

Research Article

Integration of Poor Corn Farmers' Capacity Index with Interpretive Structural Modeling (ISM) to Map Agricultural Development Dynamics in Gorontalo Province, Indonesia

Irwan Bempah^{1*}, Bachtiar², Fahrul Ilham³, Sahmin Noholo⁴ and Fahrudin Zain Olilingo⁵

¹Gorontalo State University, Faculty of Agriculture, Department of Agribusiness, Gorontalo, Jln. Prof. Ing. B.J. Habibie, Moutong, Kec. Tilongkabila, Kabupaten Bone Bolango, Gorontalo 96119; ²University of Gorontalo, Faculty of Agriculture, Jln. Jend. Sudirman, Limboto, Kabupaten Gorontalo, Gorontalo; ³Gorontalo State University, Faculty of Agriculture, Department of animal husbandry, Gorontalo, Jln. Prof. Ing. B.J. Habibie, Moutong, Kec. Tilongkabila, Kabupaten Bone Bolango, Gorontalo 96119; ⁴Gorontalo State University, Faculty of Economic, Jln. Jend. Sudirman, Kota Gorontalo, Gorontalo 96128.

Abstract | The poverty of farmers is a major challenge to agricultural development in developing regions, including Gorontalo Province, Indonesia. Therefore, this study aims to analyze the capacity index of corn farmers at the provincial, Gorontalo Regency, and Boalemo Regency levels, as well as map the dynamics of the determinants using Interpretive Structural Modeling (ISM). The ISM approach was selected to provide a comprehensive picture of poor farmers capacity and the direction of needed policies. A household survey of poor corn farmers was conducted, supplemented by in-depth interviews, expert group discussions, and secondary data analysis. The capacity index was calculated with two weighting schemes, while the relationships between capacity elements were analyzed using ISM to identify drivers, connectors, and output factors. The results showed that farmers capacity at the provincial and Boalemo Regency levels was in the low category. Meanwhile, the capacity observed in Gorontalo Regency was relatively better, categorized as moderate. The main weaknesses were limited physical resources and low farmers knowledge and skills. The structural analysis confirms that technology, innovation, and market access can only develop when the foundations of infrastructure, education, institutions, and climate vulnerability are strengthened. All the obtained results emphasize the importance of agricultural development policies oriented towards increasing basic capacity before encouraging technological modernization and market integration. This research will help to shape agricultural policies, particularly those aimed at improving the capacity of impoverished farmers.

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***Correspondence** | Irwan Bempah, Gorontalo State University, Faculty of Agriculture, Department of Agribusiness, Gorontalo, Jln. Prof. Ing. B.J. Habibie, Moutong, Kec. Tilongkabila, Kabupaten Bone Bolango, Gorontalo 96119; **Email:** irwanbempah@ung.ac.id

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Keywords | Farmers capacity index, Interpretive structural modeling, Poor farmers, Corn, Gorontalo



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Introduction

Poverty is a relevant global challenge in various developing countries, including Indonesia. This

challenge is closely related to the achievement of the Sustainable Development Goals (SDGs), Particularly the goal of eliminating extreme poverty in rural areas (Nyeleker and Suswanta, 2025). International literature

confirms that poverty is multidimensional, determined not only by income but also by access to education, health, social capital, and economic opportunities (Zhang and Huai, 2023). The experience of China shows that economic reforms reduce extreme poverty but invent new challenges in the form of income inequality (Kurniawan *et al.*, 2024). This suggests that poverty alleviation strategies need to consider the structural and cultural contexts to be effective.

As an agricultural country, Indonesia faces a similar dilemma. The agricultural sector, being the backbone of most rural households, continuously contributes to the highest poverty levels. Mukhlis *et al.* (2021); Setiyowati *et al.* (2018) found that while the agricultural sector has a significant contribution to Gross Regional Domestic Product (GRDP), the impact on poverty reduction is relatively weak.

Gorontalo Province is a prime example of the described phenomenon. According to the Indonesia Statistics Agency (BPS) data (2025), Gorontalo is among the ten poorest provinces in Indonesia, with the poverty rate decreasing from around 15.22% in 2020 to 13.87% in 2024. This condition reflects the poverty described by (Sumaila *et al.*, 2022), where low productivity leads to insufficient incomes hindering access to education, health care. Corn farmers remain the most vulnerable group despite cultivating the leading commodity of the province.

The efforts of central and regional governments tend to focus on short-term programs such as direct cash assistance, fertilizer subsidies, or grants for production inputs (Berita Gorontalo, 2023). While these measures help maintain consumption by poor households, the impact on strengthening long-term capacity is relatively limited. Dependence on aid can generate moral hazards and reduce program sustainability (Fahrudin and Santoso, 2023). Therefore, a new approach that focuses on farmers capacity building is essential to achieving sustainability in the agricultural sector.

Subsidies may provide a short-term solution, but without sustainable capacity development, farmers will remain trapped in a cycle of dependency. Through investments in training, access to technology, institutional strengthening, and the establishment of efficient market channels, the agricultural sector can increase productivity and contribute to long-

term poverty alleviation. This shows the central and regional governments need to design more holistic policies that promote the resilience and independence of farmers in Indonesia (Supriyanto, 2025; Rahman, 2022).

The results obtained emphasize that capacity building is a key strategy for escaping the poverty trap. This concept includes skills development, access to information, institutional strengthening, and the development of socio-economic networks. Cross-contextual studies show the effectiveness of social capital and *zakat*, *infaq*, and alms instruments as redistribution mechanisms to support poor households. However, the solutions require an integrative model that bridges the technical, financial, social, and institutional dimensions (Ascarya *et al.*, 2022; Rahman and Siradjuddin, 2020).

This study aims to develop a framework for mapping the integration of the capacity of poor corn farmers. While previous studies have limited farmer capacity measurements to climate change resilience, livelihoods, and farm management (Adelesi *et al.*, 2024; Albore *et al.*, 2025; Amelia *et al.*, 2020), The novelty lies in identifying the constraints encountered by farmers through the Farmer Capacity Index (FCI) analysis, subsequently developing policy solutions through Interpretative Structural Modeling (ISM) analysis, and comparing the capacities of two districts in Gorontalo Province. This approach is expected to produce a comprehensive analytical framework for the support of evidence-based policies to strengthen the resilience of poor farmers in developing regions.

Materials and Methods

Study design

A mixed-methods approach was used in this study, predominantly exploratory qualitative analysis combined with quantitative analysis. The approach was selected to capture the complexity of poverty among corn farmers in Gorontalo, influenced by economic, social, and institutional factors. Quantitative data were used to measure the FCI and the relationships between variables, while qualitative data explored farmers meanings, perceptions, and adaptation strategies.

Location and respondents

This study was conducted in two regencies with

Table 1: *Gorontalo province farmer capacity index (2025)*

Indicator	FAO percentage	Score (0-100)	Contribution FCI	Kementan percentage	Score (0-100)	Contribution FCI
Technology and innovation	25%	46	11.42	30%	46	13.71
Knowledge & skills	30%	27	8.23	25%	27	6.86
Institutions & policies	15%	48	7.15	20%	48	9.53
Market Access & finance	20%	44	8.82	15%	44	6.61
Physical resources	10%	30	2.98	10%	30	2.98
Total FCI			38.59			39.69

Description: Low – requires urgent intervention (FAO, 2018; Ministry of Agriculture, 2019).

the highest poverty rates, namely Gorontalo and Boalemo. The respondents were 200 poor corn farming households chosen through purposive selection. This figure was calculated using the Slovin formula, taking into account the enormous population size.

These also included farmers groups, the agricultural office, academics, NGOs, as well as actors in the seed and distribution industry.

Study stages

The study process was conducted in five different stages. These included (i) literature review and stakeholder mapping; (ii) primary data collection through surveys, in-depth interviews, FGDs, and participant observation; (iii) secondary data collection from BPS, RPJMD, agency reports, and CSR documents; (iv) model development and analysis using ISM and FCI calculations; as well as (v) participatory model trials in target villages with pre- and post-intervention evaluations.

Data analysis

Quantitative data were analyzed using descriptive to assess the relationship between farmers capacity and poverty levels. The outcomes were subsequently compared to the Farmer Capacity Index assessment standard (FAO, 2018; Kemeterian Pertanian, 2019). ISM analysis was used to map the hierarchy of factor interrelationships, resulting in interaction matrices and graphs that highlight drivers, links, and dependent variables (Ettah *et al.*, 2020; Zhong *et al.*, 2022).

Results and Discussion

FCI at the gorontalo province level

The results show that farmers capacity in Gorontalo Province remains low, both according to the FAO weighting approach and the Indonesian Ministry

of Agriculture. Total FCI calculated using FAO and the Ministry of Agriculture weighting was 38.59 and 39.69, respectively (Table 1). Both values consistently reflect conditions far from ideal, requiring urgent intervention in various aspects that support agricultural development at the provincial level.

Based on the indicators, technology and innovation scored 46,00 contributing 11.42% to the FAO's weighting of FCI and 13.71% to the Ministry of Agriculture's weighting. The relatively significant contribution does not show adequate technological mastery, particularly in the context of modern agriculture, which is increasingly based on digital innovation and mechanization. Knowledge and skills were recorded as very low with a score of 27, contributing only 6.86–8.23% of the total FCI. This situation confirms that farmers agricultural literacy, understanding of sustainable cultivation approach, and managerial skills are limited.

In terms of institutions and policies, the score achieved was 48 with a contribution of 7.15–9.53%, suggesting that institutional roles are quite visible but not optimal in supporting farmers independence. Market and financial access scored 44 with a contribution of around 6.61–8.82%, signifying the persistence of structural barriers in the agribusiness value chain. Physical resources, such as land availability, irrigation facilities, and agricultural infrastructure, had the lowest score at 30, with a contribution of 2.98%. This limitation corresponds with the report of FAO (2018), which emphasizes physical resources and infrastructure as important determinants in strengthening farmers capacity.

The current results show the main weaknesses of Gorontalo Province lie in knowledge and skills, as

Table 2: *Gorontalo regency farmer capacity index (2025)*

Indicator	FAO per-centage	Score (0-100)	Contribution FCI	Kementan per-centage	Score (0-100)	Contribution FCI
Technology and innovation	25%	49	12.22	30%	49	14.67
Knowledge & skills	30%	30	8.85	25%	30	7.38
Institutions & policies	15%	49	7.42	20%	49	9.89
Market access & finance	20%	45	9.09	15%	45	6.82
Physical resources	10%	32	3.18	10%	32	3.18
Total FCI			40.76			41.93

Description: Moderate – needs improvement in technology and market access (FAO, 2018; Ministry of Agriculture, 2019).

Table 3: *Boalemo regency farmer capacity index (2025)*

Indikator	FAO per-centage	Score (0-100)	Kontribusi FCI	Kementan percentage	Score (0-100)	Kontribusi FCI
Technology and innovation	25%	42	10.62	30%	42	12.75
Knowledge & skills	30%	25	7.61	25%	25	6.34
Institutions & policies	15%	46	6.88	20%	46	9.17
Market access & finance	20%	43	8.54	15%	43	6.41
Physical resources	10%	28	2.78	10%	28	2.78
Total FCI			36.42			37.44

Description: Low – requires urgent intervention (FAO, 2018; Ministry of Agriculture, 2019).

well as limited physical resources, which are two interrelated aspects because low human capacity to manage physical resources leads to stagnant agricultural productivity. This is consistent with the [Kementerian Pertanian \(2019\)](#) guidelines for developing FCI, which prioritizes human resource capacity building and basic infrastructure support in Indonesia's farmers capacity building strategy.

FCI at the gorontalo regency level

[Table 2](#) shows that the FCI in Gorontalo Regency performed relatively better than the provincial average. The total index score based on the FAO and the Ministry of Agriculture weighting was 40.76 and 41.93, respectively. This category is classified as moderate, representing a stronger foundation for farmers capacity development, although structural weaknesses remain that need to be addressed.

Concerning the technology and innovation indicator, farmers in Gorontalo Regency scored 49 with a contribution of 12.22–14.67%. This shows a higher level of innovation adoption than the provincial average. Knowledge and skills increased by 30, but the contribution remains low (7.38–8.85%). Institutions and policies scored 49, with a contribution of around 7.42–9.89%, representing a relatively strong institutional role in supporting agricultural activities.

Market and financial access scored 45, contributing 6.82–9.09%, signifying persistent constraints on access to capital and formal markets. Physical resources remain a weak point with a score of 32 and a contribution of 3.18%, representing limited production support facilities. This result corresponds with the report of previous analysis ([Ettah et al., 2020](#); [Kushwaha et al., 2024](#)) that improving access to technology and markets will have a multiplier effect on increasing farmers capacity in developing regions. The results show that although Gorontalo Regency has a better capacity, the sustainability of increasing farmers capacity requires a focus on strengthening modern agricultural technology, digitalizing marketing, and implementing policy interventions to facilitate access to capital for farming businesses.

FCI at the boalemo regency level

[Table 3](#) shows that Boalemo Regency has the lowest FCI score compared to the other two levels. The total index score obtained from the FAO weighting was 36.42, and the Ministry of Agriculture's weighting produced a score of 37.44. Both fell into the low category, representing the weak capacity of farmers in Boalemo. Furthermore, technology and innovation scored 42, contributing 10.62–12.75%. Knowledge and skills were the weakest indicator, scoring 25 and contributing 6.34–7.61%. This situation shows

a serious gap in agricultural literacy. Meanwhile, institutions and policies were relatively better, scoring 46, contributing 6.88–9.17%.

Market and financial access scored 43, contributing 6.41–8.54%, which represents limited access to formal markets and financial institutions among farmers. Physical resources scored the lowest, at 28, contributing 2.78% and reflecting the lack of basic agricultural infrastructure. This situation shows the urgent need for interventions to improve farmers skills and provide basic agricultural infrastructure. The described situation is consistent with the view of the Kemeterian Pertanian (2019), which emphasizes the importance of human resource capacity and infrastructure in increasing the competitiveness of farmers in underdeveloped regions.

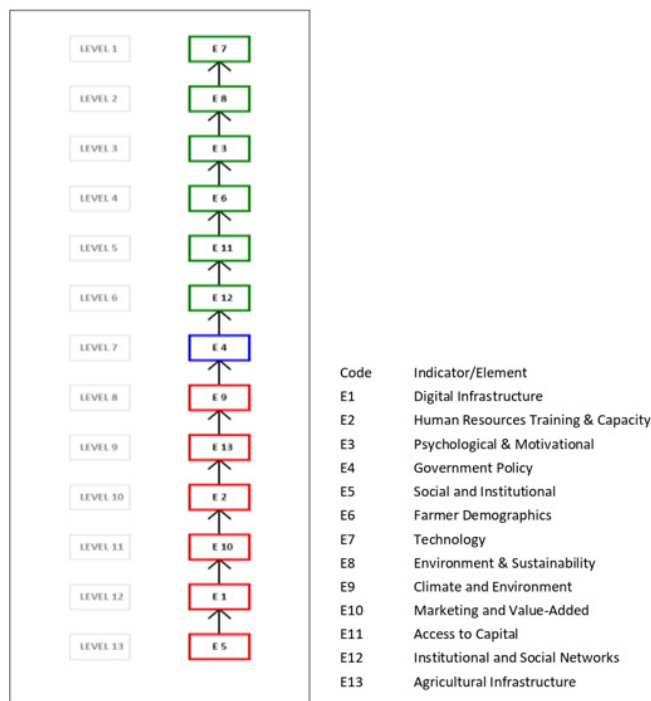


Figure 1: Sub elements enabling the development of farmer capacity in a hierarchical framework

Dynamics of ISM structure in the context of farmers capacity

The ISM structure in Figure 1 (the model) and Figure 2 (the graph) shows a complex hierarchy among the factors that determine the capacity of poor corn farmers in Gorontalo Province. The structure has three main layers, including driver factors as the foundation, linkages as critical connections, and dependent factors as outputs influenced by the layers below. This hierarchical framework corresponds with the view of previous studies (Khan et al., 2022;

Singh and Srivastava, 2021) that complex socio-economic systems should be mapped through the interconnections between elements to understand the underlying causal flows.



Figure 2: Diagram of classification for auxiliary component for the development of farmer capacity

At the driver level, there are six indicators that serve as the main drivers of system dynamics. First, pest and disease attacks, as well as the impact of climate change (E5), are fundamental components of corn cultivation vulnerability. Literature shows that climate change risks and the intensity of attacks by plant pests are fundamental factors suppressing the adaptive capacity of farmers in developing countries (Saad et al., 2024); Sarvina, (2019) Second, access to financial institutions and the availability of agricultural credit (E1) are key determinants of corn farmers resilience. Capital availability can impact the sustainability of farming. Third, the cost of technology adoption and farmers skills (E2) are also drivers. The high cost of adopting modern technology often limits smallholder farmers participation, specifically when technical literacy is low. Fourth, fear of crop failure and hesitation in adopting technology (E10) are psychosocial aspects that influence farmers behavior. A previous study (Rust et al., 2021) confirms that yield uncertainty and low trust in innovation are latent barriers to the diffusion of agricultural technology. Fifth, formal education and farmers age (E13) are key drivers determining human resource quality. Previous analysis shows that education level and age demographic structure significantly correlate with the rate of innovation adoption and farmers managerial skills (FAO, 2018). Sixth, digital marketing networks and the increasing role of farmers cooperatives (E9) play a strategic role as drivers. The entire six indicators confirm that improvements in the foundations related to climate risk, technology costs, literacy, education,

and institutional networks will enable the dynamics of agricultural systems to develop sustainably when implemented coherently.

At the linkage level, the availability of storage warehouses and village farm roads (E4) is a vital connecting element. This limited physical infrastructure is often referred to as the “missing link” in rural development because of the direct impacts on corn price stability, distribution efficiency, and harvest storage capacity (Khan *et al.*, 2022). Without adequate storage, farmers tend to sell crops immediately after harvest at low prices, maintaining weak bargaining power. Therefore, this connection is key in determining the extent to which drivers can cascade effects to the dependent level. At the dependent level, there are six indicators structurally influenced by drivers and linkages. Organic farming practices and corn waste utilization (E12) show the direction of the transformation toward sustainable agriculture.

Adoption is only possible when farmers have adequate skills and infrastructure support (Abdullah *et al.*, 2021). The use of digital agricultural applications (E11) is also a dependent factor, whose effectiveness is strongly influenced by technological literacy and market access. Without a foundation of knowledge and infrastructure, digital applications serve as symbolic instruments.

The floor price for corn and post-harvest programs (E6) are government policies often influenced by market conditions and institutional support (Shakoor *et al.*, 2015). The programs will be effective when farmers have the capacity to produce standardized quality (e.g., the moisture content of corn). The intensity of extension programs from the agricultural office (E3) is considered a dependent factor, as the success depends significantly on the readiness of farmers to accept new knowledge (Khan *et al.*, 2022). Similarly, supply chain efficiency and improved corn selling prices (E8) are impossible to achieve without the support of storage warehouses, farm roads, and the role of cooperatives as linkages. Finally, partnerships with village-owned enterprises (BUMDES) as corn offtakers (E7) are at the top of the hierarchical structure. This partnership represents an advanced form of market integration but relies heavily on strengthening the foundational and connecting elements.

Synergy between FCI indicators and the impact on policy

The analysis of the FCI at three regional levels—Gorontalo Province, Gorontalo Regency, and Boalemo Regency—shows a pattern of disparity that needs to be understood through the perspective of synergy between indicators. The ISM hierarchical structure, as shown in Figure 1 and Figure 2, emphasizes that each capacity index indicator does not stand separately but interacts in an integrated system. Therefore, the interpretation of index results should be conducted systematically, not piecemeal.

At the provincial level, the FCI score is in the low category (38–39). The main weaknesses lie in physical resources and farmers knowledge and skills, reflecting weak basic capacity. This prevents the relatively better institutional and policy roles from functioning optimally. Abdullah *et al.* (2021) emphasize that poor rural infrastructure, such as farm roads and irrigation, limits access to inputs and slows the diffusion of innovation. Although technology and institutional indicators score higher, limitations at the driver level hinder the realization of this potential.

In Gorontalo Regency, conditions are more positive, with an index score in the moderate category (40–42). Technology and institutions are relatively strong, representing a more prepared basis for increasing capacity building. However, the knowledge and skills of farmers remain low, generating barriers to linkage functions. Godart *et al.* (2016) in Trust-Based Work Time and Innovation emphasize that innovation adoption is influenced by the availability of technology and the capacity of an individual to understand, adapt, and disseminate the innovation. Therefore, low farmers literacy and skills reduce the potential for technology to have a real impact.

Boalemo Regency showed the lowest FCI score of 36–37. Knowledge, skills, and physical resources indicators are weak, leading to a fragile system. Relatively advanced technology and market access have become powerless dependents due to the lack of supporting foundations. The result is consistent with the analysis of Andrianto and Iskandar (2019), asserting that capacity imbalances in marginalized regions can exacerbate food insecurity and deepen economic disparities. In the Boalemo context, this implies that intervention strategies should primarily focus on strengthening drivers and linkages, rather than technology or markets.

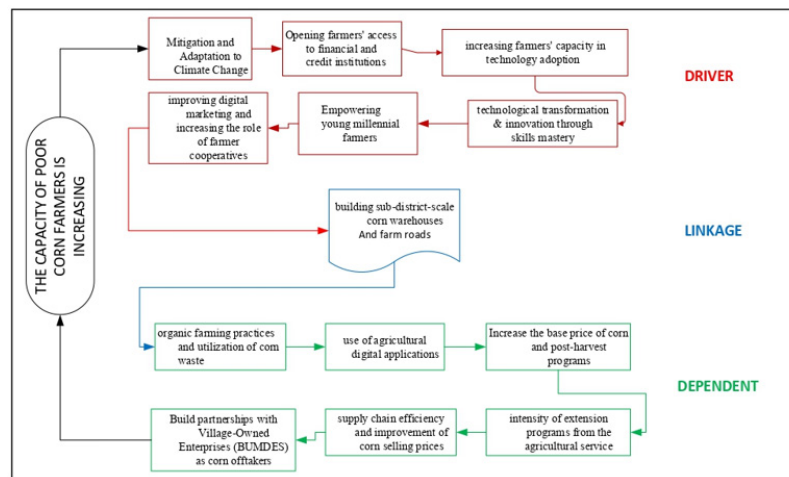


Figure 3: Model of policy stages to enhance capacity of low-income corn farmers in Gorontalo

The synergy between FCI indicators shows that the success of farmers capacity building is highly dependent on consistency across hierarchical levels. As explained by the [FAO \(2018\)](#), farmers capacity building requires a holistic capacity development approach, where improving human resources, institutions, and infrastructure is a prerequisite for sustainable innovation and market access. In other words, indicators at the driver and linkage levels act as enablers, while dependent indicators represent outcomes that can only be realized after the foundation is strengthened.

[Figure 3](#) shows the policy model implications of the results, namely the importance of prioritizing stages that correspond to the ISM structure. At the provincial level, policies should prioritize the development of basic infrastructure and agricultural literacy. In Gorontalo Regency, strategies can be directed at optimizing new technologies with the support of training programs and institutional strengthening. Meanwhile, in Boalemo Regency, policies should be more radical, with a simultaneous focus on providing physical infrastructure and strengthening human resource capacity. This principle is consistent with the polycentric governance framework proposed by [Ostrom \(2010\)](#), where interventions should be tailored to the specific context of each region but remain in a broader coordination framework.

Multilevel integration: Provincial, District, and National
Policy strategies should be developed in a tiered and adaptive manner, consistent with the specific capabilities of each region. At the provincial level, institutional development should be strengthened—including coordination between districts. Gorontalo

Regency could become a sustainable pilot project, with a hybrid intervention in the form of improving rural infrastructure while simultaneously providing intensive training. Boalemo Regency requires a more inclusive approach, through an intensive transformational program, simultaneously providing capital support, physical development, and capacity building.

The approach examines the adaptive and multilevel policy principles suggested by [Ostrom \(2010\)](#), stating that managing complex systems requires “polycentric governance” reforms—complementary interventions from the ground up to the implementation stage. In this context, the interaction between the ISM and FCI structures provides a specific roadmap. Drivers and linkages should be gradually strengthened, thereby allowing dependent outcomes to grow sustainably.

The discussion section provides a cohesive theoretical and policy framework for enhancing farmers capacity in Gorontalo based on systemic (ISM) and empirical (FCI) analysis. This is consistent with global approaches to strengthening the agricultural sector in developing regions.

Conclusions and Recommendations

In conclusion, this study confirms significant disparities in the FCI in Gorontalo Province, Gorontalo Regency, and Boalemo Regency. The results show that the capacity of poor corn farmers at the provincial and Boalemo Regency levels remains low, while Gorontalo Regency is in the moderate category. This difference reflects the unequal distribution of resources and knowledge, which directly impacts

the ability of farmers to adapt and sustain farming operations. The main weaknesses lie in limited physical resources and low farmers knowledge and skills, which are essential foundations for capacity building.

ISM analysis provides a systemic overview of the interrelationships between farmers capacity elements. Driver factors include education, financial access, technology costs, climate vulnerability, and the role of cooperatives and digital networks. These serve as the foundation for driving change. Linkage factors, such as village farm roads, storage facilities, and farmers institutions, serve as critical connections that determine the effectiveness of driver influence. Meanwhile, dependent factors, such as technology adoption, digital applications, organic farming practices, extension intensity, market access, and partnerships with Village-Owned Enterprises (Bumdes), are output factors that can only develop when the foundation and connections are strengthened.

This study contributes to the literature by integrating capacity index analysis and ISM, providing a systemic framework for evidence-based agricultural policy in developing regions. The policy implications for Gorontalo are that growth in agriculture must begin with improving basic infrastructure, supplying production inputs, and expanding human resource capacity through education and training.

Further studies are recommended to explore the long-term impacts of specific policy interventions, as well as the relationship between farmers capacity, food security, and regional economic transformation.

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Novelty Statement

The novelty of this study lies in mapping the capacity of poor corn farmers through the integration of FCI

Analysis and ISM. The approach has not been widely used in local contexts, particularly when comparing two regencies in a single province, thereby producing a systemic and comprehensive picture for evidence-based policy recommendations.

Author's Contribution

Irwan Bempah: Responsible for study conceptualization, theoretical framework formulation, and overall supervision of the article writing process.

Bachtiar: Directed the methodological design, instrument validation, and quantitative analysis of the Farmer Capacity Index.

Fahrudin Zain Olilingo: Led field data collection, survey implementation, and primary and secondary data integration.

Fahrul Ilham: Conducted qualitative analysis, processed Interpretive Structural Modeling (ISM) results, and interpreted the findings.

Sahmin Noholo: Drafted the discussion section and policy recommendations, as well as aligned the manuscript with international academic standards.

Generative AI and AI-assisted technology statement

The authors declare that no generative AI and AI assisted technology was used in the creation of this manuscript.

Conflict of interest

The authors have declared no conflict of interest

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