meets average"; 21-40% as "below average"; and 0-20% as "well below average".

RESULTS

Economic Growth and the Role of Urban Farming in Kendari City's Economy

As shown in **Figure 2**, the economy of Kendari City, measured through its GDRP, experienced fluctuations between 2018 and 2022.

Table 2. GDRP of Kendari City in 2022 based on constant prices (Central Statistics Agency Kendari City, 2023)

Sector/field	GDRP (in million IDR)
AFF (including urban farming)	1,919,333.29
Mining and quarrying	383,654.11
Manufacturing industry	1,599,685.11
Electricity and gas supply	27,191.95
Water supply, waste management, recycling	42,930.63
Construction	3,159,701.10
Wholesale and retail trade & car and motorcycle repair	2,978,827.25
Transportation and warehousing	1,648,420.82
Accommodation and food service	218,068.84
Information and communication	1,665,809.62
Financial services and insurance	1,124,120.23
Real estate	304,757.23
Business services	150,666.23
Government administration, defense, and social security	841,378.77
Educational services	1,430,916.08
Health and social work	215,412.36
Other services	302,041.19
Total GDRP of Kendari City	18,012,914.81

In 2020, economic growth was significantly impacted, recording a decline of -3.04%, attributed to the economic shock caused by the COVID-19 pandemic. However, the economy rebounded in 2021, reaching a peak growth rate of 8.57%, the highest during the observed period. Nevertheless, economic growth slowed again in 2022, recording a rate of 3.03%. This information (**Figure 2**) indicates that the city's economy is "fairly dynamic" and is highly influenced by external factors. Despite these fluctuations, Kendari City's economy demonstrates resilience, as evidenced by its recovery following the economic disruptions caused by COVID-19.

Kendari's economy comprises 17 sectors/fields, with a total GDRP value of IDR 18,012,914.81 million in 2022. The GDRP distribution across these sectors/fields is presented in **Table 2**.

The sector contributing the most to Kendari City's GDRP in 2022 was construction, with a total contribution of approximately IDR 3,159,701.10 million or 17.54% of the total

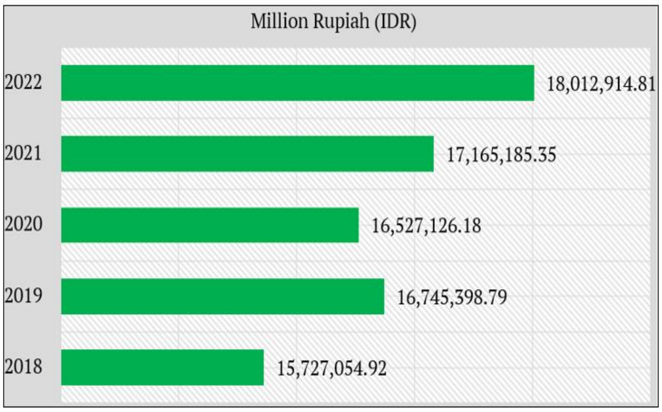

Figure 3. GDRP of Kendari City 2018-2022 (Source: Authors' analysis results, processed from Kendari City Central Statistics Agency, 2023)

GDRP. This was followed by wholesale and retail trade; car and motorcycle repair, which contributed around IDR 2,978,827.25 million or 16.54%.

The AFF sector ranked third, recording a GDRP value of IDR 1,919,333.29 million or 10.66% of the total in Kendari. This sector broadly encompasses land-based productive activities, including those occurring within urban environments. While urban farming is embedded within the AFF classification, it is not disaggregated or reported separately in official economic statistics. As such, **Figure 2** includes both rural and urban-based agricultural production, making it difficult to isolate the specific contribution of urban farming.

Nevertheless, given the growing importance of sustainable food systems and localized food production in urban contexts, the inclusion of urban farming within this aggregated sector indicates a form of economic activity whose distinct value may be under-recognized in current GDRP accounting.

Future research should prioritize disaggregated data collection and targeted analysis to more accurately reflect urban farming's contribution to the urban economy.

Figure 3 illustrates the trend of Kendari City's GDRP from 2018 to 2022 based on constant prices. The data demonstrate a generally upward trajectory in regional economic output, despite a temporary decline in 2020 most likely attributable to the economic disruptions caused by the COVID-19 pandemic. Notably, while the absolute value of GDRP increased in 2022 compared to 2021, the economic growth rate declined. This decoupling suggests that the rise in GDRP did not translate into proportionate economic dynamism, possibly due to saturation in certain sectors or uneven sectoral performance.

Throughout the 2018-2022 period, the construction sector consistently emerged as the top contributor to the city's economy, although its relative share experienced a slight decline in recent years. The wholesale and retail trade sectors, including car and motorcycle repair, remained the second-highest contributor. The AFF sector, which includes urban farming as a sub-sector ranked third. It is important to emphasize that while urban farming is not individually accounted for in official statistics, its contribution is nested within this broader category.

Conversely, sectors such as electricity and gas supply and water supply, waste management, and recycling recorded the

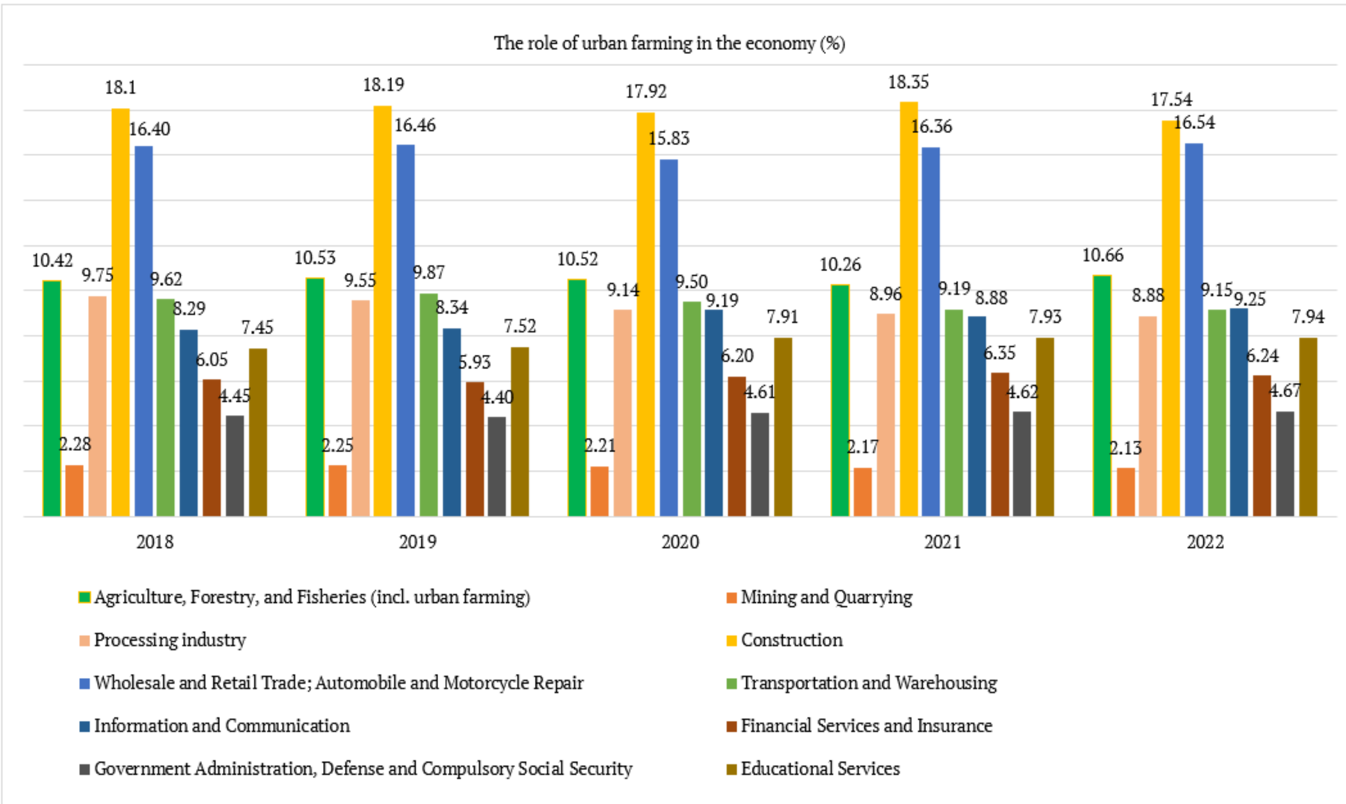

Figure 4. Urban farming's role in Kendari City's economy 2018-2022 (Source: Authors' analysis results, processed from Kendari City Central Statistics Agency, 2023)

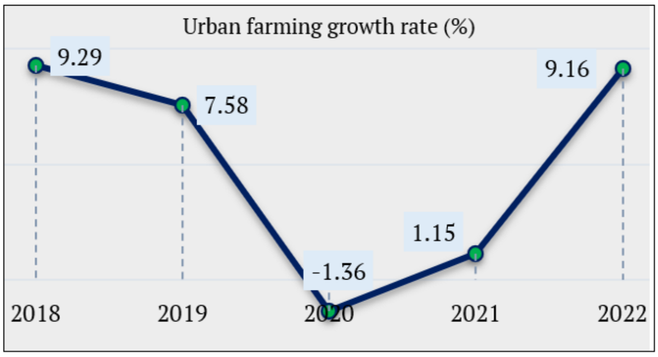

Figure 5. Trends in the economic contribution of urban farming in Kendari City, 2018-2022 (Source: Authors' analysis results, processed from Kendari City Central Statistics Agency, 2023)

smallest contributions, accounting for only 0.15% and 0.24% of the total GDRP, respectively. The relative position of the AFF sector–including the embedded contribution of urban farming within Kendari City's economic structure during the 2018-2022 period is further illustrated in **Figure 4**.

Firstly, one sector, the electricity and gas supply maintained a stable economic contribution. Secondly, six sectors demonstrated increasing contributions. Thirdly, five sectors showed declining trends, and finally, five sectors exhibited fluctuating contributions. These findings are consistent with Balaka et al. (2023), who identified key drivers of Kendari's economy as including AFF (including urban farming), mining, manufacturing, electricity, construction, wholesale and retail trade, transportation, and real estate. These sectors function as engines of regional and local development (Saputra et al., 2024), underscoring the importance of strengthening distribution networks and supply chains particularly to support the growth of urban farming.

Data from **Figure 4** indicate that urban farming activities in Kendari increased their economic contribution by 0.24%. However, in terms of economic growth, urban farming experienced a decline of approximately 0.13% between 2018 and 2022. The economic growth of urban farming during the 2019-2021 period was lower compared to that in 2018 and 2022. The overall trajectory of urban farming's economic contribution in Kendari City is depicted in **Figure 5**.

In 2022, the area allocated for urban farming in Kendari reached 6,820.85 hectares. The types of urban farming contributing to the GDRP included:

(a) food crops,

(b) horticultural crops,

(c) plantation crops,

(d) livestock, and

(e) fisheries.

Energy and CO_2 in Kendari City

Data from the state electricity company (Perusahaan Listrik Negara/PLN), Southeast Sulawesi Branch in Kendari, show that in 2020, electricity production reached 596,708,128 kWh. This was primarily generated by the Wua-Wua power plant (69.51%, or 414,743,222 kWh) and the Benu-Benua power plant (30.49%, or 181,964,906 kWh). The total amount of electricity distributed to consumers in Kendari was 440,278,279 kWh. With the city's population recorded at 392,830 in 2020, the average electricity consumption per capita was approximately 1,121 kWh/person. This level of energy consumption exceeds the green city threshold of ⩽ 900 kWh/person, as defined by the AGCI. The resulting CO_2 emissions from electricity use in Kendari were estimated at 316,560.08 tons, calculated using the following formula (Eq. [3]):

Table 3. Quantitative analysis of energy and CO_2 for electricity use in Kendari City (Analysis Results, 2024)

Indicator	Amount	Standard	Weight
Energy consumption (25% weight)	1,121 KWh/ person	⩽ 900 kwh/ person	-6.25%
Emissions CO_2 (25% weight)	316,560.08 tons	⩽ 245,410.27 tons	-7.25%

$$E = KE \times FE \times GWP, \quad (3)$$

where E is emissions (kg CO_2), KE is energy consumption (KHw), FE is emission factor (0.719 kg/Co_2/KWh), and GWP is global warming potential (1 kg Co_2). Note that FE is sourced from the Directorate General of Climate Change Control Regulation No. 12/2017, Ministry of Environment and Forestry of Indonesia, 2017.

Based on the energy consumption and CO_2 emission data, weights were assigned to determine the green city performance level for energy and CO_2 attributes. The analysis followed Eq. (1), and the results are presented in **Table 3**.

The total weighted score for the quantitative assessment of energy and CO_2 performance in support of green city development in Kendari City was -13.39% (rounded to 0%). According to the AGCI classification, this score falls within the 0-20% range, categorizing it as "well below average" or "very poor."

The subsequent evaluation assessed the qualitative aspects of energy and CO_2. The analysis results, based on Eq. (2), are presented in **Table 4**.

The clean energy policy received a score of 14.42%, climate change mitigation policies scored 18.75%, and renewable energy policies scored 8.33%. The overall average score for Kendari's qualitative performance in energy and CO_2 management was 41.66%. According to the AGCI classification, this falls within the 21-40% range, categorized as "meeting the average." This indicates that, qualitatively, Kendari's efforts toward green city development in the area of energy and CO_2 meet the average standards set by AGCI.

When combining both quantitative and qualitative assessments, the total score for Kendari City's performance in energy and CO_2 management was 28.27%. This score remains below the AGCI's average threshold, indicating that Kendari has not yet met the criteria for a sustainable city from the perspective of energy and CO_2 management.

Air Quality in Kendari City

The air quality attribute of the green city program is assessed based on four quantitative indicators: daily nitrogen dioxide (NO_2) levels (μg/m³), daily sulfur dioxide (SO_2) levels (μg/m³), and daily suspended particulate matter (PM_{10}) levels

Table 4. Qualitative analysis of energy and CO_2 in Kendari City (Analysis Results, 2024)

Indicator	Implementation	Scoring				
		0	1	2	3	4
Clean energy policy (25% weight)	Public campaigns on smart electricity usage					√
	Smart electricity usage (prepaid/token system)					√
	Policy on the use of public street lighting with solar cells			√		
	Developing an energy grid system (distribution substations)	√				
	Regulation on the creation of bicycle lanes		√			
	Regulation on the creation of pedestrian pathways				√	
	Total score	14				
	Score weight = $\left(\frac{10}{24}\right) x\ 25\% = 0.42\ x\ 25\%$	14.42%				
Policies and implementation related to climate change mitigation	Regulation on tree planting, specifically directing tree planting at emission sources (industrial and high-traffic areas)				√	
	Regulation on the designation of green open spaces and parks in energy source areas				√	
	Total score	6				
	Score weight = $\left(\frac{6}{8}\right) x\ 25\% = 0.75\ x\ 25\%$	18.75%				
Renewable energy policies and plans	Solar Cell			√		
	Steam power electricity (PLTU)					√
	Wind power electricity (Bayu)	√				
	Hydropower electricity	√				
	Waste-to-energy electricity			√		
	Biomass electricity	√				
	Total score	8				
	Score weight = $\left(\frac{8}{24}\right) x\ 25\% = 0.33\ x\ 25\%$	8.33%				

Table 5. Quantitative analysis of air quality in Kendari City (Analysis Results, 2024)

Indicator	Value	Standard	Weight
Daily NO_2 levels (25% weight)	10 μg/Nm³/day	≤ 150 μg/Nm³/day	23.33%
Daily SO_2 levels (25% weight)	16 μg/Nm³/day	≤ 365 μg/Nm³/day	23.90%
Daily PM_{10} levels (25% weight)	15 μg/Nm³/day	≤ 150 μg/Nm³/day	22.50%
Total			69.73%

(μg/m³). The qualitative aspect covers policies and planning for maintaining clean air quality. The quantitative assessment was conducted using the AQMS method, monitoring the air quality levels daily.

The analysis revealed that the average daily air quality in Kendari for September was as follows: NO_2 at 4 μg/m³, SO_2 at 5 μg/m³, and PM_{10} at 5 μg/m³. In October, NO_2 was 3 μg/m³, SO_2 was 4 μg/m³, and PM_{10} was 6 μg/m³, while in November, NO_2 was 3 μg/m³, SO_2 was 7 μg/m³, and PM_{10} was 4 μg/m³. The cumulative daily air quality levels for Kendari were 10 μg/m³ for NO_2, 16 μg/m³ for SO_2, and 15 μg/m³ for PM_{10}. These data were processed using Eq. (1) to determine the weighted performance score for air quality in accordance with the AGCI standards for sustainable cities. The results are presented in **Table 5**.

Based on the standard calculation results above, the total weighted score for the green city performance of the air quality attributed to the quantitative aspect in Kendari City is 69.73% (the sum of the three indicators). According to the green city performance classification by the AGCI, this score falls within the 61-80% range, indicating that the air quality in Kendari City is above the AGCI green city index average, which serves as the basis for determining urban sustainability. In other words, the air quality aspect in Kendari City is considered 'very good.

The qualitative aspect of air quality in this study encompasses four components, as presented in **Table 6**. The analysis employed a scoring technique based on Eq. (2). The qualitative evaluation resulted in a performance score of 17.19%, which is relatively close to the ideal benchmark of 25% set by the AGCI.

When combined with the quantitative score, the total score for air quality sustainability in Kendari City reached 43.46%. This indicates that Kendari meets the AGCI's average standards for sustainable cities in terms of air quality management.

DISCUSSION

Economic Growth and the Role of Urban Farming in Kendari City's Economy

Between 2018 and 2022, Kendari City experienced dynamic economic fluctuations, most notably a significant contraction of -3.04% in 2020 due to the COVID-19 pandemic. A strong rebound followed in 2021, reaching a growth rate of 8.57%, before moderating to 3.03% in 2022. These trends demonstrate both the vulnerability and resilience of the city's economic structure to external shocks, particularly in emerging coastal urban contexts, thereby highlighting the importance of economic diversification and adaptive livelihoods as integral components of sustainable urban development pathways in such regions.

As shown in **Figure 2**, the AFF sector, which embeds urban farming activities, ranked as the third-highest contributor to Kendari's GDRP in 2022, following construction and

Table 6. Qualitative analysis of air quality in Kendari City (Analysis Results, 2024)

Indicator	Implementation	Scoring				
		0	1	2	3	4
Policies for maintaining clean air quality	a. Tree planting					√
	b. *Car-free day*				√	
	c. Air quality monitoring				√	
	d. Vehicle emission monitoring.		√			
	Total score	11				
	Score weight = $\left(\frac{11}{16}\right) x\ 25\% = 0.69\ x\ 25\%$	17.19%				

wholesale/retail trade. The AFF sector accounted for 10.66% of the total economic output, suggesting that land-based productive sectors continue to hold economic relevance in an increasingly urbanized coastal city.

However, despite this significant contribution, the specific role of urban farming within the AFF sector remains indistinct due to data aggregation and classification limitations. Urban and rural agricultural outputs are combined under the same reporting category, making it difficult to isolate the economic weight of urban farming alone. To address this, future research could apply survey-based estimations or use proxy indicators such as land use data, household production value, or input-output modeling to more precisely capture the urban farming component in the city's economy.

While official statistics do not disaggregate urban farming, indicative trends can still be derived through proxy-based estimations. Urban farming, although not statistically separated in formal records, has shown steady if modest growth in contribution. From 2018 to 2022, its estimated share within the AFF sector increased by 0.24%, though its sectoral growth rate declined by 0.13%, indicating an inconsistent yet persistent role in Kendari's local economy (**Figure 5**). These findings are in line with studies by Poulsen et al. (2017) and Maulana et al. (2023), who emphasize that urban farming serves both economic and food security functions in developing cities. Similarly, Nelson et al. (2023) argue that small-scale urban agriculture contributes indirectly to urban economic resilience by stabilizing household income and enhancing local food systems.

When compared internationally, similar patterns have been observed in cities like Accra (Ghana), Dar es Salaam (Tanzania), and Manila (Philippines), where urban farming is recognized not for its large-scale commercial return, but for its contribution to microeconomic resilience, informal employment, and local food sovereignty (see Berdegué et al., 2014; Zezza & Tasciotti, 2010). In Bangladesh, Barois et al. (2024) report that urban farming contributes to 8-12% of household incomes among low-income families, while simultaneously improving access to nutritious food in rapidly urbanizing environments.

Despite its potential, urban farming in Kendari remains under-institutionalized. As noted by Amir and Saidin (2020), most urban farming practices in the city are informal, recreational, or subsistence-based, lacking commercial scale and structured market integration. Furthermore, limited access to land, capital, irrigation, and training constrain scalability issues echoed by Acquah et al. (2020) and Salim et al. (2019) in studies across Indonesia and West Africa.

To maximize the economic and social value of urban farming, policies must move beyond distribution of inputs (seeds and composters) toward spatial protection, land-use integration, and value chain development. This aligns with recommendations from Teoh et al. (2024) and Bindarto et al. (2024), who stress the importance of safeguarding urban green zones and recognizing urban agriculture in local economic development plans. Such policy directions are consistent with the broader objectives of the SDGs, particularly SDG2 (zero hunger) and SDG11 (sustainable cities and communities), which emphasize the development of inclusive urban food systems, spatial equity, and integrated green infrastructure.

At a broader level, the findings suggest that urban farming should be reframed not merely as a food-producing activity, but as part of a localized urban economic system that intersects with land use, environmental management, and community-based adaptation. As Paudel and States (2023) propose, urban agriculture has multifaceted benefits including ecosystem services, climate mitigation, and socio-cultural value all of which contribute to long-term urban sustainability.

The trend in Kendari also reveals a paradox: while the absolute value of the GDRP increased in 2022, the economic growth rate declined, suggesting diminishing returns in major sectors or a plateau in productivity. This trend may reflect the limitations of current urban development models and underscores the urgency of diversifying growth drivers. In this context, urban farming offers a scalable, low-carbon alternative aligned with the goals of SDGs, climate adaptation, and resilient food systems, particularly in coastal cities where land scarcity and ecological pressures converge.

Therefore, strengthening urban farming's role within the urban economy through formal recognition, incentives, and integration into spatial planning can contribute to economic inclusivity and ecological balance. This mirrors the policy pathways adopted in Shanghai, Kampala, and Medellín, where local governments have integrated urban agriculture into municipal climate action and food security strategies (see Gunapala et al., 2025).

Energy Use and CO_2 Emissions in Kendari City: A Sustainability Assessment

The environmental performance of Kendari City in the domains of energy use and CO_2 emissions two key indicators of sustainable urban development falls significantly below the thresholds established by the AGCI. Quantitatively, the city's electricity consumption per capita reached 1,121 kWh/person, exceeding the AGCI benchmark of ⩽ 900 kWh/person. Correspondingly, CO_2 emissions from electricity use were estimated at 316,560.08 tons, surpassing the acceptable emission threshold of 245,410.27 tons. These figures translate to a weighted environmental performance score of -13.39%, placing Kendari firmly in the "well below average" category for green city performance in this domain.

Qualitative indicators provide only marginally better outcomes. Clean energy initiatives, climate change mitigation policies, and renewable energy adoption yielded an average qualitative score of 41.66%, falling within AGCI's "meets average" category. When combined, the integrated performance score for Kendari's energy and emissions attributes totals 28.27%, categorizing the city as "below average" in fulfilling sustainability criteria (**Table 3** and **Table 4**).

These findings point to structural challenges in the city's urban energy system, notably the high dependence on diesel-powered electricity plants, such as Wua-Wua and Benu-Benua, which contributed more than 69% and 30% of total energy production, respectively. Without a transition strategy to cleaner sources, Kendari is unlikely to meet long-term targets for climate-resilient urban development.

Comparative research across coastal cities in developing regions confirms similar struggles. For instance, Jakarta and Semarang Bay have experienced energy-related vulnerabilities exacerbated by subsidence and fossil-fuel dependency (Bott et al., 2021). In Dar es Salaam (Tanzania) and Lagos (Nigeria), urban sustainability is hampered by inefficient grids, energy losses, and informal settlements with poor access to clean energy, leading to high per capita emissions despite relatively low economic productivity (UN-Habitat, 2024).

In contrast, Medellín (Colombia) and Kampala (Uganda) have begun integrating renewable energy sources into public infrastructure and expanding solar-powered community systems as part of their urban sustainability agendas (Montoya, 2024; Gesellschaft für Internationale Zusammenarbeit [Society for International Cooperation] [GIZ], 2022). These cities offer scalable models for low-carbon transition strategies that combine policy reform, public-private investment, and citizen engagement.

The experience of Shanghai, as an Asian benchmark in AGCI assessments, is particularly relevant. There, integrated clean energy policies, electric mobility systems, and enforced building codes have contributed to a steady decline in urban carbon intensity despite population growth (Shen et al., 2024). While Kendari operates on a different scale, such models underscore the importance of institutional alignment and regulatory enforcement in achieving energy-efficiency goals.

Kendari's moderate success in areas such as smart electricity systems (e.g., prepaid meters), solar-powered public lighting, and designated bike lanes demonstrates early steps toward sustainability. However, the absence of robust renewable energy infrastructure, limited mitigation regulation for CO_2 sources, and lack of a city-wide emissions reduction strategy suggest that these initiatives remain fragmented. Therefore, Kendari requires a strategic roadmap for energy transformation. This includes

(a) phasing out diesel-based power generation in favor of solar, hydropower, and biomass,

(b) incentivizing building energy efficiency, especially in commercial and public sectors,

(c) enhancing green transportation infrastructure, such as pedestrian zones and electric public transport, and

(d) adopting emissions-monitoring regulations based on AGCI and national climate frameworks.

Without such reforms, the city risks being trapped in an unsustainable development trajectory, particularly problematic for coastal cities exposed to both climate risks and energy vulnerability. Addressing this issue is not merely a technical challenge but a governance imperative. Urban energy governance, as emphasized in global sustainability literature (Cardoso et al., 2021; Fei et al., 2016), is essential for ensuring that energy policies translate into measurable sustainability gains.

The empirical findings from Kendari echo patterns observed in many developing coastal cities where urban growth often outpaces infrastructure modernization, and where sustainability agendas remain policy-aspirational rather than operational. Integrating energy efficiency and emissions control into the broader urban planning framework will be critical for Kendari to align with the SDGs, particularly SDG7 (affordable and clean energy) and SDG11 (sustainable cities and communities).

Air Quality in Kendari City: Environmental Performance and Global Comparison

Air quality is a crucial component of the green city framework and is assessed using both quantitative and qualitative indicators, as outlined by the AGCI. The quantitative analysis in Kendari focused on daily concentrations of NO_2, SO_2, and PM_{10}, while the qualitative assessment evaluated city-level policies and planning efforts aimed at maintaining clean air, an objective that directly aligns with SDG11.6, which targets reductions in the adverse per capita environmental impact of cities, including improvements in air quality.

The average daily pollutant levels in Kendari City, based on AQMS monitoring data, were notably low: NO_2 at 10 µg/m³, SO_2 at 16 µg/m³, and PM_{10} at 15 µg/m³. These values are significantly below the AGCI threshold limits (⩽ 150 µg/m³ for NO_2 and PM_{10}, ⩽ 365 µg/m³ for SO_2), resulting in a quantitative performance score of 69.73%, placing Kendari within the "above average" category for air quality performance (**Table 5**).

This strong quantitative outcome reflects relatively low industrial activity, moderate traffic density, and the presence of green buffer zones, as documented by Hasddin et al. (2022a) and Santoso et al. (2020). The findings align with studies in other Southeast Asian coastal cities such as Da Nang, Vietnam and Penang, Malaysia where similar low-emission profiles are attributed to policy-led green space development and coastal air flow that aids pollutant dispersion (Fabinyi et al., 2022; Linh & Son, 2023).

However, the qualitative performance score of only 17.19% indicates policy and implementation gaps (**Table 6**). Although Kendari has launched several initiatives such as tree planting programs, car-free days, and green space expansion key enforcement tools like vehicle emissions testing remain underdeveloped. This policy gap is critical, as motor vehicles are among the largest sources of NO_2 and PM_{10} in urban settings (Kyung & Jeong, 2020). Further field observations revealed that, despite local regulatory mandates in Kendari City, emission compliance stickers are currently not in use.

This contrasts with more structured approaches in cities such as Bogotá (Colombia) and Nairobi (Kenya), where air quality policies are enforced via integrated urban transport and emissions monitoring systems, often supported by international development assistance. In Shanghai, city authorities deploy real-time monitoring and enforce emission limits through automated sensors, reducing PM_{10} levels by over 20% in a five-year period (UN-Habitat, 2024).

In terms of urban green space management, Kendari has made measurable progress, with green open space coverage reaching 13,558.91 hectares or 49.89% of its total area significantly higher than the minimum 30% recommended by urban planning guidelines (Mayor Regulation No. 9/2008). This expansion is consistent with findings by Carolan (2020) and Abdullah et al. (2017), who emphasize the co-benefits of green infrastructure in improving air quality, biodiversity, and urban cooling.

Nevertheless, Kendari's air quality policies remain fragmented and reactive, often driven by short-term environmental assessments rather than long-term, integrated planning. The lack of continuous emissions testing, and the limited scope of car-free day implementation (covering <50% of city roads), highlight the need for a more comprehensive and enforceable air quality management strategy. To advance its sustainability agenda, Kendari should consider

(a) institutionalizing emissions monitoring and linking it with vehicle licensing systems,

(b) expanding the car-free zone network and integrating it with public transport corridors,

(c) deploying real-time air quality sensors in high-traffic and industrial zones, and

(d) promoting citizen awareness programs on the health impacts of air pollution.

These policy directions echo successful models from Cape Town, Bangkok, and Kigali, where multi-stakeholder coordination, funding partnerships, and digital monitoring tools have improved compliance and reduced urban air pollution levels (Curci & Chiffi, 2024; Zaki & Hegazy, 2023).

In summary, while Kendari's air quality is quantitatively strong, its qualitative governance mechanisms are still evolving. The city's experience illustrates the broader pattern in developing countries: environmental outcomes may appear favorable due to natural geography or low industrialization, but without policy enforcement, these gains are fragile and unsustainable. Strengthening institutional capacity and embedding air quality strategies within the city's long-term spatial and environmental planning will be essential for maintaining and enhancing these environmental benefits, as an integral part of achieving sustainable development outcomes in rapidly urbanizing coastal cities.

CONCLUSION

This study provides empirical evidence on the dual dimensions of urban sustainability economic contribution and environmental performance in the context of Kendari City, a rapidly growing coastal city in Southeast Sulawesi, Indonesia. The analysis shows that while Kendari's GDRP has generally increased over the 2018-2022 period, particularly following the COVID-19 economic downturn, this rise has not consistently translated into higher economic growth rates. This finding underscores the importance of examining not only economic output but also sectoral dynamics and sustainability indicators, in alignment with broader SDGs in coastal urban contexts.

The AFF sector within which urban farming is embedded–ranked as the third-largest contributor to Kendari's GDRP. Although not yet fully formalized in statistical terms, urban farming demonstrates significant potential to support food security, local economic resilience, and sustainable urban development. The study thus highlights the underappreciated but strategic role of urban farming as a localized mechanism to address urban food systems, land-use efficiency, and ecological integration.

From an environmental perspective, the city's performance in energy use and CO_2 emissions falls below average based on the AGCI, reflecting an urgent need to reduce fossil-fuel dependence and strengthen emissions governance. In contrast, air quality indicators, including NO_2, SO_2, and PM_{10} levels, remain within safe thresholds, placing Kendari in the "meets average" category. However, the city's qualitative performance particularly regarding emissions testing and clean energy policy implementation remains limited, requiring further policy refinement and enforcement, to ensure the city's trajectory remains consistent with global sustainability benchmarks such as the SDGs.

These findings affirm the study's core novelty:

1. It clarifies the distinct economic contribution of urban farming within the broader AFF sector in coastal cities, which is often overlooked in regional planning; and
2. It integrates environmental performance metrics (energy, CO_2, and air quality) using AGCI standards, offering a comprehensive sustainability assessment rarely conducted at the municipal level in Indonesia.

To advance scientific understanding and practical applications, future research should focus on developing context-sensitive models for sustainable coastal urban development, integrating land use, economic diversification, and climate adaptation strategies. It is especially recommended that future studies conduct detailed analyses of urban farming typologies, carbon reduction potential, and business feasibility, thereby positioning urban farming not only as an economic activity but also as a climate mitigation strategy within the green city framework, and a practical pathway to achieve SDGs at the municipal level.

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analysis, investigation, visualization; **TFK:** methodology, investigation, validation; MYB: validation, writing – review & editing; **HDR:** investigation, resources, data curation; **AIK:** investigation, resources, data curation; MIH: methodology, validation; **VEGS:** investigation, writing – review & editing; ESM: investigation, writing – review & editing. All authors have read and approved the published version of the manuscript.

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