A Multi-Criteria Decision Analysis of Food Security Strategies in Remote Highland Communities: Evidence From Wouma Village, Papua Pegunungan, Indonesia

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Abstract.

Food insecurity remains a persistent challenge in the Papua Highlands of Indonesia, driven by geographic isolation, limited infrastructure, low agricultural productivity, and high dependence on external food supplies. This study aims to identify priority strategies for strengthening food security through a community-based local food system approach by applying the Analytic Hierarchy Process (AHP). The analysis is structured around the four dimensions of food security proposed by the Food and Agriculture Organization (FAO), namely availability, access, stability, and utilization. Data were collected from key stakeholders through pairwise comparison questionnaires, complemented by focus group discussions and in-depth interviews. The results indicate that food availability is the most dominant criterion, followed by access, stability, and utilization. Across all dimensions, Local Food Production emerges as the highest-priority alternative, highlighting the strategic importance of strengthening upstream agricultural capacity to ensure sufficient and sustainable food supply. Infrastructure and Market Access ranks second, emphasizing the role of transportation, storage, and market connectivity in improving distribution efficiency and affordability. Community-Based Food Institutions and Nutrition Programs and Social Protection function as complementary interventions, supporting governance, coordination, and the protection of vulnerable groups. The convergence of the AHP results with the FAO food security framework and the Food Security and Vulnerability Atlas (FSVA) of the Indonesian National Food Agency (BPN) confirms that structural strengthening of local food systems, supported by infrastructure development and institutional capacity building, constitutes the most effective pathway for enhancing food security and resilience in the Papua Highlands. These findings provide an evidence-based basis for formulating integrated and context-sensitive food security policies in remote and highland regions.

Keywords: *Food security; Analytic Hierarchy Process; local food production; community-based food systems; Papua Highlands; FAO and BPN.*

I. INTRODUCTION

Food security is widely recognized as a cornerstone of human well-being and sustainable national development, particularly in remote and structurally marginalized regions. In Indonesia, the Papua Highlands represent one of the most persistent food-insecure areas, where geographic isolation, limited infrastructure, and structural poverty converge to undermine household food systems. Recent statistics reveal that the prevalence of inadequate food consumption in Tolikara Regency reached 51.68% in 2023, substantially exceeding the national average of 8.53%, while neighboring regencies exhibit similarly alarming trends [1]. These disparities underscore deep-seated regional inequalities and the urgent need for targeted, context-sensitive food security policies.Spatial analyses of food security further demonstrate that the Papua Highlands consistently rank among the lowest-performing regions in Indonesia's composite food security index, reflecting severe constraints across the dimensions of food availability, access, and utilization [2]. According to the Food Security and Vulnerability Atlas (FSVA) published by Indonesia's National Food Agency (Badan Pangan Nasional/BPN), the Papua Highlands are classified as the province with the lowest overall food security status nationwide [2].

Nearly all constituent regencies—including Jayawijaya, Yahukimo, Tolikara, Pegunungan Bintang, and Mamberamo Tengah—are categorized as food-vulnerable or food-insecure, indicating widespread

exposure to chronic food shortages.These adverse outcomes are driven by a complex set of structural constraints, including low agricultural productivity, heavy reliance on interregional food supplies, fragmented distribution systems, weak market integration, and persistent socio-economic deprivation [3]. In response, the Indonesian government has introduced a range of interventions, such as rice cultivation initiatives and the Free Nutritious Meal Program (Program Makan Bergizi Gratis/MBG), which have been adapted to local contexts to improve household food access and nutritional intake [4]. Nevertheless, the effectiveness of these programs remains limited by infrastructural deficits, conflict-affected areas, and socio-economic barriers, raising concerns about their long-term sustainability and policy coherence.

Despite a growing body of literature on food security in remote and highland regions, there remains a notable gap in systematically prioritizing food security policy interventions using transparent, multi-criteria decision-making frameworks that integrate both empirical data and expert judgment. Addressing this gap, the present study employs a mixed-methods approach, applying the Analytic Hierarchy Process (AHP) to identify and rank policy priorities for strengthening food security in the Papua Highlands. The analysis evaluates key criteria—including agricultural productivity, market access, infrastructure quality, institutional capacity, and socio-economic conditions—and assesses policy alternatives such as strengthening local food production, improving distribution networks, developing community-based economic institutions, and enhancing social protection mechanisms [5]. By integrating regional quantitative indicators with expert and stakeholder assessments through pairwise comparisons, this study contributes a context-specific, evidence-based framework for food security policymaking in remote and structurally disadvantaged regions. The findings are expected to inform more coherent and effective policy strategies aimed at enhancing food security while simultaneously addressing structural poverty in the Papua Highlands and comparable highland contexts.

II. METHODS

This community engagement activity adopts a mixed-methods approach by integrating quantitative and qualitative analyses. This approach is selected to obtain a comprehensive understanding of food security challenges and to formulate program priorities that are practical and aligned with the socio-economic conditions of communities in the Papua Highlands Province.The quantitative method applies the Analytic Hierarchy Process (AHP) as the primary multi-criteria decision-making tool. AHP is employed to determine the priority of food security policies and programs based on the relative importance of each dimension and program alternative.

Meanwhile, the qualitative method is used to strengthen the interpretation of AHP results through focus group discussions (FGDs) and in-depth interviews with key stakeholders.Food security measurement refers to the FAO Food Security Indicators (2008) [6], which conceptualize food security into four main dimensions: availability, access, stability, and utilization. The availability dimension reflects the adequacy of food at the household level in terms of quantity, quality, safety, equity of distribution, and affordability. The access dimension indicates households' ability to obtain food through physical, economic, and social means. The stability dimension refers to communities' capacity to access and utilize food in a stable and sustainable manner over time. The utilization dimension relates to communities' ability to appropriately select, process, and consume food, supported by nutritional knowledge, sanitation, and basic health services.

Table 1. Literature Review of Criteria Dimension

No.	Dimension Criteria	Literature review
1.	Avialibility	Understanding Household Access to Food ([1], [2], [3])
2.	Access	Food security refers to the capacity of households to access food physically, economically, and socially ([4], [5], [6])
3.	Stability	The capacity of communities to access and utilize food consistently and sustainably over time ([7], [8])
4.	Utilization	Supported by communities ability to select, prepare, and consume food appropriately, underpinned by nutrition knowledge, sanitation, and basic health services ([9], [10], [11])

The community engagement activities were conducted in the Papua Highlands region, specifically in Wouma Village, and involved stakeholders selected through purposive sampling, comprising 15 participants. These participants included representatives of local government, field facilitators, community leaders, and academics with expertise related to food security issues. The involvement of these stakeholders aimed to ensure that the prioritized programs were responsive to community needs and could be implemented in a sustainable manner.

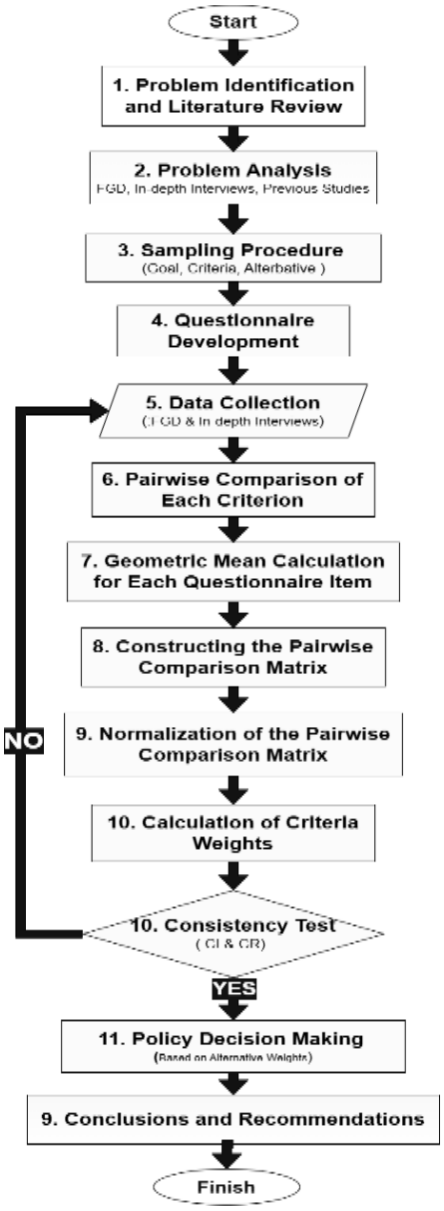

Fig 1. Flowchart

The application of the Analytic Hierarchy Process (AHP) was carried out through several stages:

1. The first stage involved the development of a hierarchical structure consisting of three levels: the objective (determining priorities for food security programs), the criteria (the four FAO food security dimensions), and the program alternatives.
2. The second stage comprised pairwise comparisons among criteria and among program alternatives using the Saaty scale (1–9).
3. The third stage involved the calculation of priority weights for each criterion and program alternative. The priority weight of each criterion was obtained by calculating the average value of each row in the normalized comparison matrix. This average value represents the eigenvector, which reflects the relative importance of each criterion in achieving the food security objective.
4. The fourth stage was the consistency test of the judgments using the Consistency Ratio (CR), with a threshold of $CR \leq 0.10$ to ensure the consistency and validity of the assessment results.

The consistency index (CI) is calculated using the following formula :
Meanwhile, the **Consistency Ratio (CR)** can be calculated using the following formula :

$$CI = \frac{\lambda - n}{n - 1}$$

Where:
CI = Consistency Index
λ = the average eigenvalue of all criteria/alternatives
n = the number of criteria/alternatives evaluated

Table 2. Index Random Consistency

n	1	2	3	4	5	6	7	8
RI	0,00	0,00	0,58	0,90	1,12	1,24	1,32	1,41

Where:
RI = *Index Random Consistency*
n = Jumlah kriteria/alternatif yang diuji

The food security program alternatives were formulated based on each FAO food security dimension. Within the availability dimension, the proposed programs include improving the adequacy of nutritious food supply, strengthening local food production, and increasing protein intake [12]. Under the access dimension, programs focus on enhancing food price affordability, addressing malnutrition, and reducing food deficits. In the stability dimension, programs are directed toward reducing production variability and stabilizing per capita food supply. Meanwhile, within the utilization dimension, the programs encompass stunting prevention, improvement of health and nutrition services for pregnant women, and the provision of vitamins for children [13].Quantitative data were obtained from the results of the AHP questionnaires, while qualitative data were collected through focus group discussions (FGDs) and in-depth interviews. Data analysis was conducted using descriptive and analytical approaches to generate a priority map of food security programs, which serves as the basis for policy recommendations and the implementation of community engagement programs[14].

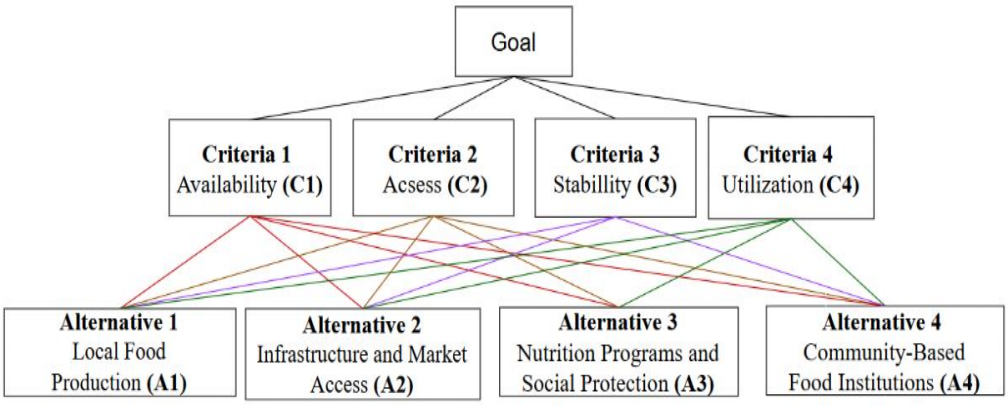

Fig 2. Goal, Criteria, and Decision Alternative AHP

III. RESULT AND DISCUSSION

After data collection and processing through the methodological stages described earlier, the study proceeded to analyze the results in order to address its main objective: identifying effective, efficient, and well-targeted strategies for strengthening food security. This study specifically focuses on the development of a community-based local food system as a strategic approach to enhancing food security in Jayawijaya Regency.The analysis draws on data obtained from 15 respondents who were directly involved in the formulation and prioritization of food security strategies in Jayawijaya Regency, particularly in Wouma Village. The respondents comprised key stakeholders with relevant expertise and contextual understanding of food security challenges in the study area, ensuring that the judgments provided were informed, contextually appropriate, and representative for the multi-criteria decision-making process.

1. Geometric Mean of the Criteria Comparison Matrix.

Table 3. Geometric Mean of the Criteria Comparison Matrix

Geometric Mean of the Criteria Comparison Matrix										
Respondent					Eigenvalue				Total	Average
Alternatif	C1	C2	C3	C4						
C1	1	4.424635	5.333436	8.164933	0.65	0.70	0.61	0.60	2.56	0.64
C2	0.226007	1	1.829929	2.783517	0.15	0.16	0.21	0.21	0.72	0.18
C3	0.187496	0.546469	1	1.612527	0.12	0.09	0.11	0.12	0.44	0.11
C4	0.122475	0.359258	0.620145	1	0.08	0.06	0.07	0.07	0.28	0.07
Total	1.54	6.330362	8 7/9	13.56098						1.000

λ Max = 4.040992
CI = 0.013664
CR = 0.015182

Notes: C1 = Availability; C2 = Acsess; C3 = Stability; C4 = Ultilization; λ Max = The average value of all criteria; CI = Consistency Index; CR = Consistency Ratio

Weight and Priority of the Criteria

Priority	Symbol	Criterion	Weight
1.	C1	Availability	0.64
2.	C2	Acsess	0.18
3.	C3	Satbility	0.11
4.	C4	Ultilizatiom	0.07

The results of criteria weighting using the Analytic Hierarchy Process (AHP), as presented in the Geometric Mean of the Criteria Comparison Matrix (Table 3), reveal clear differences in the relative importance of the food security dimensions. The consistency test indicates that respondents' judgments exhibit a very high level of consistency, with a Consistency Ratio (CR) of 0.015, which is well below the accepted threshold (CR $\leq$ 0.10). This confirms that the pairwise comparisons provided by the respondents are logical, stable, and reliable for further analysis. Based on the weighting results, the food availability dimension (Availability/C1) ranks first with a weight of 0.64, indicating that food availability is the most dominant criterion in determining the level of food security in the study area. The dominance of this dimension reflects the structural conditions of the Papua Highlands, particularly in Wouma Village, which continue to face limited local food production capacity, dependence on food supplies from outside the region, and distribution constraints due to challenging geographical conditions. The food access dimension (Access/C2) ranks second with a weight of 0.18. This finding suggests that households' ability to obtain food physically and economically—including price affordability and access to markets—is a critical factor following food availability. High transportation costs and limited market infrastructure in the highland region further reinforce the importance of the access dimension in shaping local food security conditions.

The food stability dimension (Stability/C3) receives a weight of 0.11, indicating that fluctuations in food production and supply over time remain a concern, although they are less dominant than availability and access. This dimension is closely associated with seasonal factors, climate-related risks, and vulnerability to disruptions in food distribution.Meanwhile, the food utilization dimension (Utilization/C4) has the lowest weight, at 0.07. This result suggests that aspects of food utilization—such as nutritional knowledge, dietary practices, sanitation, and access to basic health services—are perceived as relatively less constraining compared to issues of food availability and access. Nevertheless, this dimension remains important in the long term, particularly for improving nutritional quality and public health outcomes.Overall, the priority order of food security criteria is availability > access > stability > utilization. These findings provide a strong empirical basis for the formulation of food security policies and programs that prioritize strengthening community-based local food systems, particularly through enhancing food production and availability as the primary foundation for improving food security in the Papua Highlands.The dominance of food availability as the highest-ranked criterion highlights the structural challenges faced by highland and remote regions such as the Papua Highlands.

Limited local production capacity, strong dependence on external food supplies, and fragmented distribution networks make availability a critical determinant of food security. This finding is consistent with FAO's framework [15], which emphasizes availability as a foundational dimension of food security,

particularly in geographically isolated areas.Food access ranks second, underscoring the importance of physical and economic access to food, especially in regions characterized by high transportation costs and limited market infrastructure. While food stability and utilization receive lower weights, their roles remain significant in ensuring long-term resilience and improved nutritional outcomes. The relatively lower prioritization of utilization suggests that immediate structural constraints related to production and access outweigh behavioral and health-related factors in the study area.These results support policy strategies that prioritize strengthening community-based local food systems, particularly through interventions aimed at enhancing food production and availability as the primary pathway toward improving food security in the Papua Highlands.

2. Geometric Mean of the Alternative Comparison Matrix Based on the Availability

Table 4. Geometric Mean of the Alternative Comparison Matrix Based on the Availability Criterion

Geometric Mean of the Alternative Comparison Matrix Based on the Availability Criterion										
Respondent					Eigenvalue				Total	Average
Alternatif	A1	A2	A3	A4						
A1	1	3.461007	6.388132	5.969385	0.62	0.68	0.51	0.57	2.38	0.59
A2	0.288933	1	3.285029	3.031661	0.18	0.20	0.26	0.29	0.93	0.23
A3	0.15654	0.304411	1	0.542195	0.10	0.06	0.08	0.05	0.29	0.07
A4	0.167521	0.329852	1.844355	1	0.10	0.06	0.15	0.09	0.41	0.10
Total	1.61	5.09527	12 1/2	10.54324						1.000

λ Max = 4.133905
CI = 0.044635
CR = 0.049594

Notes: A1 = Local Food Production
A2 = Infrastructure and Market Access
A3 = Nutrition Programs and Social Protection
A4 =Community-Based Food Institutions
λ Max = The average value of all criteria
CI = Consistency Index
CR = Consistency Ratio

3. Criterion.

Weight and Priority of Alternative based on the Availability Criterion (C1)

Priority	Symbol	Alternative	Weight
1.	A1	Local Food Production	0.59
2.	A2	Infrastructure and Market Access	0.23
3.	A4	Community-Based Food Institutions	0.10
4.	A3	Nutrition Programs and Social Protection	0.07

The AHP results for food security program alternatives under the availability criterion indicate a satisfactory level of consistency, with a Consistency Ratio (CR) of 0.049, which is well below the acceptable threshold (CR $\leq$ 0.10). This confirms that the respondents' judgments are reliable and that the derived priority weights can be confidently used for decision-making.Local food production (A1) emerges as the top-ranked alternative with a weight of 0.59, indicating that enhancing local production capacity is perceived as the most effective strategy for ensuring food availability. Infrastructure development and market access (A2) follow in second place with a weight of 0.23, highlighting their critical supporting role in facilitating food distribution and improving the flow of agricultural products from producers to consumers. Community-based food institutions (A4) rank third with a weight of 0.10, while nutrition programs and social protection (A3) receive the lowest priority (0.07). This pattern suggests that interventions directly targeting food supply are considered more crucial than complementary measures in addressing availability constraints.Overall, the priority order of alternatives under the availability dimension is A1 > A2 > A4 > A3, emphasizing that strengthening local food systems—particularly through increased local production—constitutes the primary strategic pathway for improving food security in the study area.

The findings of this study show strong consistency with the FAO food security framework and the empirical evidence presented in the Food Security and Vulnerability Atlas (FSVA) published by the Indonesian National Food Agency (BPN).FAO conceptualizes food security through four main pillars—availability, access, stability, and utilization—with availability as the most fundamental prerequisite, particularly in geographically isolated and infrastructure-constrained regions. In line with this framework, the AHP results identify food availability as the highest-weighted criterion, reflecting the structural

limitations of the food system in the Papua Highlands, such as low local production capacity, high dependence on external food supplies, and weak distribution networks [15].The classification of Jayawijaya District as a highly food-vulnerable area in the FSVA further supports these findings. Low per capita food availability, limited regional food reserves, and a high prevalence of undernourishment indicate that the local food system has not yet been able to ensure a sufficient and sustainable supply [16].

In this context, the prioritization of strengthening local food production, as indicated by the AHP analysis, is consistent with the recommendations of both FAO and BPN, which emphasize the development of smallholder-based agriculture as a key strategy to enhance food availability, reduce reliance on external markets, and improve the resilience of the food system [17]. Moreover, the relatively high ranking of infrastructure development and market access underscores the need for improvements in storage, transportation, and market connectivity to ensure that increased production can be effectively distributed and accessed by the population. In contrast, the lower weights assigned to the utilization dimension and social protection programs suggest that, in areas where supply-side constraints remain dominant, structural investments in production and distribution are likely to generate more immediate and systemic impacts than interventions focused on consumption and nutrition.Overall, the convergence between the AHP results, the FAO conceptual framework, and the FSVA data from BPN highlights that strengthening community-based local food systems—centered on enhanced production and supported by infrastructure and institutional development—constitutes the most strategic pathway for improving food security and building long-term resilience in the Papua Highlands.

4. Geometric Mean of the Alternative Comparison Matrix based on the Acsess Criterion.

Table 5. Geometric Mean of the Alternative Comparison Matrix based on the Acsess Criterion

Geometric Mean of the Alternative Comparison Matrix based on the Acsess Criterion										
Respondent					Eigenvalue				Total	Average
Alternatif	A1	A2	A3	A4						
A1	1	0.216031	0.281994	0.133824	0.06	0.05	0.03	0.08	0.22	0.05
A2	4.628974	1	2.907238	0.329579	0.28	0.22	0.35	0.19	1.04	0.26
A3	3.546173	0.343969	1	0.239268	0.21	0.07	0.12	0.14	0.55	0.14
A4	7.472488	3.034173	4.17941	1	0.45	0.66	0.50	0.59	2.20	0.55
Total	16.65	4.594173	8 3/8	1.702672						1.000

λ Max = 4.184816
CI = 0.061605
CR = 0.06845

Notes:
A1 = Local Food Production
A2 = Infrastructure and Market Access
A3 = Nutrition Programs and Social Protection
A4 =Community-Based Food Institutions

λ Max = The average value of all criteria
CI = Consistency Index
CR = Consistency Ratio

Weight and Priority of Alternative based on the Acsess Criterion (C2)

Priority	Symbol	Alternative	Weight
1.	A4	Community-Based Food Institutions	0.55
2.	A2	Infrastructure and Market Access	0.26
3.	A3	Nutrition Programs and Social Protection	0.14
4.	A1	Local Food Production	0.05

The AHP results demonstrate a satisfactory level of consistency in respondents' judgments, as indicated by a Consistency Ratio (CR) of 0.068, which is well below the acceptable threshold of 0.10. This confirms the reliability of the derived priority weights and their suitability for supporting strategic decision-making.With respect to the food access criterion, community-based food institutions (A4) emerge as the highest-ranked alternative with a weight of 0.55, suggesting that the strengthening of local institutional arrangements is perceived as the most effective means of enhancing households' sustainable physical and economic access to food. Infrastructure development and market access (A2) occupy the second position with a weight of 0.26, underscoring the critical role of improved distribution facilities and market connectivity in alleviating spatial and economic constraints on food access. Nutrition programs and social protection (A3) rank third with a weight of 0.14, indicating that while these interventions contribute to supporting food access, their impact is considered complementary rather than primary. In contrast, local food

production (A1) receives the lowest priority (0.05), implying that increases in production alone are insufficient to substantially improve access in the absence of adequate institutional support and infrastructural connectivity. Overall, the priority order of alternatives under the food access dimension is A4 > A2 > A3 > A1.The prioritization of community-based food institutions (A4) as the main strategy for improving food access is consistent with the FAO framework and the Food Security and Vulnerability Atlas (FSVA) of the Indonesian National Food Agency (BPN).

FAO defines food access as the ability of households to obtain food physically and economically, which in remote areas is strongly influenced by institutional capacity, market functioning, and social networks [15]. FSVA data show that districts in the Papua Highlands, including Jayawijaya, face serious access constraints due to high transportation costs, limited market integration, and weak local institutions. In this context, community-based organizations such as farmer groups, cooperatives, and village food barns play an important role in organizing distribution, stabilizing prices, and ensuring fair access to food [16]. This explains why institutional strengthening (A4) received the highest priority. Infrastructure and market access (A2) ranked second, highlighting the importance of roads, storage, and market connectivity in reducing physical barriers and lowering food prices. Nutrition and social protection programs (A3) function mainly as support mechanisms for vulnerable groups, while local food production (A1) alone is not sufficient to improve access without adequate institutions and infrastructure.Overall, in line with FAO and BPN, improving food access in the Papua Highlands requires strengthening community-based institutions and supporting infrastructure, while production and social assistance play complementary roles.

5. Geometric Mean of the Alternative Comparison Matrix Based on the Stability Criterion.

Table 6. Geometric Mean of the Alternative Comparison Matrix Based on the Stability Criterion

Geometric Mean of the Alternative Comparison Matrix Based on the Stability Criterion										
Respondent					Eigenvalue				Total	Average
Alternatif	A1	A2	A3	A4						
A1	1	2.530898	5.314538	7.445803	0.58	0.64	0.51	0.46	2.19	0.55
A2	0.395117	1	3.727919	5.433333	0.23	0.25	0.36	0.34	1.17	0.29
A3	0.188163	0.268246	1	2.228372	0.11	0.07	0.10	0.14	0.41	0.10
A4	0.134304	0.184049	0.448758	1	0.08	0.05	0.04	0.06	0.23	0.06
Total	1.72	3.983193	10 1/2	16.10751						1.000

λ Max = 4.107667
CI = 0.035889
CR = 0.039877

Notes:
A1 = Local Food Production
A2 = Infrastructure and Market Access
A3 = Nutrition Programs and Social Protection
A4 =Community-Based Food Institutions

λ Max = The average value of all criteria
CI = Consistency Index
CR = Consistency Ratio

Weight and Priority of Alternative based on the Stability Criterion (C3)

Priority	Symbol	Alternative	Weight
1.	A1	Local Food Production	0.55
2.	A2	Infrastructure and Market Access	0.29
3.	A3	Nutrition Programs and Social Protection	0.10
4.	A4	Community-Based Food Institutions	0.06

The results of the Analytic Hierarchy Process (AHP) indicate that the pairwise comparison matrix for the stability criterion satisfies the consistency requirement, with a Consistency Ratio (CR) of 0.039, which is below the acceptable threshold of 0.10. This demonstrates that the respondents' judgments are consistent and reliable.Based on the priority weights, A1 (Local Food Production) ranks first with a weight of 0.55. This finding suggests that strengthening local food production is perceived as the most effective strategy for maintaining the stability of the food system, particularly in reducing dependence on external supplies and enhancing resilience to disruptions in production and distribution. Alternative A2 (Infrastructure and Market Access) ranks second with a weight of 0.29, underscoring the importance of adequate infrastructure and smooth market access in ensuring the continuity of food supply over time. Meanwhile, A3

(Nutrition Programs and Social Protection) obtains a weight of 0.10, indicating that although these programs play an important role in improving welfare, their contribution to long-term food system stability is considered relatively limited. Alternative A4 (Community-Based Food Institutions) has the lowest weight (0.06), suggesting that institutional strengthening alone is perceived to have a less direct impact on food stability compared to interventions in production and infrastructure. Overall, the priority order of alternatives under the stability criterion is A1 > A2 > A3 > A4.

The prioritization of local food production as the main determinant of food stability is consistent with the FAO framework and the vulnerability patterns reported by the Indonesian National Food Agency (BPN). FAO defines stability as the ability of a food system to ensure a continuous and reliable food supply over time and under various shocks. In the Papua Highlands, FSVA data from BPN indicate high vulnerability due to seasonal production fluctuations, limited regional food reserves, weak logistics, and strong dependence on external food inflows. These conditions explain why strengthening local production is viewed as the most effective strategy for reducing supply disruptions and enhancing system resilience [18].Infrastructure and market access rank second, in line with FAO and BPN's emphasis on the role of storage, transport, and market integration in buffering seasonal variability and maintaining supply continuity. In contrast, nutrition and social protection programs primarily function as short-term safety nets, while community-based institutions have a more indirect role in stabilizing supply. Overall, the convergence between AHP results, FAO's conceptual framework, and BPN's empirical data highlights that improving food stability in remote highland regions requires a structural focus on strengthening local production systems supported by adequate infrastructure.

6. Geometric Mean of the Alternative Comparison Matrix Based on the Ultilization Criterion.

Table 7. Geometric Mean of the Alternative Comparison Matrix Based on the Ultilization Criterion

Geometric Mean of the Alternative Comparison Matrix Based on the Ultilization Criterion										
Respondent					Eigenvalue				Total	Average
Alternatif	A1	A2	A3	A4						
A1	1	5.051178	4.757278	5.977056	0.634725	0.650759	0.65536	0.568201	2.509045	0.627261
A2	0.197974	1	1.052994	1.313843	0.125659	0.128833	0.14506	0.124899	0.524451	0.131113
A3	0.210204	0.949673	1	2.228372	0.133422	0.122349	0.137759	0.211837	0.605368	0.151342
A4	0.167306	0.761126	0.448758	1	0.106194	0.098058	0.061821	0.095064	0.361136	0.090284
Total	1.575484	7.761977	7.259031	10.51927						1

λ Max = 4.054252
CI = 0.018084
CR = 0.020093

Notes:
A1 = Local Food Production
A2 = Infrastructure and Market Access
A3 = Nutrition Programs and Social Protection
A4 =Community-Based Food Institutions
λ Max = The average value of all criteria
CI = Consistency Index
CR = Consistency Ratio

Weight and Priority of Alternative based on the Ultilization Criterion (C4)

Priority	Symbol	Alternative	Weight
1.	A1	Local Food Production	0.63
2.	A3	Nutrition Programs and Social Protection	0.13
3.	A2	Infrastructure and Market Access	0.15
4.	A4	Community-Based Food Institutions	0.09

The AHP results for the utilization criterion indicate that Alternative A1 (Local Food Production) attains the highest priority weight (0.6273), identifying it as the most important factor in enhancing food utilization. This is followed by Alternative A3 (Nutrition Programs and Social Protection) and Alternative A2 (Infrastructure and Market Access), which obtain moderate weights of 0.1513 and 0.1311, respectively. Alternative A4 (Community-Based Food Institutions) records the lowest weight (0.0903), suggesting a relatively smaller contribution compared to the other alternatives.The Consistency Ratio (CR) of 0.020, which is well below the acceptable threshold of 0.10, confirms that the respondents' judgments are consistent

and reliable. Overall, these findings indicate that strengthening local food production constitutes the primary strategy for improving the utilization dimension of food security, while nutrition and social protection programs, infrastructure development, and community-based institutional strengthening play complementary supporting roles.The dominance of local food production (A1) under the utilization criterion is consistent with the FAO food security framework and the empirical evidence reported by the Indonesian National Food Agency (BPN).

FAO defines food utilization as the proper biological use of food, which depends not only on nutritional quality, food safety, and health services, but also on the stability and diversity of food supplies at the household level. In remote highland regions, limited and monotonous food availability often constrains dietary diversity and nutrient intake, thereby directly affecting utilization outcomes.BPN's Food Security and Vulnerability Atlas (FSVA) indicates that districts in the Papua Highlands, including Jayawijaya, exhibit high prevalence of stunting, undernutrition, and limited dietary diversity, which are closely associated with insufficient and unstable local food production. The prioritization of local food production in this study therefore reflects the critical role of increasing the availability and diversity of locally produced foods in improving dietary quality and nutritional intake, in line with FAO's emphasis on food-based approaches to nutrition.The moderate ranking of nutrition programs and social protection (A3) is also supported by FAO and BPN, which recognize the importance of targeted interventions—such as supplementary feeding, conditional cash transfers, and school feeding programs—in addressing short-term nutritional deficiencies and protecting vulnerable groups.

However, both institutions emphasize that such programs are most effective when supported by adequate and diverse food supplies, which explains their complementary rather than primary role in the utilization dimension.Similarly, the role of infrastructure and market access (A2) in facilitating food utilization is acknowledged in FAO and BPN reports, particularly in relation to improving food safety, reducing post-harvest losses, and enhancing access to diverse foods through better storage and transportation. Nevertheless, without sufficient local production, improvements in infrastructure alone are unlikely to substantially enhance dietary quality. The relatively low priority of community-based food institutions (A4) suggests that, while institutional arrangements are important for coordination and program delivery, their direct impact on nutritional outcomes is limited in the absence of adequate food availability and diversity. Overall, the convergence between the AHP results, FAO's conceptualization of utilization, and BPN's nutritional vulnerability data underscores that strengthening local food production is a prerequisite for improving food utilization and nutritional outcomes in the Papua Highlands, with social protection, infrastructure, and institutional support functioning as complementary components within an integrated food systems approach.

7. Ranking of All Alternatives Based on the Geometric Mean.

Table 8. Ranking of All Alternatives Based on the Geometric Mean

Ranking of All Alternatives Based on the Geometric Mean		No. Rank
Local Food Production	0.494193	1
Infrastructure and Market Access	0.236154	2
Nutrition Programs and Social Protection	0.092641	4
Community-Based Food Institutions	0.177011	3

The ranking of alternatives based on the geometric mean indicates that Local Food Production occupies the first position with the highest weight, suggesting that local production capacity constitutes the primary determinant of the food system under analysis. This finding underscores the strategic role of upstream interventions in ensuring both the availability and sustainability of food supplies, thereby providing the foundation for the effectiveness of subsequent interventions across other components of the system. Infrastructure and Market Access ranks second, reflecting the critical importance of physical infrastructure and market connectivity in optimizing production performance. Adequate infrastructure facilitates efficient distribution, reduces post-harvest losses, and enhances the affordability and accessibility of food, thereby

strengthening linkages between producers and consumers. Community-Based Food Institutions are positioned third, indicating that community-level institutional arrangements function as supportive mechanisms in improving governance, coordination, and social participation, although their contribution is relatively smaller than that of structurally oriented interventions in production and infrastructure.Finally, Nutrition Programs and Social Protection occupy the lowest rank, implying that nutritional interventions and social safety nets are perceived primarily as corrective and protective measures for vulnerable groups rather than as the main drivers of systemic transformation.

Overall, these results suggest that strategies for enhancing food security should prioritize strengthening local food production and supporting infrastructure, while institutional and social interventions play complementary roles in fostering a sustainable food system. The overall ranking, which places Local Food Production as the top priority, is consistent with the FAO food security framework and the Food Security and Vulnerability Atlas (FSVA) of the Indonesian National Food Agency (BPN). Both emphasize that strengthening local production is fundamental for improving food availability and reducing dependence on external supplies, particularly in remote and highland regions with structural constraints. The second priority assigned to Infrastructure and Market Access reflects the critical role of logistics, storage, and market connectivity in supporting efficient distribution and minimizing post-harvest losses, as highlighted by FAO and BPN.Community-Based Food Institutions, ranked third, contribute to improving coordination and governance but are less influential than structural investments in production and infrastructure. Nutrition Programs and Social Protection function primarily as safety nets for vulnerable groups rather than as drivers of systemic change. Overall, the convergence of the AHP results with FAO and BPN evidence indicates that food security strategies in the Papua Highlands should prioritize strengthening local food production supported by infrastructure development, while institutional and social interventions play complementary roles.

IV. CONCLUSION AND RECOMMENDATIONS

Conclusion

This study applied the Analytic Hierarchy Process (AHP) to prioritize food security strategies in the Papua Highlands based on the four FAO dimensions: availability, access, stability, and utilization. The results demonstrate that food availability is the most critical criterion, followed by access, stability, and utilization. This hierarchy reflects the structural constraints of the region, particularly limited local production capacity, high dependence on external food supplies, weak infrastructure, and geographic isolation.Across all criteria, Local Food Production consistently emerged as the highest-priority alternative, indicating that strengthening community-based agricultural production is the most strategic intervention for improving food security.

Infrastructure and Market Access ranked second, underscoring the importance of transportation, storage, and market connectivity in supporting production and reducing distribution bottlenecks. Community-Based Food Institutions occupied the third position, highlighting their supportive role in governance, coordination, and collective action. Nutrition Programs and Social Protection were ranked last, suggesting that these interventions primarily function as safety nets and corrective mechanisms rather than as structural drivers of food system transformation.The convergence between the AHP results, the FAO food security framework, and empirical evidence from the Food Security and Vulnerability Atlas (FSVA) of the Indonesian National Food Agency (BPN) confirms that structural strengthening of local food systems—centered on production and supported by infrastructure—constitutes the most effective pathway for enhancing food security and resilience in the Papua Highlands.

Recommendations

Based on the findings, several policy and programmatic recommendations can be proposed:

1. Prioritize Strengthening Local Food Production Government and development programs should focus on increasing the productivity, diversity, and sustainability of local agriculture through support for smallholder farmers, provision of quality inputs, extension services, and climate-resilient farming practices.

2. Improve Infrastructure and Market Connectivity Investments in roads, storage facilities, transportation systems, and local markets are essential to reduce post-harvest losses, stabilize food prices, and enhance physical and economic access to food.
3. Strengthen Community-Based Food Institutions The capacity of farmer groups, cooperatives, and village food barns should be enhanced to improve coordination, collective marketing, food reserve management, and local governance of food systems.
4. Integrate Nutrition and Social Protection as Complementary Measures Programs such as school feeding, maternal and child nutrition interventions, and social assistance should be aligned with local food production initiatives to ensure that increased availability translates into improved dietary quality and nutritional outcomes.
5. Adopt an Integrated Food Systems Approach Future food security policies in the Papua Highlands should be formulated using a holistic framework that links production, infrastructure, institutions, and social protection, in line with FAO and BPN recommendations, to build a resilient and sustainable local food system.

Overall, a development strategy that prioritizes local food production and supporting infrastructure, while strengthening institutions and maintaining social protection for vulnerable groups, is crucial for achieving long-term food security and reducing structural vulnerability in the Papua Highlands.

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REFERENCES

[1] M. A. Usman and D. Callo-Concha, “Does market access improve dietary diversity and food security? Evidence from Southwestern Ethiopian smallholder coffee producers,” Agricultural and Food Economics, vol. 9, no. 1, p. 18, Dec. 2021, doi: 10.1186/s40100-021-00190-8.

[2] M. A. Usman and M. G. Haile, “Market access, household dietary diversity and food security: Evidence from Eastern Africa,” Food Policy, vol. 113, p. 102374, Nov. 2022, doi: 10.1016/j.foodpol.2022.102374.

[3] V. Camacho-Vallejo and A. Totosaus, “Food Availability, Accessibility, and Affordability through the Scope of Food Security Level and Food Environment Perception in Mexico City’s Marginated Area,” ***Journal of Nutrition and Food Security***, Feb. 2025, doi: 10.18502/jnfs.v10i1.17768.

[4] D. Bernaschi, D. Marino, A. Cimini, and G. Mazzocchi, “The Social Exclusion Perspective of Food Insecurity: The Case of Blacked-Out Food Areas,” Sustainability, vol. 15, no. 4, p. 2974, Feb. 2023, doi: 10.3390/su15042974.

[5] A. Drewnowski, E. C. Monterrosa, S. de Pee, E. A. Frongillo, and S. Vandevijvere, “Shaping Physical, Economic, and Policy Components of the Food Environment to Create Sustainable Healthy Diets,” Food Nutr. Bull., vol. 41, no. 2_suppl, Dec. 2020, doi: 10.1177/0379572120945904.

[6] A. A. Hailu, S. Thornhill, M. Tessema, A. B. Weldesilassie, and E. Lahiff, “The influence of the food environment on diet quality: Insights from an extensive household survey in Ethiopia, focusing on women of reproductive age,” BMC Nutr., vol. 11, no. 1, p. 107, Jun. 2025, doi: 10.1186/s40795-025-01097-z.

[7] G. M. Vedovato, S. H. Ali, C. M. Lowery, and A. C. B. Trude, “Giving Families a Voice for Equitable Healthy Food Access in the Wake of Online Grocery Shopping,” Nutrients, vol. 14, no. 20, p. 4377, Oct. 2022, doi: 10.3390/nu14204377.

[8] Drysdale, Skinner, Lazarescu, Couture, Young, and Idzerda, “Initiatives and exposures associated with food security in remote and isolated communities: a scoping review,” Rural Remote Health, Aug. 2024, doi: 10.22605/RRH8627.

[9] A. Bryce Hoflund, John C. Jones, and Michelle C. Pautz, The Intersection of Food and Public Health. Routledge, 2017. doi: 10.1201/9781315153094.

[10] E. C. Okanmelu *et al.*, “Supporting community health workers in South Africa for context-specific food and nutrition literacy: implementation of a multi-media education-entertainment intervention,” BMC Nutr., vol. 11, no. 1, p. 144, Jul. 2025, doi: 10.1186/s40795-025-01124-z.

[11] E. Muehlhoff, R. Wijesinha-Bettoni, E. Westaway, T. Jeremias, S. Nordin, and J. Garz, “Linking agriculture and nutrition education to improve infant and young child feeding: Lessons for future programmes,” Matern. Child Nutr., vol. 13, no. S2, Oct. 2017, doi: 10.1111/mcn.12411.

[12] J. Schmidhuber and I. Matuschke, “Shift and swing factors and the special role of weather and climate,” in Food Crises and the WTO, Cambridge University Press, 2010, pp. 136–164. doi: 10.1017/CBO9780511712005.007.

[13] S. K. Young and H. Stewart, “U.S. Fruit and Vegetable Affordability on the Thrifty Food Plan Depends on Purchasing Power and Safety Net Supports,” ***Int. J. Environ. Res. Public Health***, vol. 19, no. 5, p. 2772, Feb. 2022, doi: 10.3390/ijerph19052772.

[14] J. Hutagalung, “Application of the AHP-TOPSIS Method to Determine the Feasibility of Fund Loans Penerapan Metode AHP TOPSIS untuk Menentukan Kelayakan Pinjaman Dana,” ***Jurnal_Pekommas***_*Vol._6_No._1*, pp. 1–11, 2021, doi: 10.30818/jpkm.2021.2060101.

[15] “FAO 2015”.

[16] Badan Pangan Nasional, “Ringkasan Peta Ketahanan Dan Kerentanan Pangan 2025,” 2025.

[17] A. E. Stratton, L. Kuhl, and J. Blesh, “Ecological and Nutritional Functions of Agroecosystems as Indicators of Smallholder Resilience,” Front. Sustain. Food Syst., vol. 4, Oct. 2020, doi: 10.3389/fsufs.2020.543914.

[18] G. Jackson, K. E. McNamara, and B. Witt, “‘System of hunger’: Understanding causal disaster vulnerability of indigenous food systems,” ***J. Rural Stud.***, vol. 73, pp. 163–175, Jan. 2020, doi: 10.1016/j.jrurstud.2019.10.042.