Jurnal Agrisep: Kajian Masalah Sosial Ekonomi Pertanian dan Agribisnis. 25 (01): 341–362 (2026)

AGRISEP: Journal of Agricultural Socio-Economics and Agribusiness Studies

https://ejournal.unib.ac.id/agrisep

RESEARCH ARTICLE

DOI: https://doi.org/10.31186/jagrisep.25.01.341-362

STRATEGIC FACTORS INFLUENCING THE SUSTAINABILITY OF INDONESIA'S FOOD ESTATE PROGRAM IN CENTRAL KALIMANTAN: A MICMAC APPROACH

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ARTICLE INFO

Keywords:
Borneo island,
Food estate,
Sustainability,
MicMac

ABSTRACT

The Food Estate program, a national initiative to strengthen food security through increased food production on peatlands, faces substantial challenges, including difficult land conditions, inadequate infrastructure, and potential social and environmental impacts such as land degradation and community displacement. This study aims to identify key factors influencing the sustainability of the Food Estate program in the Kapuas and Pulang Pisau districts, Central Kalimantan, by employing the MICMAC method (Matrix of Crossed Impact Multiplications Applied to a Classification). Primary data were collected through interviews with 50 respondents, consisting of 20 farmer group members and 30 individuals from relevant institutions and stakeholders. The findings reveal that government policies and infrastructure are the dominant factors directly and indirectly influencing the program's success. Both the Matrix of Direct Influences (MDI) and the Matrix of Indirect Influences (MII) consistently identify government policies and infrastructure as key driving variables. Conversely, variables such as local economy and agricultural technology demonstrate a high level of dependence on other factors, particularly government policies and infrastructure. These results underscore the importance of strong policy frameworks and robust infrastructural support for program viability. Recommendations include the need for sustainable policy enhancement, accelerated development of supporting infrastructure, improved market access, and adaptive technology training for farmers. Addressing social and environmental considerations alongside economic factors will be crucial for the long-term success and sustainability of the Food Estate program in Central Kalimantan.

Submitted:
21 December 2024
Revised:
12 December 2025
Accepted:
17 December 2025

***Cite as*:**
Ompusunggu, D. P., Rakhmawati, D., Husnatarina, F., Suherman, Tiur Roida Simbolon, T. R., & Nasrida, M. F. (2026). Strategic Factors Influencing the Sustainability of Indonesia's Food Estate Program in Central Kalimantan: A MICMAC Approach. *Jurnal AGRISEP: Kajian Masalah Sosial Ekonomi Pertanian dan Agribisnis*, 25(01), 341-362. https://doi.org/10.31186/jagrisep.25.01.341-362

INTRODUCTION

Maintaining long-term food security for Indonesia's population continues to be a major challenge. A central strategy that has been implemented is the Food Estate program, which seeks to develop extensive agricultural zones to increase national production. One of the main locations for food estate development is Central Kalimantan province, with a focus on Kapuas and Pulang Pisau districts. This area was chosen due to the availability of large areas of land, around 164,598 hectares in Pulang Pisau and 293,488 hectares in Kapuas, which have the potential to develop food commodities such as rice, corn and cassava (Ministry of Agriculture, 2020; Mahardhika et al., 2023).

The Food Estate Program in Central Kalimantan is projected to play an important role in strengthening Indonesia's food security, particularly by supporting the national food security agenda and enhancing community nutrition through the availability of high-quality food (Rasman et al., 2023). In addition, the program is also expected to lessen reliance on food imports and improve the well-being of local communities by creating employment opportunities and boosting regional economic development (Coordinating Ministry for Economic Affairs, 2021).

Nevertheless, the execution of the Food Estate program in Central Kalimantan encounters a range of obstacles. The development of food estates on swampland faces major challenges in the development of irrigation infrastructure and agricultural roads, land preparation, selection of cultivation technology, and the application of local wisdom (Wahyudi, 2022). Peatlands have a high level of acidity with a pH ranging from 3.0 to 5.0, which can inhibit plant growth if not managed properly (Saputra, 2023). Moreover, the adoption of modern agricultural technologies, such as precision agriculture and high-yielding crop varieties, can significantly increase productivity and resilience to climate change (Bappenas, 2020; Yeny, 2022).

In addition to natural factors, the success of the Food Estate also relies heavily on infrastructure support and sustainable government policies (Ihsannudin et al., 2016). Good infrastructure will help increase agricultural productivity and reduce the impact of environmental damage (Risdianto, 2024). Data shows that inadequate infrastructure can lead to decreased production and difficulties in distributing agricultural products to the market, which impacts price stability and program sustainability (Ihsannudin et al., 2016). In this case, the government's policy in realizing food security is shown by the government's active role in building a good and resilient food security system (Salasa, 2021). From a political–economy perspective, decisions on large-scale land allocation, investment priorities, and incentive structures are central elements that link public policy choices to outcomes in food security, employment, and local economic growth.

Several studies have shown that a structured approach to identifying factors affecting the sustainability of food estate programs can provide deep insights. The MICMAC method, introduced by Duperrin and Godet, has been widely used in analyzing the interrelationships between variables in complex systems, such as regional competitiveness, infrastructure provision, and policy implementation (Durance & Godet, 2011; Soesanto, 2021). This method allows researchers to map the key factors that influence program sustainability, such as infrastructure support, agricultural technology, local community involvement, and government policies.

This article contributes to that literature by adapting the MICMAC method to a comprehensive sustainability framework for a peatland-based food estate. First, the study operationalizes six dimensions—reinforcing factors, human resources, market, environment, economic sustainability, and social sustainability—into 23 interrelated variables specifically tailored to the Central Kalimantan Food Estate context (Liana et al., 2024). Second, it integrates expert-based structural analysis with systematic validation procedures (FGD, content validation, and consistency checks), thereby strengthening the robustness of the MICMAC application in policy-oriented agricultural research. Compared to previous MICMAC studies that generally focus on regional competitiveness indices or industrial systems, this article emphasizes the configuration of variables that directly shape food security outcomes, farmer livelihoods, and local economic dynamics in a state-led agricultural megaproject

A structured approach is crucial because food estate programs involve multiple interconnected components that influence their long-term viability. The MICMAC method is particularly effective in assessing direct and indirect relationships among variables, helping policymakers and stakeholders identify leverage points for intervention. For example, infrastructure development, such as irrigation systems and transportation networks, plays a vital role in ensuring the success of food estates by facilitating efficient agricultural production and distribution (Benjumea-Arias et al., 2016; Santoso & Widodo, 2023). Similarly, the adoption of modern agricultural technology, such as precision farming and high-yield crop varieties, can significantly enhance productivity and resilience against climate change, while cooperation between the government, academic personnel, and industry is very important in encouraging the application of modern agricultural technology to achieve better food security in the future (Rachmawati, 2020; Zai et al., 2025.

Community involvement is another critical factor in ensuring the sustainability of food estates. When local communities actively participate in decision-making processes and benefit from agricultural initiatives, they are more likely to support and sustain these programs over time (Rasman et al., 2023). Social and economic incentives, such as land tenure security and financial assistance, can further enhance community engagement (Soesanto, 2021). Moreover, government policies, including regulatory frameworks, subsidies, and market access facilitation, are essential in creating an enabling environment for food estate development (Durance & Godet, 2011). In this sense, political decision-making determines how risks and benefits are distributed among actors and how far food estate projects contribute to wider development goals such as job creation, poverty reduction, and regional economic diversification.

In the context of food estates, these variables do not stand alone but interact with each other and have a significant reciprocal influence on the overall success of the program. A systemic perspective is necessary to understand how these factors reinforce or hinder one another, ultimately affecting the sustainability of food estate initiatives. This study therefore aims to explore the key factors that influence the sustainability of the Food Estate program in Central Kalimantan using the MICMAC approach and to map how these factors relate to concrete outcomes in terms of food security, agricultural production, job creation, and local economic growth. By identifying strategic variables and their position in the influence–dependence structure, the article provides an analytical basis for designing policy interventions that are more targeted, coherent, and responsive to the specific challenges of peatland-based agriculture. The results of this study are expected to provide strategic recommendations for the government and relevant stakeholders to improve the effectiveness and efficiency of the program so that the Food Estate can contribute to providing quality and affordable food, expanding decent employment opportunities, and strengthening inclusive economic development in Central Kalimantan and, more broadly, in Indonesia.

RESEARCH METHOD

This study was carried out in two main Food Estate development areas in Central Kalimantan Province, namely Kapuas Regency and Pulang Pisau Regency, which serve as the core zones of the national Food Estate program. These regions were selected due to their extensive peatland areas and their inclusion in the National Strategic Project (PSN) for food security (Ministry of Agriculture, 2020; Bappenas, 2021).

To enhance clarity in presenting the research setting, this article includes a location map that illustrates the study are, as shown in Figure 1, Figure 2, and Figure 3.

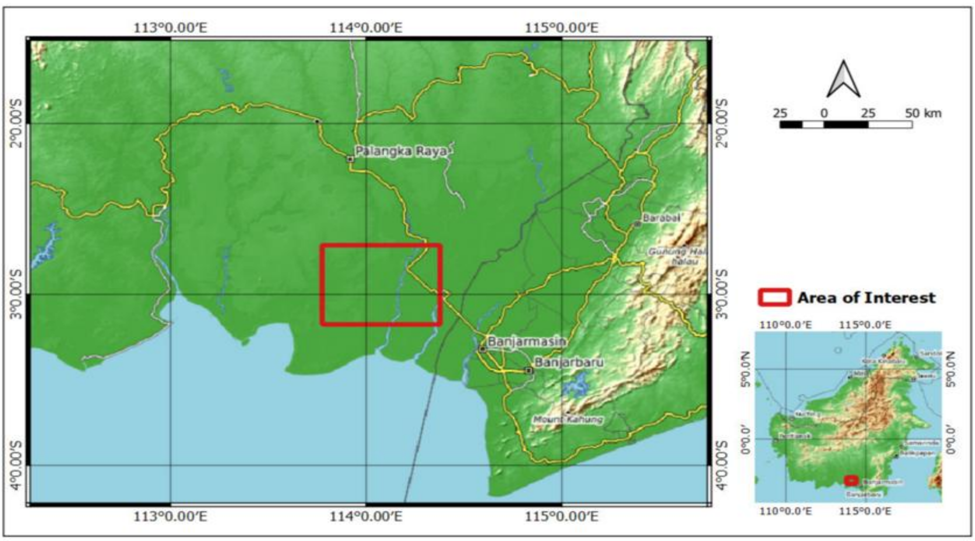

Figure 1.
Administrative boundaries of Kapuas and Pulang Pisau Regencies

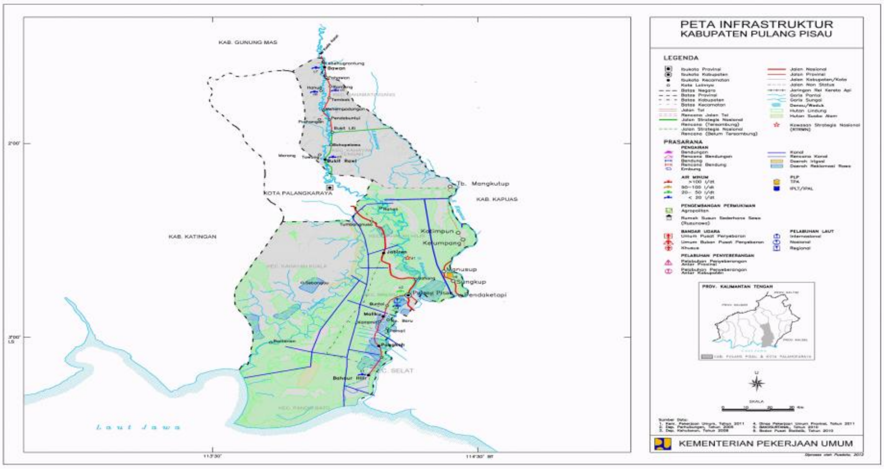

Figure 2.
Specific Food Estate clusters, Including Designated Cultivation Blocksies

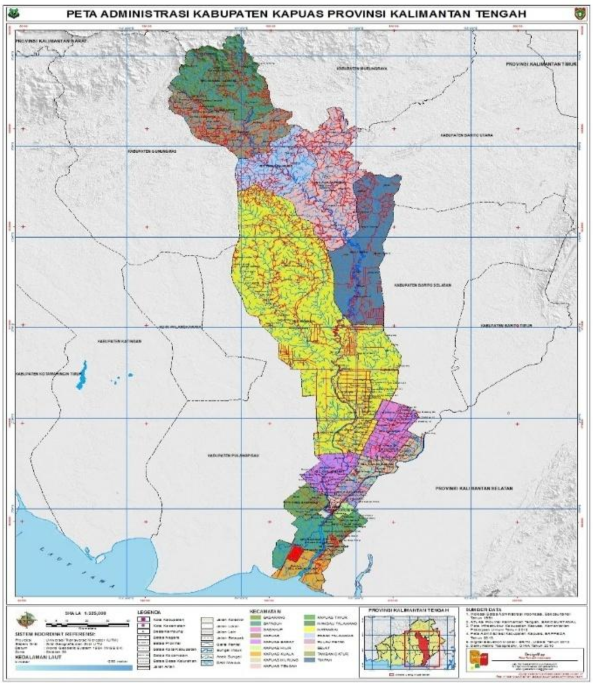

Figure 3.
Accessibility features, such as Primary Road Networks and River Systems and Legend Identifying Research Villages, District Boundaries, and Peatland Zones

The map is adapted from authoritative sources such as the Geospatial Information Agency (BIG) and the Central Kalimantan Provincial Planning Agency (Bappeda Kalteng) to ensure accuracy and cartographic reliability. The inclusion of this map allows readers to clearly understand the geographical context, spatial distribution of the project area, and environmental characteristics that influence agricultural activities in peatland ecosystems.

Kapuas Regency covers approximately 17,514 km², with key Food Estate locations concentrated in the districts of Dadahup, Kapuas Murung, and Mantangai. Meanwhile, Pulang Pisau Regency covers around 8,997 km², with program implementation centered in Pandih Batu and Maliku districts (BPS Kalimantan Tengah, 2023). These areas consist predominantly of peatland with varying depths and hydrological sensitivity, making them critical for evaluating sustainability challenges in large-scale agricultural programs.

The categories of data collected in this study consist of primary data and secondary data, each obtained through a systematic and transparent process. Primary data refer to data collected directly from respondents and field settings. These data were obtained through structured questionnaires, in-depth interviews, and field observations. The structured questionnaires were used to measure the direct and indirect relationships among the variables in the MICMAC framework. Respondents included members of farmer groups, agricultural extension workers, and stakeholders from relevant institutions at the district level who are directly involved in the implementation of the Food Estate program. In-depth interviews were conducted with key informants such as government officials, agricultural officers, and local institutional actors to validate the relevance of the variables, clarify the inter-variable influence, and confirm the challenges encountered in the field. Field observations were also carried out to verify infrastructure conditions, land suitability, peat characteristics, and the operational activities of the Food Estate areas.

Secondary data refers to supporting information obtained from credible and official sources. These include regional statistical reports, agricultural and land-use data from Statistics Indonesia (BPS Kalimantan Tengah, 2023), official Food Estate program documentation from the Ministry of Agriculture (2020) and Bappenas (2021), as well as geospatial datasets and administrative maps issued by the Geospatial Information Agency (BIG). Relevant academic literature, policy analyses, and studies concerning large-scale agricultural programs and peatland management from FAO and other reputable scientific publications were used to strengthen the theoretical background and assist in the formulation and refinement of the research variables.

In this study, the term "variable" is used consistently, as each component represents measurable and analytically interpretable elements within the MICMAC structural analysis. The variables were developed based on six sustainability dimensions: reinforcing factors, human resources, market, environment, economic sustainability, and social sustainability. These dimensions were operationalized into specific variables derived from literature review, expert consultation, and field verification. As referenced in this section, Table 1—which presents the full list of variables, their descriptions, and dimensional classification—appears immediately after this paragraph to maintain clarity and consistency with academic writing standards.

Analysis Method

Data analysis was conducted using a prospective method through the MICMAC approach. MICMAC performs analysis, mapping, and identification of key variables. The results of this analysis can be used as a tool in planning policy strategies, especially to identify and conclude various relationships between factors in certain problems or issues (Godet & Durance, 2011). This study follows the procedures that have been established in the sustainability analysis series using the MICMAC application (Harsuko, et al. 2023).

Methodological validation was carried out through the following stages. First, the selection of panel experts was carried out purposively by considering their competence, experience, and scientific relevance to the issues being studied. The involvement of experts from various backgrounds is anticipated to enrich perspectives and minimize potential bias. Second, content validity was tested through a comprehensive literature study, variable screening based on theoretical and practical relevance, and confirmation of the variable list through focus group discussions (FGD) with experts. This step ensures that all variables described do indeed represent the situation as a whole. Third, a consistency check was carried out by checking the results of filling in the matrix between experts, identifying potential discrepancies, and discussing significant differences to reach a more stable agreement. Fourth, validation of the final results is carried out by returning the variable classification map to the experts to obtain confirmation of the fairness of the analysis results. This stage is important to ensure that the research findings are in line with the theoretical knowledge and practical experience of the experts, so that they have strong face validity. Fifth, the entire analysis process is documented in detail to ensure methodological transparency. This documentation includes variable selection, matrix preparation, expert filling process, and the interpretation of the results. This comprehensive documentation allows the research to be replicated or verified by other parties, which ultimately increases the credibility of the overall research.

It should be noted that since MICMAC is a qualitative-structural analysis method, formal statistical validity tests such as internal reliability tests (e.g., Cronbach's alpha) were not applied. Nevertheless, the combination of data triangulation approaches, expert involvement, content validation, and reflection of results is considered sufficient to ensure methodological validity in the context of this study. With this comprehensive validation approach, the results of this study will be able to provide an accurate, in-depth, and accountable picture of the structure of influence between the variables that are the focus of the study.

The process of analyzing the data from filling out the questionnaire using MICMAC is by converting the weight of each variable into a matrix of direct influence (MDI) as presented in Table 2. According to Fauzi (2019), the stages of MICMAC analysis are based on two main stages. The first stage is understanding the scope of the problem and the system to be studied. The flow of analysis using MICMAC can be seen in Figure 4. For better clarity, this article should be supported by a location map. It is easy to provide such a map. Please clearly indicate the research location by adding an appropriate map legend.

	Var 1	Var 2	Var 3 . . .	Var n	Influence (Y-Axis)
Var 1	0	(V1,2)	(V1,3) . . .	(V1,n)	$\sum_{j=1}^{n}(Var_1, j)$
Var 2	(V2,1)	0			
Var 3	.				
.	.				
.	.				.
Var n	(Vn,1)			0	
Dependence (X-Axis)	$\sum_{i=1}^{n}(Var_i, 1)$ ..			...	

Figure 4.
Matric of Direct Influence

The next stage is to analyze the intensity of influence and dependence between variables determined by the location of variables on the quadrant map. The structural classification of variables based on their influence and dependence is further illustrated in Figure 5.

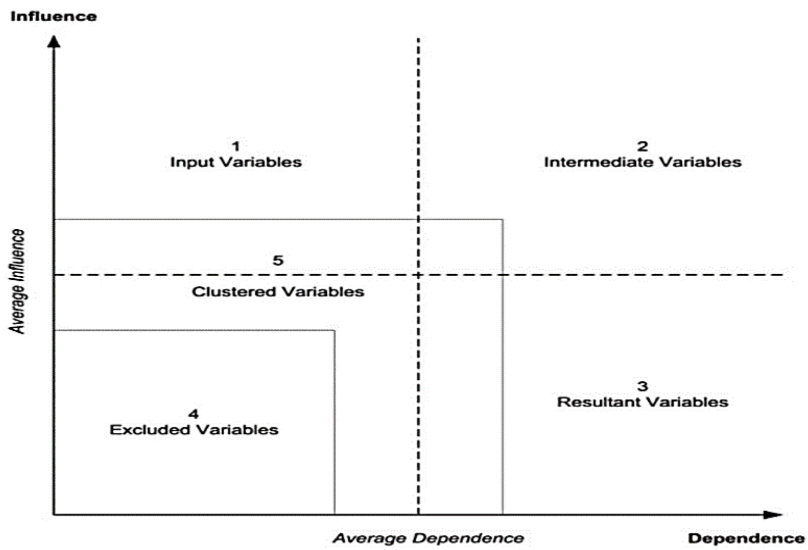

Figure 5.
Illustration of MICMAC Analysis (Godet, 1994; Chatziioannou and Alvarez-Icaza, 2017)

Table 1. The Relationship Between Influence and Dependence

Dimension[a)]	Variables/ Attribute[b)]	Short Labels
Amplifying Factor	Institution	(Inst)
	Infrastructure	(Infr)
	Local Economy	(Econ)
	Government Policy	(GovPol)
	Business Capital	(Cap)
Human Resources	Agricultural Technology	(AgTech)
	Level of Education	(Educ)
	Farmer Experience	(Exp)
	Farmer Training and Guidance	(Train)
Market	Market Access	(MktAcc)
	Product Price	(ProdPrice)
	Distribution	(Distrib)
	Product Marketing	(Mktng)
Environment	Land Quality)	(LandQlty)
	Water Availability	(Water)
	Climate Conditions	(Climate)
	Waste Managemen	(WasteMngmt)
Economic Sustainability	Farmer Income	(Income)
	Local Industry Development	(LocIndDev)
	Financial Sustainability	(FinSus)
Sosial Sustainability	Community Involvement	(ComInv)
	Job Diversity	(DivJobs)
	Access to Education	(PedAccess)

[a)]Kemenristekdikti BRIN (2019); [b)] data processed from FGD

RESULT AND DISCUSSION

The results of the direct influence matrix (MDI) show that government policy, infrastructure, and institutional capacity are the most influential variables determining the sustainability of the Food Estate program in Central Kalimantan. Government policy consistently appears as the strongest driver due to its role in regulating land allocation, budget distribution, and program governance. This finding aligns with national and international evidence that state-led agricultural programs are highly policy dependent (FAO, 2021; Bappenas, 2020).

Infrastructure also holds a dominant influence, as limited irrigation channels, access roads, and supporting facilities directly constrain productivity and market access. Similar patterns have been documented in agricultural development across peatland and marginal areas, where infrastructure gaps significantly increase production risks and transaction costs (World Bank, 2020; Liu et al., 2019). Institutional capacity supports these drivers by facilitating coordination, extension services, and local decision-making, reinforcing its strategic importance.

In contrast, variables such as local economy and farmer income exhibit high dependency, indicating that economic outcomes strongly rely on policy effectiveness, infrastructure readiness, and institutional performance. This relationship reflects commonly observed dynamics in rural development, where socio-economic gains depend on upstream structural factors (IFAD, 2019).

Agricultural technology, product prices, and farmer training function as dependent variables influenced by policy and infrastructure conditions. Their limited influence suggests that technological adoption and farmer capacity building cannot be optimized without improvements in foundational system drivers—consistent with findings on sustainable agriculture interventions in peatland ecosystems (Yeny et al., 2022).

The indirect influence matrix (MII) strengthens these patterns. Government policy and infrastructure retain their top positions, demonstrating long-term systemic effects. Meanwhile, economic variables become even more dependent when indirect interactions are considered, highlighting their sensitivity to structural conditions.

The overall system shows strong interdependencies, where improvements in key drivers are expected to generate broad positive effects on productivity, farmer income, and local economic development. These findings emphasize the need for prioritizing policy coherence, infrastructure enhancement, and institutional strengthening to achieve sustainable outcomes in the Food Estate program.

Matrix of Direct Influence

Based on the analysis of questionnaire responses and Focus Group Discussion (FGD) data, a set of variables was identified, defined, and quantified, resulting in the construction of a direct influence matrix, as presented in Table 1. Using the MICMAC approach, the Matrix of Direct Influence (MDI) was subsequently transformed into a variable mapping diagram, which illustrates the influence–dependence relationships among variables by classifying them into four distinct sectors or quadrants (Figure 4).

The processing of data obtained from questionnaires and FGDs enabled the identification of key variables that affect the sustainability of the Food Estate program in Central Kalimantan. Each variable was assessed and quantified according to the strength of its influence, allowing for a more comprehensive analysis of inter-variable relationships. This procedure produced the Matrix of Direct Influence (MDI), which highlights the direct interactions among variables and helps determine those with a dominant role within the system.

Through the MICMAC method, the MDI results were visualized into an influence–dependence map, also known as the Matrix of Data Influence, to facilitate interpretation. This map represents the degree of influence and dependence among variables, positioning each variable based on its level of influence on other variables and its dependence on the system. As a result, the variables were categorized into four sectors or quadrants (see Figure 6), including:

1. Determinant Variables: Variables characterized by a high level of influence and low dependence. These variables play a crucial role in shaping system outcomes, as they significantly affect other variables while being relatively independent of external influences.

2. Key Variables: Variables that exhibit both high influence and high dependence. These variables are central to the system and are critical to the success of the program; however, their effectiveness is strongly influenced by interactions with other variables.
3. Result Variables: Variables that have low influence but high dependency. Other variables influence these variables in the system and show the result or impact of changes in other variables.
4. Autonomous Variables: Variables that have low influence and low dependency. These variables function as supporting variables and have minimal involvement in determining the overall sustainability of the program.

Through this mapping, the influence–dependence diagram enables the identification of strategic variables that must be managed effectively to enhance the success of the Food Estate program. Variables located in the Determinant Variables quadrant require priority attention, as they exert a strong influence on the overall system while having relatively low dependence on other factors. Conversely, variables classified as Result Variables represent the outcomes of interactions among other variables and can therefore serve as indicators for evaluating the effectiveness of program implementation. By utilizing this mapping, policymakers and stakeholders are able to gain a clearer understanding of the complex relationships and dynamics among variables within the Food Estate program.

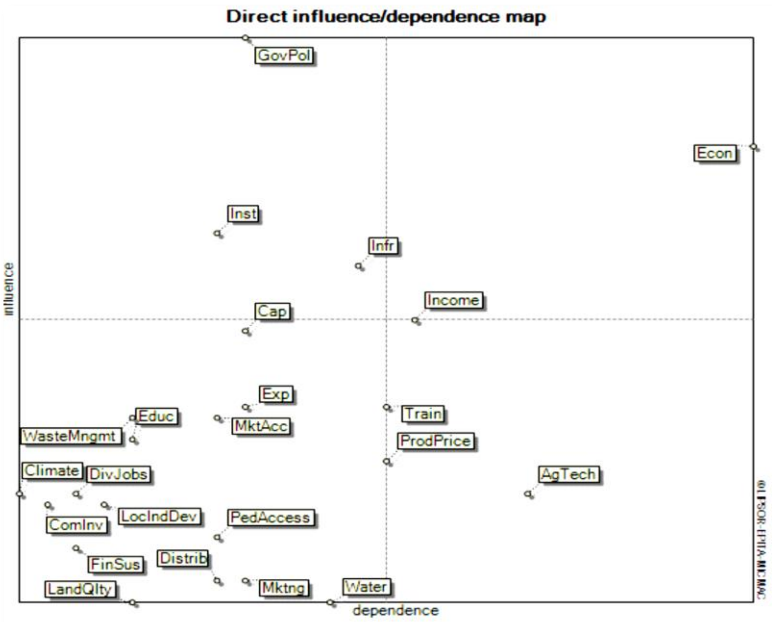

Figure 6.
Position of a System Variable in the Direct Influence-Dependence Map

Quadrant I – Determinant Variables (High Influence, Low Dependence): variables that strongly influence the system but are not heavily affected by other variables; Quadrant II – Key/Labile Variables (High Influence, High Dependence): variables that both significantly influence and are influenced by other variables; typically unstable and highly sensitive; Quadrant III – Result Variables (Low Influence, High Dependence): variables that represent outcomes or downstream effects within the system; Quadrant IV – Autonomous Variables (Low Influence, Low Dependence): variables that have minimal interaction with the rest of the system

Based on the results of the MICMAC analysis, the variables in the first quadrant (determinant variables) are government policy (GovPol), institutions (Inst), and infrastructure (Infr). The characteristics of the first quadrant are variables that have a high level of influence and low dependence. Then variables with strong influence with high dependency, but unstable relationships between variables in the second quadrant (key variables) are the local economy (Econ) and farmer income (Income). Based on the findings in the field, the variables education level and market access were identified as being in the low quadrant in the MICMAC analysis, namely having low driving power and low dependence. This shows that these two variables are not the main driving factors for system change, nor are they factors that are greatly influenced by changes in the system.

More specifically, the level of education affects the quality of human resources (HR), so it is seen as a background factor or long-term supporting factor. In the context of the system being studied, improvements in the level of education do not immediately drive major policy changes or operational dynamics directly, but rather work gradually in shaping the quality of the main actors in the field (Suprayitno & Hartati, 2019). Therefore, although important, this variable tends to have a low influence score in short-term structural mapping.

Meanwhile, market access is positioned in the low quadrant due to the less strategic location of the study and inadequate infrastructure conditions. Geographical factors and limited infrastructure (e.g., roads, transportation, distribution facilities) are the main obstacles that make it difficult for market access to change quickly, even when there is intervention from development policies or programs (Situmorang et al., 2020). In previous studies, market access variables were often seen as structural factors that were beyond the direct influence of local actors or micro policies, so that their role in driving system change was considered relatively limited (Arifin, 2021).

Variables categorized in Quadrant Three (Result Variables) are characterized by low influence but high dependence, particularly on factors such as agricultural technology (AgTech), farmer training and extension services (Train), and product pricing (ProdPrice).

Meanwhile, Quadrant Four (Autonomous Variables) includes business capital (Cap), education level (Educ), farmer experience (Exp), market access (MktAcc), distribution (Distrib), product marketing (Mktng), land quality (LandQlty), water availability (Water), climate conditions (Climate), waste management (WasteMngmt), local industry development (LocIndDev), financial sustainability (FinSus), community participation (ComInv), job diversification (DivJobs), and access to education (PedAccess). Variables within this quadrant exhibit both low influence and low dependence, indicating a limited direct impact on the overall system.

According to the figure, the green lines represent weak influence, blue lines indicate moderate influence, dark blue lines reflect relatively strong influence, and red lines denote the strongest influence among variables. In addition, the MICMAC visualization of the 23 analyzed variables, illustrated by arrow directions, demonstrates the patterns and intensity of dependency relationships within the system, as illustrated in Figure 7.

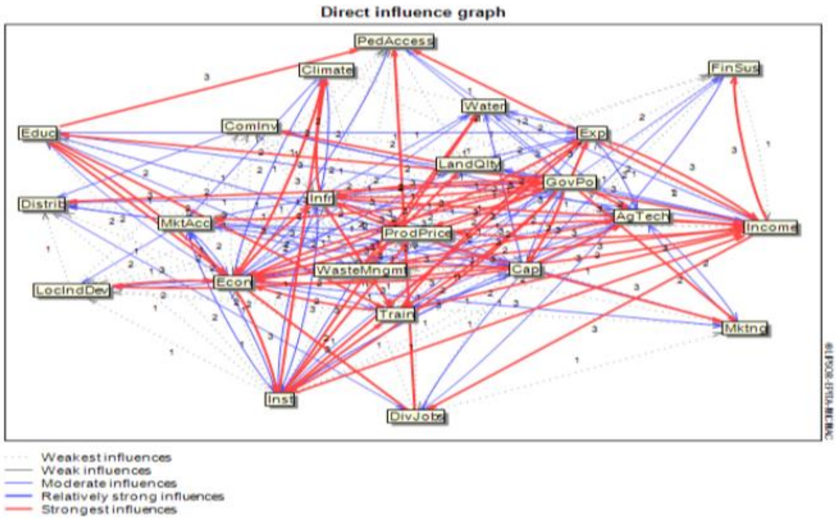

Figure 7.
Graphic Illustration of Influence - Dependence Variables

The direction of an arrow originating from a variable represents the extent to which that variable exerts influence on other variables. Conversely, arrows pointing toward a variable indicate that it is affected by, or dependent on, other variables within the system. A variable that displays a greater number of outgoing arrows accompanied by thick red lines signifies a strong influence over multiple variables. Similarly, a large number of incoming arrows and thick red lines toward a variable indicates a high level of dependence on other variables.

Based on the figure, several variables—such as government policy, infrastructure, institutional capacity, business capital, and product pricing—exhibit substantial influence on other variables. This is reflected by the prominent thick red lines and outward-directed arrows associated with these variables. In contrast, variables including farmer income, local economic conditions, and access to education are predominantly shaped by other factors, as shown by the numerous arrows directed toward them. This pattern suggests that these variables possess a high degree of dependency within the overall system.

Based on examples of international food estate projects, some have succeeded, and some have failed. In Brazil, the food estate program was economically successful, but socio-environmental issues were a challenge. In Ethiopia, the project was considered a failure due to many challenges and obstacles, including land issues, lack of infrastructure, and unclear land ownership rights. China succeeded with the Grain Production Bases program (FAO, 2019).

A food estate is considered successful if it has strong infrastructure, technology, and market access support. Likewise, the failure of the food estate program occurred without taking into account the maturity of local conditions, ecology, and social aspects.

The emergence of accompanies many food estates that have succeeded in increasing food production; social issues (inequality, land conflicts); environmental issues (deforestation, land degradation); issues of desire (dependence on external inputs or foreign investors). Long-term success depends on national policy support, local community involvement, and good environmental management. (FAO, 2021).

Matrix of Indirect Influence

Apart from being based on MDI, the position of variables in the influence-dependence chart quadrant is also based on MII (Matrix of indirect Influence), so that changes in their position can be seen through the displacement map presented in Figure 8 and Figure 9.

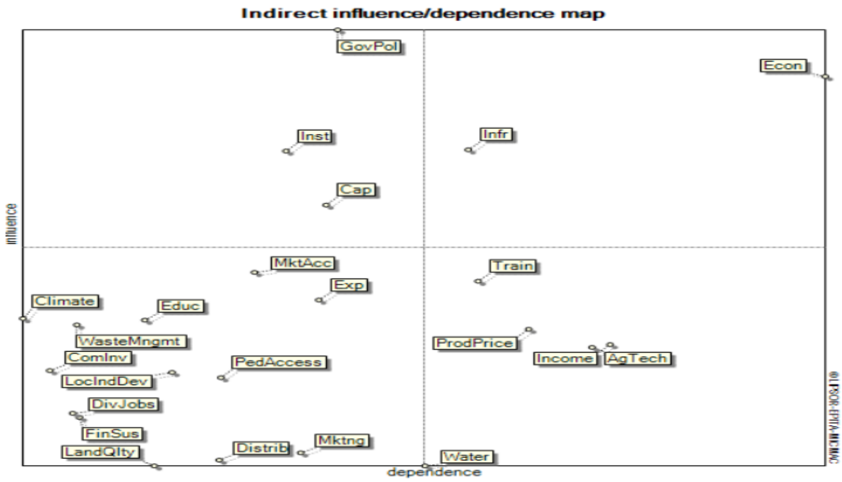

Figure 8.
Position of a System Variable Indirect Influence

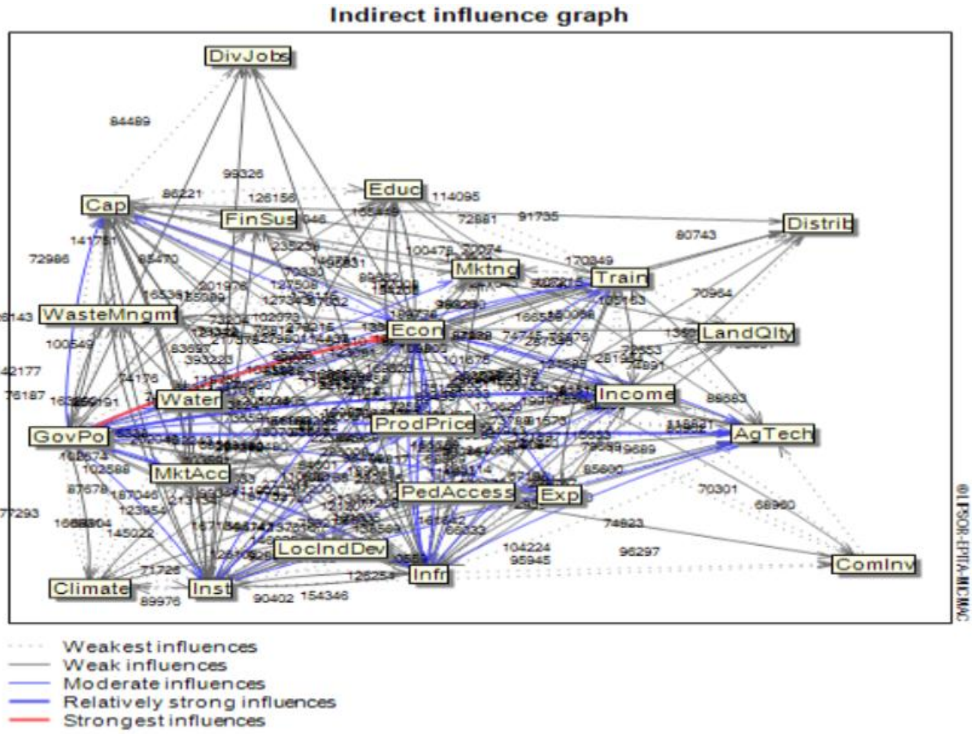

Figure 9.
Interaction of Indirect Influence Between Variables

Based on their levels of influence and dependence, the variables were re-ranked, as illustrated in Figure 10. In this figure, the red line represents a decline in a variable's rank, whereas the green line indicates an improvement in rank resulting from indirect interactions among variables. The analysis shows that the five variables exerting the greatest influence are government policy, local economy, infrastructure, institutions, and business capital. In contrast, the variables demonstrating the highest levels of dependence are local economy, farmer income, agricultural technology, product prices, and farmer coaching and training.

The results also indicate that government policy and local economy variables are mutually influential, both affecting and being affected by one another. Each arrow in the diagram reflects the magnitude of influence generated through iterative processing of the Boolean matrix. Compared to direct effects, the indirect influence analysis reveals that most variables exhibit strong dependence on other variables, as evidenced by the prevalence of red lines.

In addition, the transition from the Matrix of Direct Influence (MDI) to the Matrix of Indirect Influence (MII) produces the relationships shown in Figure 11. Through this process, variables were re-ordered based on their indirect influence on the system, allowing changes in variable rankings between MDI and MII to be observed. Several variables experienced either an increase or a decrease in rank following Boolean iteration, indicating the presence of indirect effects among variables. These changes are summarized in Figure 10, where red lines denote declining ranks and green lines signify improving ranks.

The five most influential variables remain government policy, local economy, infrastructure, institutions, and business capital, while the most dependent variables continue to be local economy, farmer income, agricultural technology, product prices, and farmer coaching and training. The movement of each variable from MDI to MII is further illustrated in the displacement map shown in Figure 11, which categorizes variables according to whether their positions increased, decreased, or remained unchanged over the long term. Notably, most of the observed displacement occurred within the same quadrants.

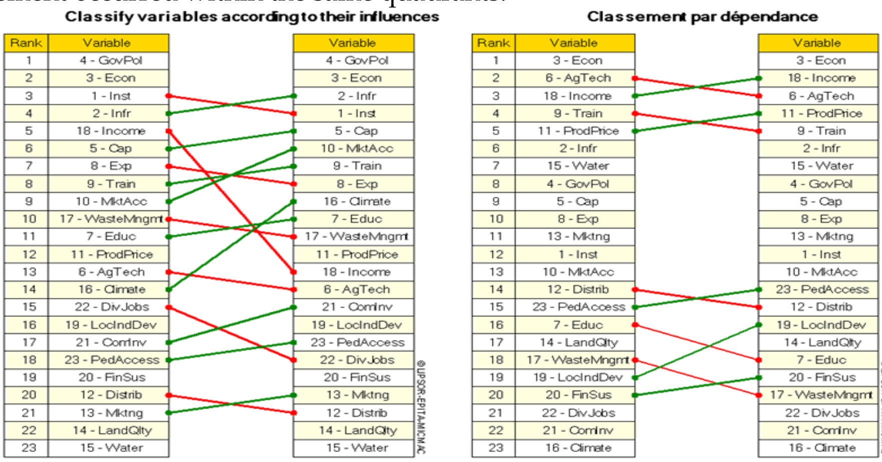

Figure 10.
Changes in the Ranking of Variables from MDI to MII Based on the Level of Influence

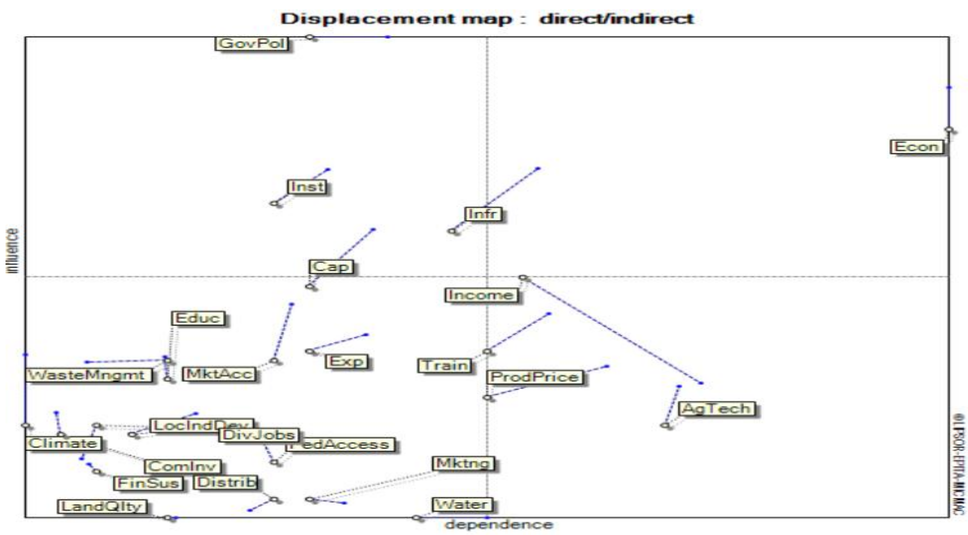

Figure 11.
Position Of A System Variable in the Direct Influence/ Dependence Map

The final synthesis of the MICMAC analysis is visually represented in Figure 11, which displays the Direct Influence/Dependence Map. This map is critical for identifying the strategic leverage points necessary for the sustainability of the Food Estate program in Central Kalimantan.

As illustrated in the figure, the variables are distributed across four distinct quadrants based on their strategic roles. The factors located in the Linkage Quadrant (upper-right) are particularly significant; they are unstable and highly sensitive, meaning any policy intervention directed at these factors will have a cascading effect on the entire system. Meanwhile, the factors in the Driving Quadrant (upper-left) act as the primary engines of the program, possessing high influence with low dependence on other variables.

By analyzing this distribution in Figure 11, it becomes evident which strategic factors require immediate government attention to ensure long-term stability. This mapping provides a clear roadmap for stakeholders to prioritize resources, moving beyond symptomatic issues and focusing instead on the root drivers that will determine the program's success in achieving food security and regional development.

CONCLUSION

This study aimed to identify and analyze the key factors influencing the sustainability of the Food Estate program in Central Kalimantan. Based on the results of the structural analysis, three variables consistently emerge as the primary drivers of system performance: government policy, infrastructure, and institutional capacity. These variables demonstrate the strongest influence both directly and indirectly, shaping the dynamics of technological adoption, farmer capacity, economic outcomes, and the overall effectiveness of program implementation.

The findings show that the sustainability of the Food Estate program depends heavily on coherent policy direction, adequate and functional infrastructure, and well-coordinated institutional arrangements. Meanwhile, variables such as local economy, farmer income, agricultural technology, and market-related factors display high dependency, indicating that improvements in these areas rely on the strength of the key driving variables identified above. These results are consistent with broader evidence on the role of structural determinants in large-scale agricultural development, especially in peatland ecosystems that require integrated governance and specialized management approaches.

The implications of these findings are significant. Strengthening the leading variables is anticipated to enhance agricultural productivity, expand livelihood opportunities, support rural economic growth, and contribute directly to national food security objectives. The study provides an evidence-based foundation for redesigning intervention priorities within the Food Estate program, ensuring that policy efforts target the most influential components of the system.

Nevertheless, this study also has several limitations. First, the variables used in the analysis depend on expert judgment and stakeholder perceptions, which may introduce subjective interpretations despite validation procedures. Second, the research is limited to two regencies within Central Kalimantan, and therefore, the findings may not fully represent conditions in other Food Estate areas across Indonesia. Third, the analysis focuses on structural relationships rather than measuring quantitative impacts; thus, further studies are needed to assess causal effects and long-term outcomes. These limitations should be considered when interpreting the results and in designing future research.

To strengthen the sustainability of the Food Estate program in Central Kalimantan, several strategic recommendations can be proposed. The government should prioritize enhancing policy coherence, particularly through clearer regulatory frameworks, improved program governance, and stronger coordination between national and regional institutions. Infrastructure development must be accelerated, especially in irrigation, road access, and logistic facilities, to support production efficiency and reduce transaction costs. Institutional capacity should be improved through better coordination mechanisms, increased extension services, and strengthened community-based organizations.

Efforts to improve the dependent variables such as farmer income, local economic activity, agricultural technology adoption, and market performance should be integrated with the strengthening of key drivers. This includes expanding training programs, improving access to adaptive technologies suitable for peatland conditions, and enhancing market linkages to stabilize prices and reduce volatility. Future research is encouraged to explore more comprehensive models, incorporate longitudinal data, and evaluate the broader socio-economic and environmental impacts of Food Estate implementation.

AUTHOR CONTRIBUTION STATEMENT

[Author 1]: research designed, data collection, the initial manuscript draft and addressed reviewer's comments. [Author 2]: research designed, data collection, research supervision, and edited the manuscript. [Author 3]: data collection, data analysis, research supervision of the literature review, and edited the manuscript. [Author 4]: research supervision, analytical guidance, interpreted the results, and reviewed and edited the manuscript. [Author 5]: data collection, visualization of results, and edited the manuscript. [Author 6]: data collection, data analysis and discussion sections, and edited the manuscript. [Author 7 dan Author 8]: analytical guidance, edited the manuscript.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

ACKNOWLEDGMENT

Thanks to the entire team that has participated, thanks to LPPM UPR, related agencies, related farmer groups, related agricultural extension workers, and all stakeholders who have helped.

ETHIC STATEMENT

Ethical review and approval were waived for this study as it involved interviews and surveys with farmers and stakeholders that did not constitute highrisk intervention or involve vulnerable groups. All participants provided informed verbal consent prior to their involvement, were informed of the purpose of the research, and were assured of confidentiality. No personally identifiable information was collected, and all data were anonymized during processing and analysis to protect participant privacy.

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