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ANALYSIS OF FOOD SECURITY INDEX IN EAST JAVA: A SPATIAL APPROACH AND POLICY PROJECTION

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Abstract

This study aims to analyze food security in East Java Province using a quantitative spatial approach and statistical projection. Secondary data from 2019 to 2023 were obtained from BPS (Statistics Indonesia), BKP (Food Security Agency), and the Ministry of Agriculture, covering indicators of food availability, accessibility, and utilization. The analysis was conducted using ArcGIS software for map visualization and the Single Exponential Smoothing (SES) method for projecting the Food Security Index for 2024. Spatial analysis revealed disparities in food security across regions: northern and western districts tend to be classified as "very resilient," while eastern regions and Madura Island, such as Bangkalan and Bondowoso, remain in the "resilient" category with high vulnerability levels. The 2024 Food Security Index projection presents three scenarios: optimistic (91.62), moderate (82.94), and pessimistic (73.91). Food security is strongly influenced by poverty, low Farmer's Terms of Trade (NTP), limited infrastructure, and dependence on rice commodities. This study emphasizes the importance of data-driven policies, strengthening food distribution systems, investing in women's education, and utilizing geospatial technology for monitoring and mitigating food crises. These findings reinforce the view that high food production alone does not guarantee food security without equitable access and adequate nutritional utilization. The study provides a foundation for formulating sustainable food security strategies aligned with Sustainable Development Goal (SDG) number 2.

Keywords: ***Food Security Index, Spatial data integration in food policy, Single Exponential Smoothing***

INTRODUCTION

Food security is a fundamental human need that must be fulfilled by the state through strategic policies, as mandated by the 1945 Constitution and reinforced by Law No. 18 of 2012 concerning Food. Food security not only serves as a human right but also as a strategic geopolitical instrument, as exemplified by the "Food as a Weapon" approach once employed by the United States (Riadi, 2023) . In the Indonesian context, food security faces complex challenges including dependence on food imports, exponential population growth, and the increasingly tangible impacts of climate change. East Java Province, as one of the national food barns, produces approximately 5.5 million tons of rice but still faces a socio-economic paradox: a relatively high per capita income of IDR 66.4 million is not aligned with a high poverty rate of 10.35% and significant disparities in the Food Security Index among its regencies (Subroto & Witjaksono, 2022). The conceptual framework of food security encompasses three main aspects: food availability, food accessibility, and food utilization, which must be sustainably fulfilled to enable communities to live healthy, active, and productive lives (FAO, 2022).

Previous studies have shown that high food production does not always positively correlate with the Food Security Index, as found in North Sulawesi and Central Java, where non-technical factors such as poverty, women's education, and infrastructure access play a more dominant role in determining food security(Pujiati et al., 2020). his study employs a quantitative method with spatial analysis based on ArcGIS to identify vulnerable areas in East Java, particularly in three regencies Bangkalan, Bondowoso, and Probolinggo that still experience poverty rates above 15% and food expenditures exceeding 60% of total household spending (BPS Jawa Timur, 2023). The policy implications of this research emphasize the need for a holistic approach integrating GIS-based social protection, investment in women's education, improved access to clean water, and diversification of local food sources to reduce

dependence on rice. This approach aligns with the success of Bali Province, which has the highest Food Security Index in Indonesia (Badan Pangan Nasional, 2022). he study also highlights limitations of using secondary data that do not cover micro-level variables such as consumption culture, recommending further studies with qualitative approaches and analysis of climate change impacts on agricultural productivity in East Java (Auliya et al., 2024). Theoretically, this study enriches the discourse on food security by demonstrating that high food production does not automatically guarantee a good Food Security Index, aligning with the paradigm shift from a supply-focused approach to one emphasizing entitlements. Practically, these findings provide important guidance for policymakers in formulating evidence-based strategies, particularly in budget allocation and community empowerment programs. Through cross-sector collaboration and the utilization of digital technologies such as GIS, East Java's food security has the potential to achieve the optimistic scenario in line with Sustainable Development Goal (SDG) number 2 (FAO, 2022)

METHOD

This research employs a quantitative approach grounded in positivist philosophy, where data are systematically collected and analyzed using statistical techniques to test the research hypotheses. The data sources include official institutions such as the Central Bureau of Statistics (BPS), the Ministry of Agriculture, the Food Security Agency, and literature reviews from previous studies, covering the period from 2019 to 2023. The main indicators analyzed encompass food availability, accessibility, and utilization in East Java Province. The study population covers all provinces in Indonesia to identify variations in food security characteristics influenced by social, economic, and geographic factors during this period. A purposive sampling method is used, focusing on East Java Province due to its role as a national food barn, large population, and socio-economic diversity that allows in-depth analysis related to food access, health facilities, and education levels.

Data analysis combines geospatial mapping and forecasting modeling techniques. Spatial mapping is conducted using ArcMap (part of ArcGIS) to visualize the distribution of the Food Security Index at the district/city level in East Java. This process involves collecting geospatial data from the Geospatial Information Agency (BIG), integrating Food Security Index data with spatial information to produce thematic maps, visualizing the distribution of the Food Security Index with color categorization, and conducting spatial analysis to identify food security patterns and provide policy recommendations. Furthermore, forecasting of the food security index values is performed to predict one-year trends based on historical data from 2019 to 2023 using the Single Exponential Smoothing method. This method is chosen because the data do not exhibit clear trends or seasonality. The forecasting model uses an optimized smoothing parameter α to generate accurate predictions. Model validation is conducted by measuring accuracy using the Mean Absolute Percentage Error (MAPE). The forecasting stages include historical trend analysis, model selection, and validation of prediction results to ensure the model's reliability in supporting food security policy in East Java.

RESULTS AND DISCUSSION

This study begins with an analysis of the Food Security Index data in East Java Province for the year 2023, aiming to identify areas vulnerable to food insecurity through a spatial approach. The Food Security Index values are categorized into six priority groups of food vulnerability and visualized through the map shown in Figure 1.

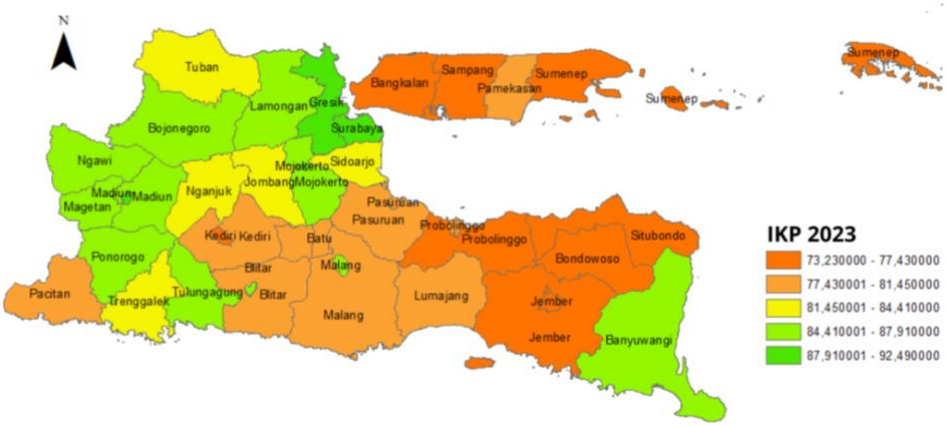

Image 1: Distribution of the Food Security Index Scores by Regency/City in East Java

The visualization results show disparities in food security among regions in East Java. Regencies/cities with high food security index values (≥81), marked in green and yellow, are predominantly located in the northern and western parts of the province. These areas demonstrate good food security performance, characterized by relatively easy access to food, stable food production, and adequate distribution and infrastructure. This aligns with the findings of (Virtriana et al., 2022) who stated that a region's food security is highly influenced by infrastructure development, economic stability, and local institutional support. Conversely, regencies/cities with food security index values below 81 (marked in orange), such as Bangkalan, Bondowoso, and most areas on Madura Island and eastern East Java, show a higher level of food insecurity. This low index is associated with various constraints, such as high poverty rates, low local food production, limited market access, and inadequate infrastructure. (Khabibur Rahman et al., 2024) also highlighted that regions with high dependence on external food distribution and minimal food diversification are vulnerable to food insecurity, especially in crisis conditions.

Furthermore, the classification of food vulnerability based on the Food Security Index shows that most areas fall into the "very resilient" category (priority 6), while some other areas such as Bangkalan and Probolinggo are classified as "resilient" (priority 5). However, as emphasized by (Hakim et al., 2025), the food security index classification is not static. Climate fluctuations, ecosystem disturbances, and food price dynamics can significantly affect the food security status of a region over time. These findings indicate that although some areas demonstrate good food security, special attention needs to be given to regions with low food security indices. A place-based policy approach and strengthening local production capacity are recommended as key strategies to reduce regional food security disparities (Rachmasari et al., 2023).

Image 2: Distribution of Food Vulnerability Based on the Composite Food Security Index Values of Regencies/Cities in East Java Province in 2022

Based on Figure 2, there are two main groups reflecting the level of food security in each regency/city in East Java. Blitar, Probolinggo, Bondowoso, and all regencies on Madura Island fall into priority group 5 (resilient). This indicates that these areas have fairly good food security, although they still face some challenges related to optimal food availability and access. Despite being in the resilient category, these regions require special attention regarding food distribution, utilization of nutritious food, and improvement of food security infrastructure to more effectively address existing obstacles. Meanwhile, other regencies/cities in East Java belong to priority group 6 (very resilient), indicating a more stable level of food security capable of providing sufficient, safe, and nutritious food for their populations. Regencies in this group generally have good food availability, adequate food access, and optimal food utilization. This condition reflects significant progress in food security in these areas, supported by efficient natural resource management, good food distribution infrastructure, and success in overcoming food access challenges for all segments of society.

Image 3: Distribution of Food Vulnerability Based on the Composite Food Security Index Values of Regencies/Cities in East Java Province in 2023

The distribution of the food vulnerability map of regencies/cities in East Java in 2023, depicted in Figure 3, shows positive developments compared to the previous year, with more regencies falling into the "very resilient" category. This change reflects intensive efforts to improve food security in areas previously vulnerable to food insecurity, while also confirming achievements in ensuring more equitable food security across all regencies/cities in East Java Province. Related research on food security in East Java emphasizes the importance of resource management and improving human resource quality. For example, accelerated efforts to reduce stunting rates in several regencies in East Java serve as a key indicator of improving human resource quality closely linked to food security and community nutrition (Hariani et al., 2023). Additionally, the development of healthy and sustainable agricultural systems, such as organic farming in Tuban Regency, contributes to enhancing food security by reducing dependence on chemical fertilizers and increasing farmers' income (Saribanon et al., 2023). Spatially, mapping of priority interventions for child health issues like pneumonia also shows correlation with food security, where several regencies prioritized for pneumonia intervention among toddlers overlap with areas classified as food resilient. This highlights the necessity of multidimensional interventions to simultaneously strengthen food security and public health(Delfiyanti & Eryando, 2024)

Relationship Between Poverty and Food Security

Food security is closely linked to poverty, where an increase in household income contributes to a reduction in food insecurity, while barriers to food access can exacerbate poverty, creating a mutually reinforcing cycle (FAO, 2022). ice production as a main commodity has a direct impact on food security, with the low Farmer's Terms of Trade in Bangkalan Regency limiting investment in agricultural technology and negatively affecting productivity and the sustainability of the agricultural sector (Tenriawaru et al., 2021). he agricultural sector in Bangkalan significantly contributes to the Gross Regional Domestic Product (GRDP), but faces challenges such as dependence on rainy season irrigation and a lack of adequate food processing and storage facilities, which increases post-harvest vulnerability(Poudel & Shaw, 2024). Analysis of the nine Food Security Index indicators shows that Bangkalan, Probolinggo, and Bondowoso regencies have weaknesses in food accessibility and utilization due to limited market access, low income, and lack of nutritional knowledge, further exacerbated by underdeveloped infrastructure (Lermating et al., 2024). Compared to 2022, there has been a significant increase in the food security index in most areas of East Java, indicating progress in food distribution and strengthening of the agricultural sector, although some regions still require special attention (Sutrisno et al., 2023).

Figure 4 illustrates a strong correlation between poverty and food vulnerability in Bangkalan, Probolinggo, and Bondowoso. Poor households allocate 60–70% of their income to food, making them highly susceptible to price

shocks or production declines, which directly affect food security (Hana Fatimah et al., 2025). The low NTP further worsens food access, while the high prevalence of stunting (12.72% in Bondowoso) indicates a failure in the utilization of nutritious food and a strong link to poverty (Dewi et al., 2024). Research in Indonesia confirms that poverty has a negative and significant effect on food security; a 1% increase in poverty can reduce food security by 1.9 points. This relationship is primarily due to the limited purchasing power of the poor, which restricts their ability to access adequate and nutritious food. Thus, efforts to improve food security must also address poverty reduction, enhancement of farmers' welfare, and improvement of infrastructure and nutritional education (Hannida & Sambodo, 2025)

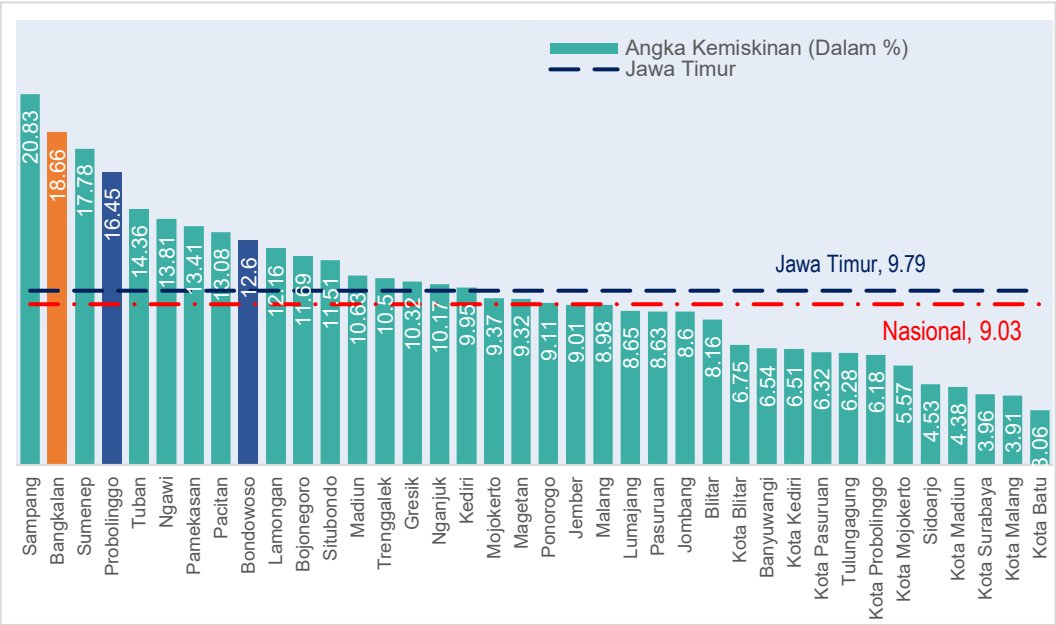

Image 4: Poverty Rates of Regencies and Cities in East Java

A data-driven approach is crucial in formulating policies to reduce food security disparities in priority 5 areas. (Miller & Thomas, 2020) recommend targeted subsidy programs, strengthening distribution infrastructure through geospatial optimization, and empowering farmers with real-time monitoring systems. This aligns with the effectiveness of data-based interventions that increased the food security index by 8.2% in East Java (Yudha & Mu'izz, 2020). The integration of machine learning and GIS for predicting crop failures and optimizing food aid in Bondowoso has also proven effective (Arifin et al., 2022). However, institutional capacity remains a major challenge, with 60% of priority 5 district governments lacking adequate data analysis units, making governance capacity building and data analysis training for local officials essential (Yunus et al., 2021).

Projection Results Using Single Exponential Smoothing (SES)

Based on calculations using the Single Exponential Smoothing (SES) method for projecting the food availability indicator value in 2024, with historical data from 2019 to 2023, a forecast value of 90.715 was obtained. This projection reflects the estimated food availability indicator expected in 2024 based on previous data trends. With a prediction range of a lower bound of 87.03 and an upper bound of 93.28 at a 5% significance level, it can be concluded that the Food Security Index value for 2024 is likely to fall within this range, indicating relatively small variation and trend stability (Beaumont et al., 1984). The model's accuracy is supported by a Mean Absolute Percentage Error (MAPE) of 1.40, indicating low prediction error and a fairly reliable model for short-term projections. Additionally, the optimal smoothing parameter alpha for the ARIMA model was calculated at 0.630, showing that the model places more weight on recent data, thereby capturing trend changes responsively and improving projection accuracy (Hyndman & Athanasopoulos, 2018). A similar approach was applied to the food accessibility indicator, with projection results shown in Figure 5.

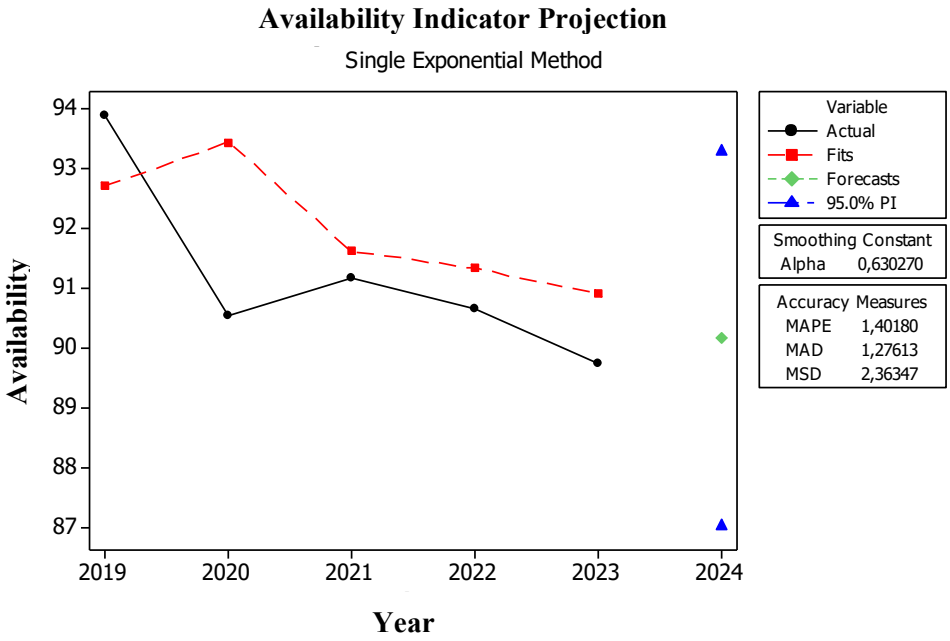

Image 5: Projection of Food Availability Indicator in East Java Province Using Single Exponential Smoothing.

The use of forecasting methods such as SES and ARIMA in the context of food security has been widely applied to support policy decision-making, particularly in anticipating fluctuations in food availability and optimizing resource distribution(Sihombing et al., 2024). Thus, these projection results can serve as an important foundation for strategic planning to maintain food security stability in East Java, in line with the research focus on rice production and poverty reduction in the region

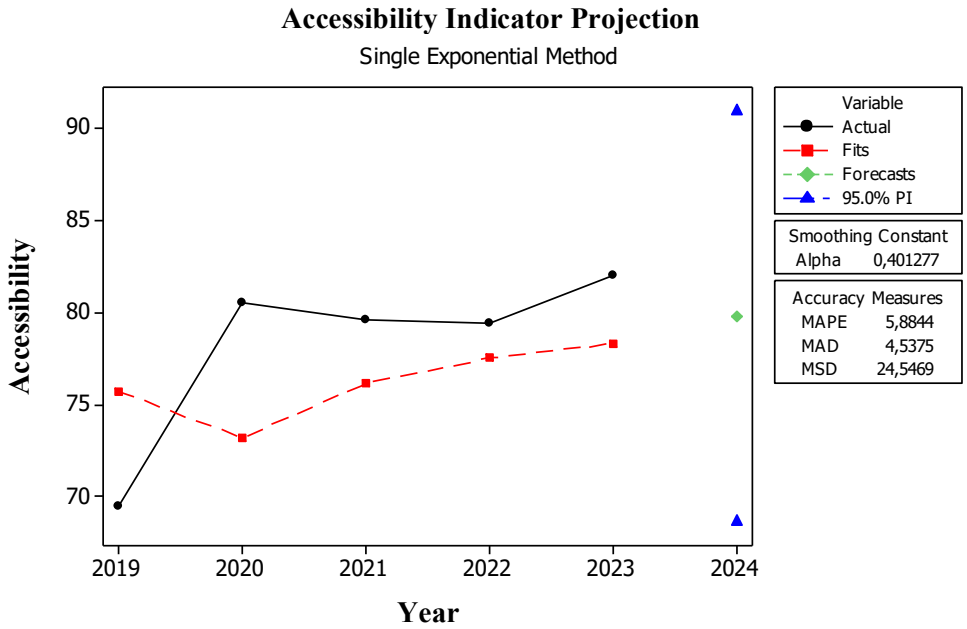

Image 6: Projection of the Accessibility Indicator for East Java Province Using Single Exponential Smoothing

Using the same method, the projected value of the accessibility indicator for 2024, based on data from 2019 to 2023, is forecasted at 79.76. This result represents the predicted value of the accessibility indicator expected for 2024, based on historical data trends. Additionally, with a lower bound of 68.64 and an upper bound of 90.87, it can be concluded that the accessibility projection for 2024 falls within this range, indicating a more controlled level of uncertainty. The model's accuracy is also demonstrated by a Mean Absolute Percentage Error (MAPE) of 5.884 and an optimal ARIMA alpha of 0.401. The same calculation was applied to the utilization indicator, with projection results shown in Figure 6.

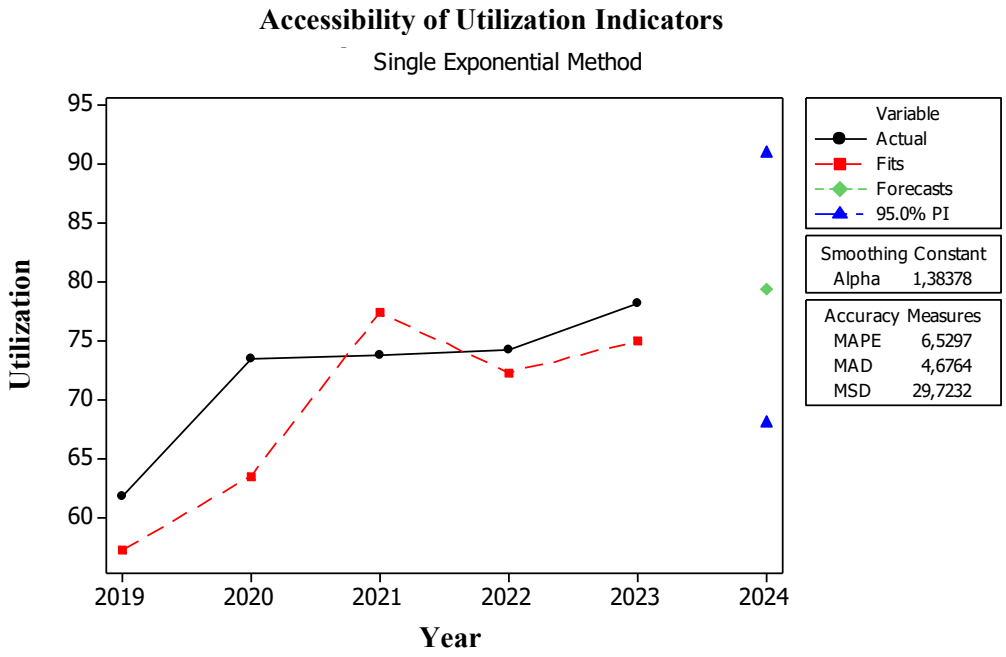

Image 7: Projection of the Utilization Indicator for East Java Province Using Single Exponential Smoothing

Next, a projection was made using data from 2019 to 2023, resulting in a forecast value of 79.48. This result represents the predicted value of the accessibility indicator expected for 2024 based on existing historical data trends. Additionally, the lower bound is 68.02 and the upper bound is 90.94. The model's accuracy is demonstrated by a Mean Absolute Percentage Error (MAPE) of 6.53 and an optimal ARIMA alpha calculation of 1.383. Using the projected values of the components of the Food Security Index and calculations weighted according to the assessment of the food security index indicators, the projected Food Security Index values for East Java Province under optimistic (upper bound), moderate (forecast), and pessimistic (lower bound) scenarios are presented in Table 1.

Table 1. Scenario of Food Security Index Values for 2024 Based on Indicator Projection Results

Scenario	Availability	Accessibility	Utilization	Food Security Index
Optimistic	93.28	90,87	90,94	91,62
Moderate	90,72	79,76	79,48	82,94
Pessimistic	87,03	68,64	68,02	73,91

The 2024 Food Security Index projection for East Java based on three scenarios shows significant differences in the performance of food availability, accessibility, and utilization indicators. In the optimistic scenario, the food security index is estimated to reach 91.62, reflecting an ideal condition where food availability remains stable at 93.28, accessibility at 90.87, and utilization at 90.94. This condition can be achieved if food availability remains productive, poverty decreases alongside improved farmer welfare through increased Farmer's Terms of Trade, and food consumption does not exceed 65% of total household expenditure (Faradilla et al., 2022). Additionally, reductions in stunting prevalence, increased education levels among women over 15 years old, and high life expectancy are key supporting factors. Cross-sector synergy among government, private sector, and community stakeholders is also crucial for the success of this scenario (Abdillah & Vaulina, 2023) The moderate scenario projects a food security index of 82.94, with food availability still relatively good (90.72), but accessibility (79.76) and utilization (79.48) experiencing significant declines. This situation reflects a realistic condition where food production is relatively stable, but persistent poverty limits food access and utilization (Mufidah et al., 2025). An increase in the number of poor people and suboptimal consumption patterns systematically reduce the food utilization variable. Therefore, assistance and empowerment of poor farming families are essential to prevent further declines in food access and utilization (Yunus et al., 2021). The pessimistic scenario shows the lowest results with a food security index of 73.91, where food availability drops to 87.03, accessibility reaches only 68.64, and utilization is 68.02. This scenario reflects serious challenges such as crop failures, food inflation, high poverty, poor healthcare services, and limited educational access for poor families. This condition has the potential to trigger a

multidimensional crisis that worsens food security, especially if cross-sector coordination and budget efficiency are inadequate. Collaborative efforts from all parties are vital to prevent this scenario from occurring (Ahmed, 2024).

CONCLUSION

This study confirms that food security in East Java is highly influenced by economic access and social capability factors, especially in areas facing structural challenges such as Bangkalan, Bondowoso, and Probolinggo. Policy projections indicate the need to shift from a production-centric approach to a model emphasizing equitable access and strengthening the capacity of small farmers, as well as integrating GIS-based technology for early warning systems. These findings reinforce the understanding that food security depends not only on food availability but also on the distribution and the ability of marginalized communities to optimally access and utilize food resources.

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