 https://doi.org/10.1051/e3sconf/202566503005

Navigating Food Security In Land-Limited Areas: The Case Of Yogyakarta's Energy and Protein Supply

Oki Wijaya*

Department of Agribusiness, Faculty of Agriculture, University of Muhammadiyah Yogyakarta, Indonesia

Abstract. This study aims to analyze the dynamics of food availability in the Special Region of Yogyakarta (DIY) during 2020–2022, focusing on the balance between energy and protein under land constraints. Data were obtained from the *Food Balance Sheet (Neraca Bahan Makanan)* and analyzed descriptively and comparatively against the *National Food and Nutrition Workshop (WNPG X, 2012)* recommendations. The results reveal that although energy availability remained stable at 3,731–3,735 kcal per capita per day (155% of the national standard), protein availability declined from 108.4 grams to 101.5 grams per capita per day over the same period. This trend reflects a state of *nutritional fragility*—caloric stability without nutritional balance. The high dependence on cereals and limited diversification of protein sources highlight structural challenges caused by farmland conversion, rising animal food prices, and policy bias toward staple crops. The findings emphasize that food security in land-limited regions requires a paradigm shift from *food quantity* to *food quality*, through the protection of productive farmland, the development of local protein supply chains, and strengthened nutrition education for communities.

1 Introduction

Food security has become an increasingly complex issue in regions where agricultural land is shrinking due to urbanization and land conversion. As defined by the Food and Agriculture Organization (FAO, 1996), food security exists when all people, at all times, have physical and economic access to sufficient, safe, and nutritious food to meet their dietary needs for an active and healthy life. In areas with limited land availability, maintaining food production capacity is particularly challenging. The pressure of population growth, industrial expansion, and urban development often reduces the extent of arable land, thereby affecting local food supply systems [1]. This condition creates structural vulnerability, as reduced agricultural land directly influences local production capacity and food self-sufficiency.

Yogyakarta, one of Indonesia's smallest provinces, epitomizes the tension between rapid urban expansion and agricultural sustainability. According to Badan Perencanaan Pembangunan, Riset, dan Inovasi Daerah (BAPPERIDA), Yogyakarta's agrarian land area declined by approximately 2.5% annually from 2010 to 2022, decreasing from 84,000 hectares to just about 64,000 hectares [2]. This reduction has significant implications for food

*Corresponding author: okiwijaya@umy.ac.id

production, particularly staple crops such as rice that constitute the main source of energy and protein for local households. Despite being a relatively small province, Yogyakarta remains a significant contributor to the regional food supply; however, its limited agricultural area constrains production resilience [3]. The shrinking farmland raises concerns about the region's ability to sustain adequate levels of energy and protein availability amid growing demand and climatic uncertainty.

Energy and protein availability are critical indicators of food security and nutritional adequacy. Energy reflects the caloric sufficiency required for daily activities, while protein is essential for growth and maintenance of body functions. Recent data indicate that Yogyakarta maintains relatively high energy availability, around 3,731 kcal per capita per day, exceeding national recommendations. However, protein availability has declined from 108.4 grams in 2020 to 101.5 grams in 2022, signaling a worrying downward trend [2]. This reduction, though modest, reflects potential imbalances in dietary quality and the overreliance on a few food sources such as rice and vegetable oils [4,5]. The nutritional vulnerability of such monocentric food systems underscores the importance of diversifying local diets to maintain resilience under spatial and environmental constraints.

Diversification strategies, through promoting non-rice crops, legumes, vegetables, and animal-based products, have been widely acknowledged as an adaptive pathway for land-limited regions. Diversification enhances the stability of food supply, improves dietary quality, and mitigates risks associated with overdependence on a single staple crop. In Yogyakarta, where the land base for traditional farming continues to decline, integrating diversified production systems such as mixed cropping, urban agriculture, or vertical farming offers opportunities to enhance food availability per unit area. Moreover, diversification is not merely an agronomic response; it also represents a nutritional strategy to address deficits in protein and micronutrient intake that commonly emerge in rice-dependent diets .

Despite increasing attention to issues of land contraction and diversification, several important gaps remain in the current body of research. Many studies focus on increasing production volume or documenting land-use change on national or global scales, but there is limited research that links the reduction of agricultural land area at the subnational level, such as Yogyakarta, with changes in key nutritional availability indicators, particularly energy and protein. Research on food systems has called for more locally grounded, micro-level studies that connect spatial dynamics with food availability outcomes [6]. Furthermore, while diversification is widely promoted as a food security strategy, empirical evidence on how diversification functions within land-limited and urbanizing provinces remains scarce, especially regarding its effect on nutritional sufficiency rather than merely crop diversity or yield outcomes [7]. The interplay between land shrinkage, nutritional availability, and diversification pathways under climatic uncertainty is also poorly integrated within existing food systems frameworks. Although food systems research increasingly emphasizes resilience and the full chain from production to consumption, there is still a lack of models specific to regions like Yogyakarta that combine land-use dynamics, nutritional outcomes, and diversification strategies [8].

This study addresses these gaps by offering a provincial-level empirical assessment of energy and protein availability in Yogyakarta from 2020 to 2022, directly linking observed farmland reduction with nutritional outcomes. It explores diversification strategies as adaptive responses to spatial and environmental constraints, moving beyond the generic discourse of diversification to a contextually grounded analysis relevant to land-limited regions. The study also integrates quantitative assessment with theoretical insights from food systems, diversification, and resilience frameworks, thereby contributing to a more holistic understanding of how to mitigate nutritional vulnerability under spatial limitations.

Empirically, this study provides evidence-based insights into the magnitude of the impact of farmland shrinkage on nutritional availability, which can inform policy formulation at the provincial level and beyond. Conceptually, by linking land-use change, nutritional outcomes, and diversification strategy within a unified analytical framework, the study advances the theoretical understanding of food-system resilience in spatially constrained contexts. Practically, the research offers policy recommendations for local governments, cooperatives, and community stakeholders in Yogyakarta to design and implement diversification pathways, such as promoting non-rice crops, small-scale livestock systems, and urban agriculture models, that can sustain nutritional sufficiency despite ongoing land conversion. Through these empirical, conceptual, and practical contributions, this study enhances the understanding of food security in land-limited regions and supports the development of resilient, diversified, and nutrition-sensitive food systems.

2 Research method

This study employed a quantitative descriptive approach to examine the dynamics of food availability, particularly energy and protein, in the context of land limitations in Yogyakarta. The research design focuses on describing and interpreting temporal changes in food supply from 2020 to 2022, aiming to provide an empirical overview of how farmland reduction affects regional food security. The descriptive quantitative method is suitable for this purpose because it enables the systematic measurement of existing conditions without variable manipulation, aligning with approach to explanatory quantitative analysis.

The research relied entirely on secondary data obtained from the *Central Bureau of Statistics (BPS)* and *Food Balance Sheets (Neraca Bahan Makanan)* of Yogyakarta Province. Data included per capita daily energy availability (kcal), per capita daily protein availability (grams), food composition by commodity group, and total agricultural land area. These datasets were cross-referenced with national dietary standards from Widya Karya Nasional Pangan dan Gizi (WNPG X, 2012), which recommend a daily intake of 2,500 kcal and 63 grams of protein per person. The use of official statistics ensures the reliability, comparability, and validity of data for regional food security assessments, as recommended by the FAO [9].

Data analysis followed the food availability framework as one of the four pillars of food security—alongside access, utilization, and stability. Within this framework, food availability represents the physical presence of food resulting from domestic production, imports, and stock variation. The study examined trends in energy and protein availability and compared them with national adequacy standards to evaluate Yogyakarta's capacity to meet nutritional requirements. It further identified structural shifts in food composition, emphasizing the growing dominance of cereals and the limited diversification toward other food groups. Such an approach is consistent with Pingali's (2015) argument that an overreliance on staple grains can weaken nutrition outcomes, and with Kennedy et al. (2003), who emphasize diversification as a determinant of dietary quality [5].

Descriptive statistical techniques were used to calculate mean values, adequacy ratios, and percentage changes. Visualization through charts and comparative analysis provided additional interpretation of temporal variations. The analytical discussion then contextualized empirical findings within the theoretical perspectives of nutrition-sensitive agriculture and food diversification frameworks, thereby integrating statistical trends with conceptual insights on resilience under land pressure [4].

While the study primarily addresses the availability dimension of food security, it acknowledges limitations related to access and utilization aspects due to the absence of household-level consumption data. Nonetheless, this approach remains sufficient to depict the macro-level capacity of Yogyakarta's food system to sustain energy and protein availability despite shrinking agricultural land.

3 Result and discussion

The analysis of food availability in Yogyakarta from 2020 to 2022 reveals that while the province maintained a stable and even surplus energy supply, a gradual decline in protein availability was evident during the same period. Average energy availability reached approximately 3,731 kcal per capita per day, exceeding the national dietary recommendation of 2,500 kcal by more than 40%. However, protein availability decreased from 108.4 grams in 2020 to 101.5 grams in 2022, indicating a 6.4% reduction. Although the total caloric supply remains adequate, this downward trend in protein availability suggests a deterioration in nutritional quality rather than quantity, echoing findings from previous studies that associate caloric sufficiency with "hidden hunger" in developing countries.

Table 1. Energy and Protein Availability in DIY (2020–2022)

Year	Availability (per Capita per Day)		Percentage of WNPG 2012 Recommendation	
	Energy (kkal)	Protein (gram)	Energy (%)	Protein(%)
2020	3.735	108,40	155,63	172,06
2021	3.732	103,72	155,50	164,63
2022	3.731	101,52	155,46	161,14

Source: Data Analysis, 2024

This pattern aligns with the dietary transition hypothesis, which posits that as regions urbanize and incomes rise, diets shift from diverse, nutrient-rich foods to energy-dense but less balanced options [10]. In Yogyakarta's case, the dominance of cereals, particularly rice, continues to shape the structure of energy and protein sources. According to data from the *Food Balance Sheet (NBM)*, more than 60% of total energy and nearly 40% of total protein originate from rice and cereal-based commodities. While such reliance ensures caloric stability, it creates vulnerability to supply shocks and limits nutritional resilience [5].

Table 2. Contribution of Food Groups to Energy Supply (kcal/capita/day)

No.	Food Groups	2020	2021	2022
1	Cereals and cereal products	1,816	1,876	1,839
2	Starchy roots and tubers	245	328	319
3	Sugar and sweeteners	299	255	286
4	Oil crops and nuts	389	439	429
5	Fruits	81	78	76
6	Vegetables	44	50	46
7	Meat and meat products	167	139	144
8	Eggs	51	47	38
9	Milk and dairy products	22	23	21
10	Fish and seafood	60	62	62
11	Oils and fats	558	430	466
12	Animal fats	4	5	6
Total		**3,735**	**3,732**	**3,732**

Source: Data Analysis, 2024

The steady reduction of agricultural land further compounds this problem. Data from the Badan Perencanaan Pembangunan, Riset, dan Inovasi Daerah (BAPPERIDA) indicate that Yogyakarta lost approximately 20,000 hectares of farmland between 2010 and 2022, primarily due to conversion into residential and industrial uses [2]. Land scarcity constrains opportunities for crop diversification, leading to monocentric agricultural patterns that prioritize staple grains. This structural shift mirrors findings by Kamaludin et al. (2021), who observed that land conversion in Indonesia significantly reduces local capacity to produce high-protein crops such as legumes and soybeans, which are vital for dietary diversity and soil fertility [1].

Table 3. Contribution of Food Groups to Protein Supply (g/capita/day)

No.	Food Groups	2020	2021	2022
1	Cereals and cereal products	43.86	44.23	43.87
2	Starchy roots and tubers	0.70	2.33	2.09
3	Sugar and sweeteners	1.35	1.22	1.22
4	Oil crops and nuts	24.02	24.76	24.34
5	Fruits	0.78	0.76	0.75
6	Vegetables	8.28	2.30	2.32
7	Meat and meat products	11.92	10.57	10.69
8	Eggs	4.00	3.62	2.96
9	Milk and dairy products	1.18	1.22	1.09
10	Fish and seafood	11.77	11.88	12.10
11	Oils and fats	0.19	0.08	0.09
12	Animal fats	0.01	0.01	0.01
Total		**108.06**	**102.98**	**101.52**

Source: Data Analysis, 2024

Despite this, Yogyakarta demonstrates adaptive potential through modest diversification efforts in horticulture, mixed cropping, and small-scale livestock farming. However, these efforts have yet to compensate for the declining share of protein-rich commodities in the overall food balance. Widowati and Nurfitriani (2023) emphasize that diversification should not merely focus on production variety but also on enhancing consumption diversity at the household level. Such integration between supply and demand dimensions is essential to achieving nutrition-sensitive food systems, as also highlighted by Ruel, Quisumbing, and Balagamwala (2018) [4].

Table 4. Contribution of Food Groups to Fat Supply (g/capita/day)

No.	Food Groups	2020	2021	2022
1	Cereals and cereal products	8.92	11.33	10.84
2	Starchy roots and tubers	0.58	0.73	0.69
3	Sugar and sweeteners	4.50	4.01	4.06
4	Oil crops and nuts	29.09	31.51	30.39
5	Fruits	0.41	0.65	0.65
6	Vegetables	0.52	0.49	0.44
7	Meat and meat products	12.86	10.60	10.93
8	Eggs	3.62	3.31	2.71
9	Milk and dairy products	1.29	1.33	1.19
10	Fish and seafood	1.01	1.45	1.45
11	Oils and fats	62.18	27.74	29.81
12	Animal fats	0.39	0.58	0.65
Total		**125.37**	**93.75**	**93.81**

Source: Data Analysis, 2024

From a food security perspective, the province can still be categorized as *food secure in energy terms,* but *potentially vulnerable in protein sufficiency*. The energy adequacy ratio (EAR) exceeded 100% throughout the study period, whereas the protein adequacy ratio (PAR) declined from 172% to 161%. This decline indicates that even within an adequate caloric environment, nutritional imbalances may persist, reflecting what FAO (2017) calls a "quality deficit" in food security [9]. This situation aligns with global trends in middle-income regions, where caloric intake improves faster than nutrient adequacy due to the accessibility of inexpensive carbohydrate-based foods [11].

Table 5. Desirable Dietary Pattern (DDP) of the Yogyakarta Special Region, 2021

No.	Food Groups	Energy (Kcal)	% AKE	Weighting Factor	Actual Score	PPH Score	Maximum Score
1	Cereals and cereal products	1,876	78.2	0.5	39.1	25.0	25.0
2	Starchy roots and tubers	331	13.8	0.5	6.9	2.5	2.5
3	Animal-based foods	266	11.1	2.0	22.2	22.2	24.0
4	Oils and fats	441	18.4	0.5	9.2	5.0	5.0
5	Oil crops and nuts	94	3.9	0.5	2.0	1.0	1.0
6	Legumes and pulses	347	14.4	2.0	28.9	10.0	10.0
7	Sugar and sweeteners	255	10.6	0.5	5.3	2.5	2.5
8	Vegetables and fruits	123	5.1	5.0	25.6	25.6	30.0
9	Others	–	–	–	–	–	–
Total		**3,732**	**155.5**		**139.1**	**93.8**	**100.0**

Source: Data Analysis, 2024

The implications of these findings extend beyond the nutritional domain. The concentration of food supply in a few commodity groups weakens systemic resilience, making the region more sensitive to climatic and market disruptions. Studies by Allen et al. (2019) and Tendall et al. (2015) suggest that resilience in food systems depends not only on production volume but also on functional diversity, the capacity to maintain output through multiple pathways [12,13]. Therefore, policy interventions in Yogyakarta should aim to reinforce local agrodiversity and reduce land-use dependency on rice monoculture.

Strengthening urban and peri-urban agriculture could be one viable strategy to offset land scarcity. Initiatives such as rooftop gardens, hydroponic systems, and vertical farming may improve access to fresh vegetables and protein sources within limited spaces [14,15]. Moreover, community-based cooperatives can play a role in coordinating local production and distribution, ensuring that diversification contributes to both food availability and economic inclusion. As emphasized by Pingali (2015), integrating agricultural policy with nutrition outcomes requires aligning production incentives with dietary goals, a shift that remains crucial for Yogyakarta's long-term food security under spatial constraints [5].

In summary, Yogyakarta's experience exemplifies a broader structural paradox faced by land-limited regions: abundant energy but declining nutritional adequacy. While the province demonstrates resilience in maintaining food quantity, its food quality trajectory highlights an urgent need for diversification and innovation within the agricultural system. To sustain food security under land pressure, the province must pursue policies that simultaneously preserve farmland, promote diversified cropping systems, and encourage consumption of varied, nutrient-rich foods.

4 Conclusion and recommendation

This study reveals that although Yogyakarta maintains an adequate and stable level of energy availability, there has been a decline in protein availability during the 2020–2022 period. This condition indicates that the food system in land-limited regions remains focused on quantity rather than nutritional quality. The high dependency on cereal commodities, particularly rice, has resulted in a less diverse and more supply-vulnerable food structure. Therefore, Yogyakarta's food security can be categorized as strong in terms of energy, yet vulnerable in terms of protein sufficiency and food diversification.

First, the protection of productive agricultural land is essential through the enforcement of spatial planning and land-use conversion regulations to prevent the continuous decline in food production capacity. Second, local resource-based food diversification policies should be strengthened, particularly by promoting high-protein crops such as legumes and horticultural products. Third, urban agriculture and community-based food systems should be promoted to make efficient use of limited space and enhance access to fresh food, in line with the principles of *nutrition-sensitive agriculture*. Fourth, food security policy should shift from a "maximum production" paradigm to a "diverse and nutritious production" approach, enabling Yogyakarta to maintain a balance between food quantity and quality under increasing land-use pressures.

References

1. Nasikh, M. Kamaludin, B.S. Narmaditya, A. Wibowo, I. Febrianto, Agricultural Land Resource Allocation to Develop Food Crop Commodities: Lesson from Indonesia, Elsevier Ltd, Heliyon **7**, 1 (2021) https://doi.org/10.1016/j.heliyon.2021.e07520.
2. R. dan I.D. (BAPPERIDA) D. Badan Perencanaan Pembangunan, Neraca Bahan Makanan Daerah Istimewa Yogyakarta, *Neraca Bahan Makanan Daerah Istimewa Yogyakarta* (Yogyakarta, 2023).
3. Z. Rozaki, Food Security Challenges and Opportunities in Indonesia Post COVID-19, Elsevier Ltd, in *Advances in Food Security and Sustainability* (Elsevier Ltd, Washington, 2021), pp. 119–168 https://doi.org/10.1016/bs.af2s.2021.07.002.
4. M.T. Ruel, A.R. Quisumbing, M. Balagamwala, Nutrition-Sensitive Agriculture: What Have We Learned so Far?, Elsevier B.V., Glob Food Sec **17**, 128 (2018) https://doi.org/10.1016/j.gfs.2018.01.002.
5. P. Pingali, Agricultural Policy and Nutrition Outcomes – Getting beyond the Preoccupation with Staple Grains, Kluwer Academic Publishers, Food Secur **7**, 583 (2015) https://doi.org/10.1007/s12571-015-0461-x.
6. S. Munialo, C.M. Onyango, J.A. Lukachi, O.V. Wasonga, J.G. Maina, J.M. Nzuma, A. Dawood, L.M. Sibanda, Gaps and Opportunities in Research on Food Systems; a Micro-Institutional Analysis of the University of Nairobi, Frontiers Media SA, Front Sustain Food Syst **7**, (2023) https://doi.org/10.3389/fsufs.2023.1125094.
7. Y. Huang, Y. Yang, F. Nie, X. Jia, Production Choices and Food Security: A Review of Studies Based on a Micro-Diversity Perspective, Multidisciplinary Digital Publishing Institute (MDPI), Foods **13**, 1 (2024) https://doi.org/10.3390/foods13050771.
8. J. Fanzo, N. Covic, A. Dobermann, S. Henson, M. Herrero, P. Pingali, S. Staal, A Research Vision for Food Systems in the 2020s: Defying the Status Quo, Elsevier B.V., Glob Food Sec **26**, 1 (2020) https://doi.org/10.1016/j.gfs.2020.100397.
9. Food and Agriculture Organization (FAO), The State of Food Security and Nutrition in the World 2017: Building Resilience for Peace and Food Security, *The State of Food Security and Nutrition in the World 2017: Building Resilience for Peace and Food Security* (Rome, 2017).
10. B.M. Popkin, Nutrition, Agriculture and the Global Food System in Low and Middle Income Countries, Elsevier Ltd, Food Policy **47**, 91 (2014) https://doi.org/10.1016/j.foodpol.2014.05.001.
11. C.P. Timmer, Behavioral Dimensions of Food Security, PNAS, Proc Natl Acad Sci U S A **109**, 12315 (2012) https://doi.org/10.1073/pnas.0913213107.
12. D.M. Tendall, J. Joerin, B. Kopainsky, P. Edwards, A. Shreck, Q.B. Le, P. Kruetli, M. Grant, J. Six, Food System Resilience: Defining the Concept, Elsevier B.V., Glob Food Sec **6**, 17 (2015) https://doi.org/10.1016/j.gfs.2015.08.001.

13. T. Allen, P. Prosperi, Modeling Sustainable Food Systems, Springer New York LLC, Environ Manage **57**, 956 (2016) https://doi.org/10.1007/s00267-016-0664-8.
14. O. Wijaya, Widodo, R. Latifah, N. Rahmawati, C.W. Rubiyanto, Household Dietary Patterns in Food Insecurity Areas, Department of Agribusiness, Universitas Muhammadiyah Yogyakarta, AGRARIS: Journal of Agribusiness and Rural Development Research **6**, 154 (2020) https://doi.org/10.18196/agr.6298.
15. A. Slamet Widodo, Widodo, N. Man, B. Ulum, The Influence of Welfare Level on Food Security in Farmer Households, EDP Sciences, in *E3S Web of Conferences* (EDP Sciences, Yogyakarta, 2024), pp. 1–9 https://doi.org/10.1051/e3sconf/202459503016.