Vol. 15, No. 1 (2026): 456 - 469 http://dx.doi.org/10.23960/jtepl.v15i1.456-469

Agricultural Engineering
UNIVERSITY OF LAMPUNG

JURNAL TEKNIK PERTANIAN LAMPUNG

ISSN 2302-559X (print) / 2549-0818 (online)
Journal homepage : https://jurnal.fp.unila.ac.id/index.php/JTP

Evaluation of Sustainable Environmentally Friendly Agriculture: Empirical Evidence in Ngawi Regency

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Article History:

Received : 20 October 2025
Revised : 2 February 2026
Accepted : 3 February 2026

Keywords:

Environmentally Friendly Agriculture,
MDS,
RAP-FARM,
SDGs,
Sustainability.

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ABSTRACT

Ngawi Regency is a major rice production center in East Java, playing a strategic role in supporting food security. However, conventional farming practices that depend heavily on chemical inputs have caused environmental degradation, soil nutrient imbalance, and reduced farmer welfare. To address these issues, the local government implemented the Sustainable Environmentally Friendly Agriculture (PRLB) program to promote a more adaptive and sustainable system. This study evaluates the sustainability status of PRLB across five dimensions—ecological, economic, social, technological, and institutional—and identifies key leverage factors. A multidimensional quantitative approach using Multi-dimensional Scaling (MDS) with RAP-FARM software was applied. Data were collected from 204 farmers and experts, supported by institutional records. The analysis included the calculation of sustainability indices, identification of sensitive attributes through leverage analysis, and Monte Carlo validation. Results show that PRLB is moderately sustainable, with an overall index of 67.28 on a 0–100 scale. Dimension scores were 63.43 (ecology), 69.04 (economy), 71.30 (social), 65.30 (technology), and 67.32 (institutional). Sensitive attributes include organic fertilizer use, waste management, by-product valorization, farmer group participation, youth regeneration, and extension services. Monte Carlo validation confirmed stable results. Overall, PRLB shows positive progress but requires strengthening, particularly in ecological, technological, and institutional aspects.

1. INTRODUCTION

The global population is projected to reach 9.7 billion by 2050, placing significant pressure on the sustainability of the world's food systems. Indonesia, as the fourth most populous country in the world, faces serious challenges in meeting its national food needs. Population growth directly drives an increase in food demand, making food security an increasingly urgent strategic agenda that must be addressed based on the latest research findings (Prabowo, 2010). Based on the 2022 Global Food Security Index, Indonesia ranks 63rd out of 113 countries with a food security score of 60.2, which is categorized as moderate. Of all the assessment components, affordability received a relatively high score of 81.4, reflecting the community's ability to access food. This achievement is inseparable from the role of government policy, particularly through food subsidy programs and social protection schemes aimed at maintaining the stability of community access to food (Badan Riset dan Inovasi Nasional, 2025). Food security, according to the FAO (Food and Agriculture Organization), is defined as a condition in which all people, at all times, have physical and economic access to sufficient, safe, and nutritious food to meet their nutritional needs for an active and healthy life

(FAO, 2003). In the Indonesian context, rice (*Oryza sativa* L.) plays a central role as a staple food commodity that serves as a benchmark for social and economic stability (Indriyani, 2004; Rivani, 2012).

In an effort to meet the ever-increasing demand for food, Indonesia has adopted a conventional agricultural model since the green revolution era that focuses on intensification and increased productivity through the intensive use of external inputs, such as chemical fertilizers and pesticides. Although this approach succeeded in significantly increasing food production at the time, its negative impacts are now increasingly being felt. The Green Revolution approach increased food production in developing countries, but recent evidence shows that long-term dependence on chemical inputs causes environmental degradation and socio-economic pressure on farmers (Congreves, 2025; FAO, 2022; Tilman *et al*., 2017). Conventional agricultural systems have caused serious environmental degradation. Excessive use of inorganic fertilizers has led to a decline in organic matter content and water pollution through eutrophication, which damages aquatic ecosystems (Akinnawo, 2023). Similarly, the continuous application of chemical pesticides not only leaves harmful residues on agricultural products, but also causes pest resistance and eliminates non-target organisms, including natural enemies and pollinators, which disrupts the balance of the ecosystem (Jamin *et al*., 2024). Ecological sustainability is one of the key variables in any development system, including agricultural systems. The ecological dimension can be viewed as a necessary condition because it serves to maintain environmental carrying capacity and the long-term sustainability of natural resources (Congreves, 2025). However, ecological sustainability alone is not sufficient to ensure the overall sustainability of agricultural systems, which require support from other dimensions as sufficient conditions, namely economic, technological, social, and institutional dimensions. Various studies over the past five years show that in conventional agricultural systems in developing countries, these four dimensions are generally still at a relatively low level of sustainability due to limited access to technology, weak farmer institutions, low economic added value, and the social vulnerability of small farmers (FAO, 2022). Therefore, a multidimensional evaluation of the sustainability of agricultural systems is important to encourage transformation towards a more sustainable agricultural system, including in Ngawi Regency.

Ngawi Regency in East Java Province is one of the nation's vital rice granaries, contributing significantly to regional and national rice production. However, as an area with intensive agricultural practices, Ngawi also faces the same sustainability challenges. Dependence on chemical inputs has degraded soil quality, and rising production costs are eroding farmers' profitability (Dzikrillah *et al*., 2017; Parmawati *et al*., 2024). Recognizing this threat, the Ngawi Regency Government initiated a transition to Sustainable Environmentally Friendly Agriculture (PRLB) in 2021.

The success of this transition cannot only be measured in terms of production, but also needs to be evaluated holistically. The partial implementation of PRLB and the uncertainty surrounding its sustainability raise critical questions: Is this program truly moving towards sustainability, or is it merely a change in name without any systemic impact? Without a comprehensive evaluation, it is difficult to identify weaknesses, strengths, and leverage factors that can accelerate the achievement of objectives. Based on this background, the purpose of this study is to evaluate the sustainability status of PRLB in Ngawi Regency and determine the sensitivity of each attribute as a lever for the sustainability level of each dimension. This research is in line with the principles of sustainable development (Sustainable Development Goals/SDGs) launched by the United Nations (UN), particularly SDGs 2 (Zero Hunger), SDGs 12 (Responsible Consumption and Production), SDGs 13 (Climate Action), and SDGs 15 (Protecting Terrestrial Ecosystems).

2. MATERIALS AND METHODS

The research was conducted in August-September 2025 in Ngawi Regency, East Java Province, with a focus on Karangjati and Padas subdistricts. These two subdistricts were selected purposively because they are the areas with the most active implementation of the PRLB program and are representative of the sustainable agricultural system in Ngawi Regency.

Data collection was carried out using three methods, namely field observation, structured interviews, and distribution of questionnaires to farmer respondents and experts. Structured interviews were conducted using a pre-determined set of questions to explore information about PRLB implementation, socioeconomic conditions, and institutional support. The interview guide was compiled based on relevant research factors, including the socioeconomic conditions of farmers, agricultural institutional support, and the implementation of environmentally friendly agricultural practices (Hartono, 2018; Shofiyah & Hakim, 2020). The questionnaire was compiled using closed statements with five response categories on a Likert scale to measure respondents' perceptions of the attributes observed, namely: 5 = strongly agree, 4 = agree, 3 = neutral, 2 = disagree, and 1 = strongly disagree (Sugiyono, 2019). Before use, the research instruments were tested for validity and reliability to provide an important picture of measurement accuracy.

The determination of PRLB sustainability dimensions and indicators was based on an open attribute approach, whereby each expert or specialist was free to assess the actual condition of the attributes, which were then synthesized by the researchers based on specific benchmarks (Pitcher & Preikshot, 2001). Ordinal scores are assigned using a range of 1–4, which describes conditions from poor (score 1) to good (score 4), with assessment criteria for each attribute in each dimension determined based on operational indicators as presented in Table 1. The five dimensions used to assess the sustainability of PRLB include ecology, economy, society, technology, and institutions. The indicators for each dimension are presented in Table 1.

Table 1. Dimensions and indicators of sustainable environmentally friendly agriculture in Ngawi Regency

Dimension	Sustainability Indicators/Attributes
Ecology	1. Percentage of organic fertilizer use. 2. Intensity of chemical pesticide use. 3. 3. Management of agricultural waste (straw, husks, liquid waste). 4. Soil and water conservation practices. 5. Utilization of biodiversity (refugia and natural enemies).
Economy	1. Added value of agricultural by-products. 2. Market access for environmentally friendly products. 3. Stability of farmers' income. 4. Efficiency of production costs. 5. Profitability of farming businesses.
Social	1. Farmer participation in farmer groups. 2. Regeneration of agricultural labor (young farmers). 3. Adoption of innovations and new knowledge. 4. Fairness in benefit sharing. 5. The role of women in farming activities.
Technology	1. Use of composting technology and liquid organic fertilizer (POC). 2. Implementation of water-efficient irrigation. 3. Utilization of agricultural tools and machinery (alsintan). 4. Implementation of post-harvest technology. 5. Access to digital technology and agricultural information.
Institutional	1. The active role of field agricultural extension workers (PPL). 2. The effectiveness of local government policies related to PRLB. 3. The strength of farmer groups or agricultural cooperatives. 4. Partnerships with the private sector/market. 5. Farmers' access to capital and agricultural business credit facilities.

Table 2. Sustainability index value categories based on MDS analysis (RAP-FARM)

Sustainability index value (%)	Category	Description
0.00 – 25.00	Poor	The agricultural system is unsustainable, requiring major intervention and comprehensive change.
25.01 – 50.00	Insufficient	Sustainability is low, with several basic aspects not yet fulfilled and still dependent on conventional systems.
50.01 – 75.00	Adequate	The agricultural system is fairly sustainable, but still requires improvement in sensitive areas.
75.01 – 100.00	Good	The agricultural system is highly sustainable, having met most of the cross-dimensional criteria.

Source : (Kavanagh & Pitcher, 2004)

The analysis method used in this study was Multidimensional Scaling (MDS) with RAP-FARM software, a statistical technique used to describe the relative position of sustainability levels between dimensions in the form of a sustainability index (0–100%). MDS analysis was performed for each dimension (ecological, economic, social, technological, and institutional), which then produced an overall index value. The sustainability index values were then grouped into four categories (Kavanagh & Pitcher, 2004) as presented in Table 2.

In addition to MDS, Leverage Analysis was also conducted to identify the attributes that most influence the sustainability of each dimension, as well as Monte Carlo analysis to test the stability of MDS results and measure the reliability of the model against data variation and respondent subjectivity.

3. RESULTS AND DISCUSSION

3.1. Index and Status of PRLB in Ngawi Regency

In this study, the sustainability status of Sustainable Environmentally Friendly Agriculture (PRLB) in Ngawi Regency was reviewed from five dimensions of sustainable development, namely ecological, economic, social, institutional, and technological dimensions. Through a Multidimensional Scaling (MDS) approach using RAP-FARM software, the results of the analysis of the five dimensions using a scale of 0–100 showed that it was quite sustainable with an average index value of 67.07. The kite diagram (Figure 1) shows that all dimensions indicate sustainability with the following sustainability index values for each dimension: ecological dimension 63.43, economic dimension 69.04, social dimension 71.30, technological dimension 65.30, and institutional dimension 67.32. The resulting index values indicate that each dimension analyzed is classified as moderately sustainable, as they fall in the range of 50.00–74.99.

The error rate in MDS analysis was evaluated by comparing the difference between RAP-FARM values and Monte Carlo simulation results (Table 1). The results of the Monte Carlo analysis at a 95% confidence interval showed no difference between the Monte Carlo analysis and MDS results, with a difference value of 0–0.05. This means that the error factor in each attribute is relatively small, whether from differences in respondents' assessments of the attributes studied, errors in data entry, or missing data (Syarifatullah *et al*., 2022). The MDS and Monte Carlo analysis index values are presented in Table 3 below.

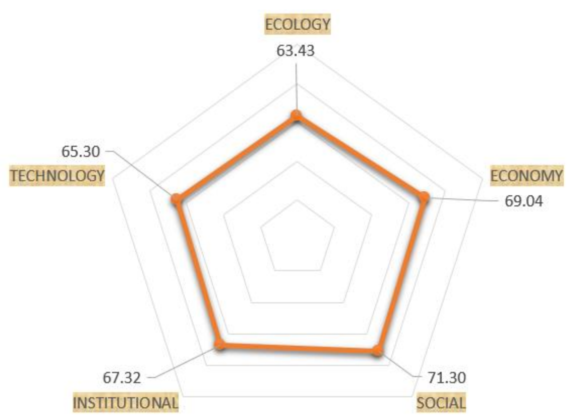

Figure 1. PRLB sustainability index and status in Ngawi District

Table 3. MDS and Monte Carlo analysis index values

Variable	Analysis Index Values (%)		Difference
	RAP-FARM	MONTE CARLO	
Ecology	63.43	63.43	0.00
Economy	69.04	69.04	0.00
Social	71.30	71.25	-0.05
Institutional	67.32	67.32	0.00
Technology	65.30	65.30	0.00

3.2. Ecological Dimension Sustainability Index

The MDS analysis results show that the ecological dimension of PRLB in Ngawi Regency has a fairly sustainable status with a sustainability index value of 63.43 (scale of 0–100). This value is in the moderate category, which means that the ecological aspects of PRLB are relatively well maintained, but there are still challenges in its implementation. This assessment is based on a number of ecological attributes, namely (1) the use of organic fertilizers, (2) the utilization of biodiversity (refugia and natural enemies), (3) agricultural waste management, (4) soil and water conservation measures, and (5) the intensity of chemical pesticide use.

Figure 2 shows the results of the ecological dimension leverage analysis, where attributes with the highest Root Mean Square (RMS) values are considered the most sensitive. The higher the RMS value, the greater the role of that attribute in influencing sustainability (Rochmah *et al*., 2021). The leverage results show that of the five attributes assessed, there are four attributes that are highly sensitive to the ecological sustainability of PRLB, namely the use of organic fertilizers (RMS = 10.05), utilization of biodiversity (RMS = 8.11), management of agricultural waste (RMS = 6.32), and conservation of soil and water (RMS = 6.18).

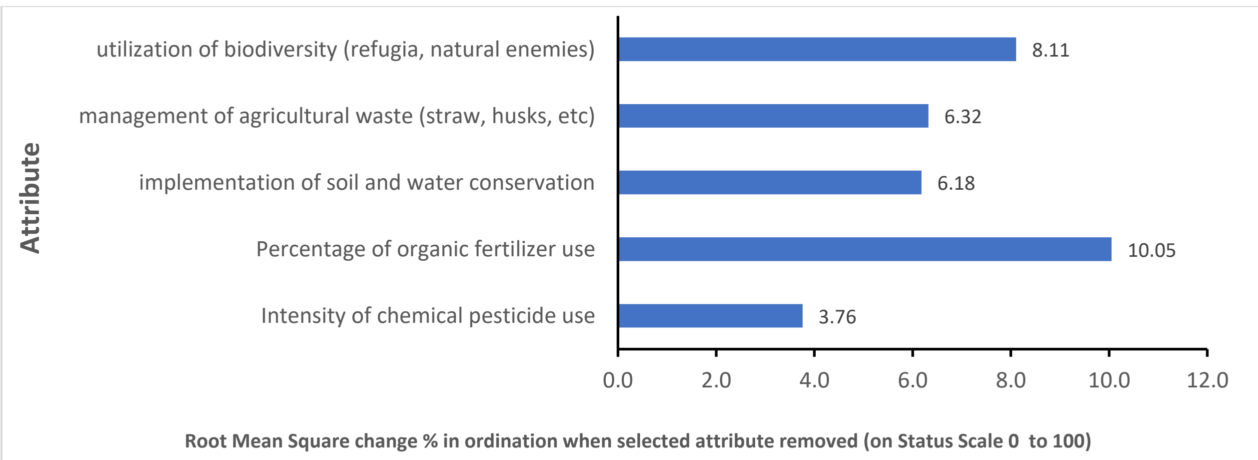

Figure 2. Results of the analysis of the leverage value of each attribute of the ecological dimension

The attribute with the highest RMS is the use of organic fertilizers (10.05). This high sensitivity indicates that increasing the adoption of organic fertilizers is key to maintaining the ecological sustainability of PRLB. Research by Chittora *et al*. (2023) confirms that chemical fertilizer residues can contaminate soil and water, damage soil organisms, and in the long term reduce productivity. In contrast, organic fertilizers increase organic matter content, improve soil structure, and support environmentally friendly agricultural systems. Rani *et al*. (2023) reported similar findings, stating that low soil organic matter due to the dominance of synthetic fertilizers is one of the main factors contributing to agricultural ecological degradation (Rani *et al*., 2023).

The next attribute is the utilization of biodiversity (RMS = 8.11). The existence of refugia and natural enemies serve as natural pest control agents, thereby reducing dependence on chemical pesticides. Light traps and refugia are able to suppress the populations of brown planthoppers, stem borers, and leafhoppers, which have been the main pests of rice (Erdiansyah & Putri, 2019). This strategy not only reduces production costs but also strengthens the balance of the rice field ecosystem. Agricultural waste management attributes (RMS = 6.32) also have a significant effect. Straw and husk waste that is not optimally managed often becomes an environmental problem, even though it can be used as compost or alternative fuel (Megasari *et al*., 2024). Straw incorporation increases soil nutrient content and improves land quality (Lawolo, 2025). Thus, optimizing farm wastes in Ngawi can be both an ecological and economic strategy.

Soil and water conservation attributes (RMS = 6.18). Conservation practices such as water-efficient irrigation systems or drainage channels can maintain water availability and prevent erosion (Abdillah *et al*., 2025). This is particularly relevant in Ngawi, which is prone to seasonal droughts. Meanwhile, the intensity of chemical pesticide use

(RMS = 3.76), although lower, still needs to be addressed. Excessive pesticide use increases pest resistance, reduces biodiversity, and causes residues that are harmful to humans (Zhou *et al*., 2025). Therefore, despite its lower sensitivity, reducing pesticide use remains part of the sustainability strategy. Thus, it can be concluded that to improve the ecological sustainability of PRLB in Ngawi Regency, the steps that need to be prioritized are increasing the adoption of organic fertilizers, strengthening the utilization of biodiversity, optimizing agricultural waste management, and promoting broader soil and water conservation.

3.3. Economic Dimension Sustainability Index

The MDS analysis results show that the economic dimension of PRLB in Ngawi Regency has a fairly sustainable status with a sustainability index value of 69.04%. This value indicates that economically, farmers have begun to feel the benefits of implementing PRLB, although there are still challenges that need to be addressed. This assessment is based on a number of attributes, namely (1) added value from by-product processing, (2) market access for environmentally friendly products, (3) income stability, (4) profit levels, and (5) production cost efficiency.

Figure 3 shows the results of the economic dimension leverage analysis. Based on the Root Mean Square (RMS) value, the attribute that is most sensitive in influencing the sustainability of the economic dimension is the added value of by-products (RMS = 6.31), followed by market access for environmentally friendly products (RMS = 5.03), income stability (RMS = 4.37), profit levels (RMS = 3.93), and production cost efficiency (RMS = 2.70). The higher the RMS value, the greater the role of the attribute in determining sustainability status, so attributes with high RMS should be the focus of policy intervention (Rochmah, 2021).

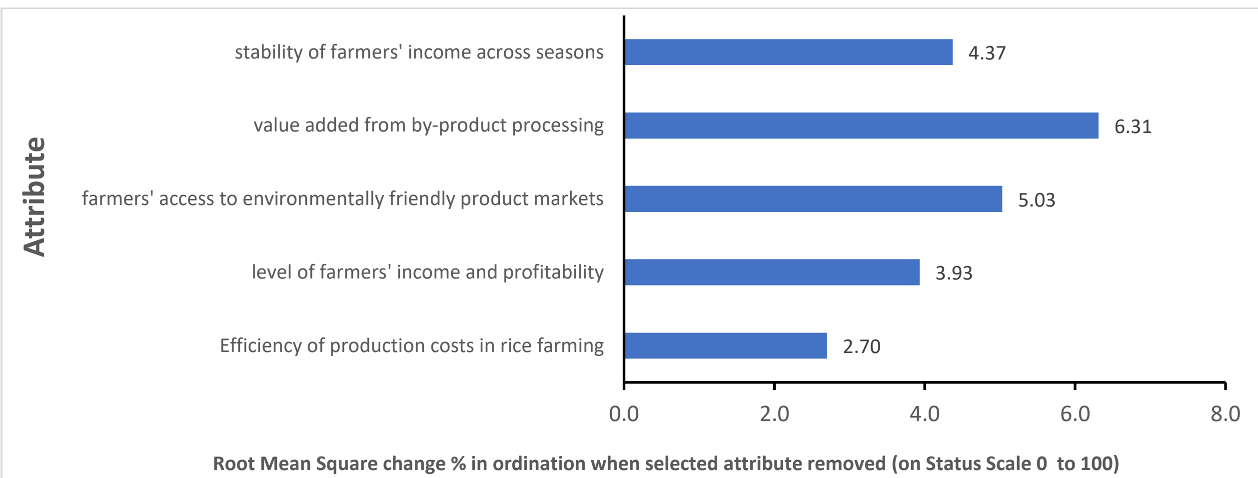

Figure 3. Results of the analysis of the leverage value of each attribute of the economic dimension

The attribute with the highest RMS is the added value of by-product processing (6.31). This high sensitivity indicates that the economic sustainability of PRLB in Ngawi will be greatly influenced by the extent to which agricultural waste can be utilized to produce value-added products. Straw, husks, and bran, which have been considered waste, can actually be processed into compost, animal feed, and energy briquettes. Nurhayati *et al*. (2024) emphasize that by-product processing not only increases farmers' income but also supports business diversification, thereby reducing dependence on a single main product (rice). This condition is important in Ngawi, which is one of the national food barns, because farmers are very vulnerable to fluctuations in grain prices.

The next attribute is market access for environmentally friendly products (RMS = 5.03). Limited market access means that products produced by PRLB farmers are not valued differently from conventional products. This keeps the economic incentive to switch to environmentally friendly practices low. Agustina *et al*. (2024) found that farmers often only sell to middlemen at standard prices, even though their products are healthier and more environmentally friendly. Usman *et al*. (2024) suggest the need for marketing strategies, organic certification, and the use of digital platforms to expand the market network for environmentally friendly products. Thus, strengthening the market is an important step so that farmers can truly reap the benefits of PRLB.

The income stability attribute (RMS = 4.37) also has a significant influence. Farmers' income in Ngawi is still volatile due to dependence on a single commodity and uncertainty in grain prices. Nugraha & Maria (2021) explain that land ownership and capital are the main factors determining the stability of rice farmers' income, so farmers with small plots of land are more vulnerable to price shocks. Business diversification through the utilization of by-products and access to green markets can help reduce this instability (Widowati, 2011).

Profitability attributes (RMS = 3.93) are also important despite their lower value. Farmers' profitability is greatly influenced by input costs, selling prices, and productivity. In many cases, high production costs due to the use of chemical fertilizers and pesticides actually erode profits. This is in line with research by Dwiastuti & Dillak (2019), which shows that the application of environmentally friendly technologies can reduce production costs and increase profit margins. Meanwhile, production cost efficiency (RMS = 2.70) is the attribute with the lowest influence. However, even though it is not very sensitive in leverage analysis, cost efficiency remains important for maintaining the competitiveness of farming businesses. The use of organic fertilizers, water-saving technologies, and agricultural machinery can help reduce long-term production costs.

Thus, it can be concluded that in order to improve the economic sustainability of PRLB in Ngawi Regency, efforts need to be made to increase the added value of by-products, expand market access for environmentally friendly products, diversify businesses to maintain income stability, and improve production cost efficiency. If this strategy can be implemented consistently, the economic aspects of PRLB will not only survive, but also provide a strong incentive for farmers to continue implementing environmentally friendly agricultural practices.

3.4. Social Dimension Sustainability Index

The MDS analysis results show that the social dimension of PRLB in Ngawi Regency has a fairly sustainable status with a sustainability index value of 71.30%. This value is the highest compared to other dimensions, indicating that the social aspect of the farming community is relatively more prepared to support the implementation of PRLB.

Figure 4 shows the results of the social dimension leverage analysis. Based on the Root Mean Square (RMS) value, the most sensitive attribute is farmer participation in farmer groups (RMS = 7.01), followed by labor availability and farmer regeneration (RMS = 6.33), adoption of innovations and new knowledge (RMS = 5.17), the role of women (RMS = 4.72), and fairness in benefit sharing (RMS = 3.75). These attributes with high RMS are key in determining the sustainability of the social dimension of PRLB in Ngawi Regency.

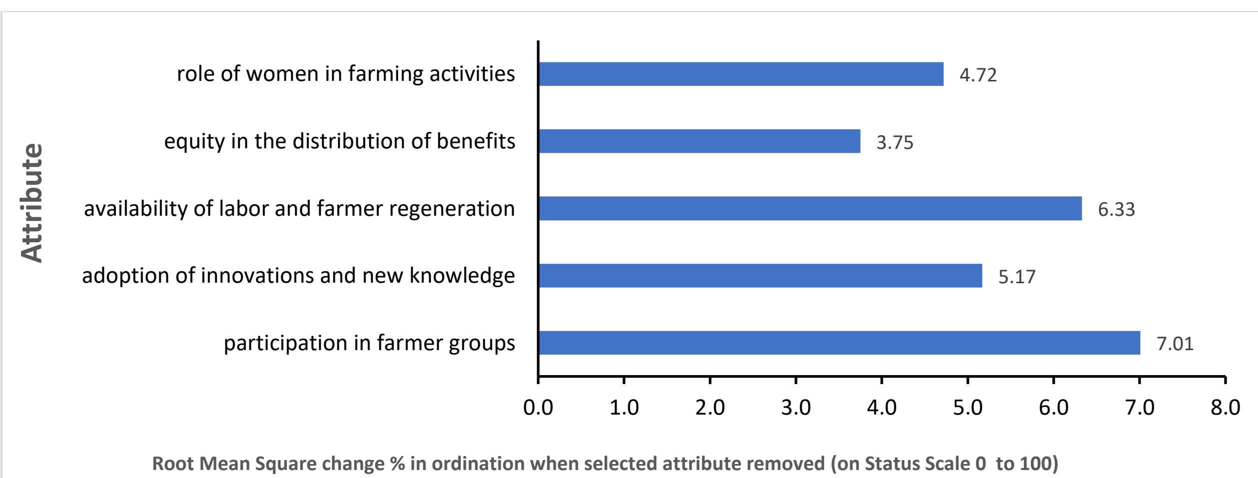

Figure 4 Results of the analysis of the leverage value of each social dimension attribute

The attribute with the highest RMS is farmer participation in farmer groups (RMS = 7.01). Farmer activity in farmer groups has a positive impact on access to information, the application of environmentally friendly technology, and the strengthening of farmers' bargaining position in the market. Research by Nugraha & Maria (2021) shows that farmer groups with strong social ties are able to increase productivity while strengthening social solidarity among farmers. Similar results were reported by Yanfika *et al*. (2022), which confirms that active farmer groups play an important role in maintaining the sustainability of agricultural resources. Conditions in Ngawi show that more organized farmer groups are able to adopt PRLB innovations more quickly than groups that are still passive.

The next attribute is the availability of labor and farmer regeneration (RMS = 6.33). The main problem in the social dimension is the declining interest of the younger generation in working in the agricultural sector. Based on the survey results, many young people in Ngawi choose to migrate to cities because they consider agriculture to be economically unpromising. Research by Marpaung & Bangun (2023) emphasizes that farmer regeneration is a key factor in maintaining agricultural sustainability, because without a new generation, the agricultural system will lose its main actors. Therefore, PRLB must also be positioned as a model of modern agriculture that is more attractive to the younger generation.

The attribute of innovation and new knowledge adoption (RMS = 5.17) shows that farmers' ability to accept new technologies is very important. However, in the field there are still obstacles in the form of limited capital, familiarity with old ways, and a lack of technical understanding. Nuryanti & Swastika (2016) states that active participation in farmer groups encourages farmers to more readily accept innovations, even though implementation is not always uniform. This indicates the need to increase the role of extension services and field demonstrations so that innovations can be adopted more quickly.

The role of women (RMS = 4.72) in PRLB also has an important contribution. Women often play a role as farm workers, family financial managers, and in post-harvest processing. Widiyani & Kurniawati (2025) shows that women's role in farming households is very significant in supporting family income, so their involvement in PRLB programs must be given more attention.

Finally, fairness in benefit sharing (RMS = 3.75), despite having a lower leverage value, remains important. Inequity in the distribution of business profits can lead to social conflict and reduce farmers' motivation to actively participate in PRLB. Therefore, transparent and fair mechanisms for profit sharing must be developed so that all parties feel they are benefiting. It can be concluded that to improve the sustainability of the social dimension of PRLB in Ngawi Regency, the steps that need to be prioritized are strengthening farmer group participation, young farmer regeneration programs, increasing innovation adoption capacity, recognizing the role of women, and implementing a fair benefit distribution system. If this is done consistently, the social aspect will become a strong foundation for the sustainability of PRLB in the future.

3.5. Technology Dimension Sustainability Index

The results of the MDS analysis show that the PRLB technology dimension in Ngawi Regency has a fairly sustainable status with a sustainability index value of 65.30%. This value indicates that the technological aspects have begun to be implemented, but are not yet optimal and still require further intervention (Febriana *et al*., 2025). This assessment covers a number of attributes, namely (1) composting technology and liquid organic fertilizer (POC), (2) water-efficient irrigation, (3) utilization of agricultural tools and machinery (alsintan), (4) post-harvest technology, and (5) access to digital/information technology.

Figure 5 shows the results of the technology dimension leverage analysis. The attribute with the highest Root Mean Square (RMS) value is composting technology and liquid organic fertilizer (RMS = 7.62), followed by water-efficient irrigation (RMS = 6.71), utilization of alsintan (RMS = 6.67), post-harvest technology (RMS = 6.08), and access to digital/information technology (RMS = 5.59). Based on the presentation Rochmah *et al*. (2021), attributes with high RMS values are the main key to improving the sustainability of the technological dimension.

The most sensitive attribute is composting technology and liquid organic fertilizer (RMS = 7.62). The application of this technology plays a major role in replacing farmers' dependence on chemical fertilizers. Research by Budiyanto *et al*. (2025), shows that consistent use of rice straw compost can increase soil organic matter content, improve soil

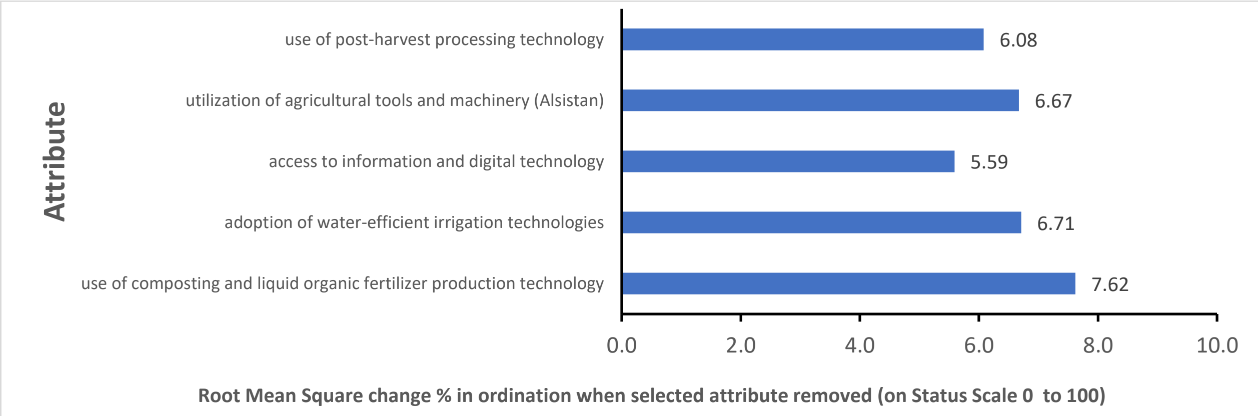

Figure 5. Results of the analysis of the leverage value of each attribute of the technology dimension

physical structure, and reduce the cost of purchasing chemical fertilizers. This confirms that increasing farmers' capacity to produce and use POC is one of the main strategies for the sustainability of PRLB technology.

The next attribute is water-efficient irrigation (RMS = 6.71). In Ngawi, which is an area with intensive rice cultivation, water availability is a critical factor. Conventional irrigation systems that are wasteful of water often cause seasonal drought problems. According to research Budianto *et al*. (2025), The implementation of water-saving irrigation systems such as alternate wetting and drying (AWD) can save up to 55.03% of water usage without reducing productivity. Thus, the adoption of water-saving irrigation technology is highly relevant to strengthening the sustainability of PRLB.

Furthermore, the use of agricultural tools and machinery (RMS = 6.67) is also sensitive to the sustainability index. The use of agricultural tools and machinery such as tractors, water pumps, and harvesting machines can reduce labor costs while increasing time efficiency. However, limited capital and access mean that not all farmers in Ngawi can use them (Indrayanti *et al*., 2024). Based on Aldillah (2016), The existence of agricultural machinery service units (UPJA) managed by farmer groups is an effective solution for distributing technology more evenly.

Post-harvest technology attributes (RMS = 6.08) are also important to consider. Yield losses due to improper post-harvest handling are still common among farmers. Traditional drying of grain on roadsides or open yards reduces rice quality (Mahmood *et al*., 2024). Husniyyah *et al*. (2024) reported that the use of flat bed dryers can reduce crop losses by 10–15% while maintaining grain quality. This shows the need for improved post-harvest facilities that are easily accessible to farmers.

In addition, access to digital technology and information (RMS = 5.59) plays an important role in sustainability. Currently, some farmers in Ngawi already use smartphones, but their use is still limited to communication and has not been maximized for access to market price information, weather forecasts, or online training. According to research Sahputra *et al*. (2024), Low digital literacy among farmers is a major obstacle to the use of information technology in agriculture. Therefore, digital literacy training needs to be strengthened so that digital technology can truly support the sustainability of PRLB.

Based on the above description, it can be concluded that improving the sustainability of the technological dimension of PRLB in Ngawi Regency needs to focus on increasing the implementation of compost and POC technologies, adoption water-efficient irrigation systems, strengthening access to agricultural machinery through farmer institutions, providing more adequate post-harvest facilities, and improving farmers' digital literacy. If this strategy is implemented systematically, the technological dimension will become the main driver of PRLB sustainability in the future.

3.6. Institutional Dimension Sustainability Index

The results of the MDS analysis show that the institutional dimension of PRLB in Ngawi Regency has a fairly sustainable status with a sustainability index value of 67.32%. This value is in the moderate category, which means that institutional support for the implementation of PRLB already exists but is not yet optimal, so it needs to be strengthened, especially in terms of capacity, roles, and synergy between actors (Setiawan *et al.*, 2025). This assessment covers the attributes (1) active role of field agricultural extension workers (PPL), (2) strength of farmer groups/cooperatives, (3) partnerships with the private sector/market, (4) access to capital, and (5) effectiveness of government policies.

Figure 6 shows the results of the institutional dimension leverage analysis. The most sensitive attribute is the active role of field agricultural extension workers (RMS = 6.17), followed by the strength of farmer groups/cooperatives (RMS = 5.21), partnerships with the private sector/market (RMS = 4.72), access to capital (RMS = 4.47), and the effectiveness of government policies (RMS = 3.30). These values indicate that the sustainability of PRLB institutions is largely determined by how effectively local actors and supporting institutions can function.

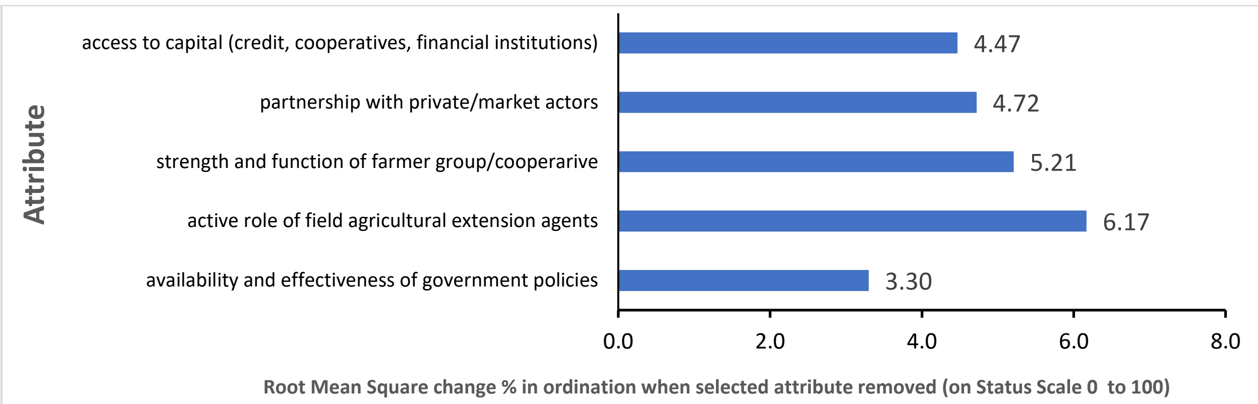

Figure 6. Results of the analysis of the leverage value of each attribute of the institutional dimension

The attribute with the highest RMS is the active role of field agricultural extension workers (RMS = 6.17). PPLs are at the forefront of policy implementation in the field, serving as information disseminators, technology adoption facilitators, and farmer assistants. However, the limited number of PPLs in Ngawi and their heavy workload mean that they are not yet able to perform their roles optimally (Rosdiana *et al*., 2025). Putri *et al*. (2022) explains that the success of agricultural programs is highly dependent on the intensity of PPL interaction with farmers. Therefore, increasing the number, capacity, and support facilities for PPL is key to strengthening institutional sustainability.

The next attribute is the strength of farmer groups/cooperatives (RMS = 5.21). Strong farmer groups are able to improve farmers' bargaining position, expand access to inputs, technology, and markets, and become a forum for social learning. Research by Mutmainah & Sumardjo (2015) emphasizes that the success of agricultural development cannot be separated from the role of farmer groups as local organizations. In Ngawi, some farmer groups are quite active, but there are still groups that are passive or merely formalities. Therefore, strengthening the institutional capacity of farmer groups through management training, access to capital, and market networks is important.

The attribute of partnership with the private sector/market (RMS = 4.72) also has a significant effect. PRLB farmers often face difficulties in selling their products at premium prices due to limited access to environmentally conscious markets (Olagunju *et al*., 2025). Pasaribu (2016) emphasizes that partnerships with the private sector can provide market guarantees and more stable prices for farmers. Therefore, encouraging partnership contracts with processing companies, modern retailers, or marketing cooperatives can improve the institutional sustainability of PRLB.

Access to capital (RMS = 4.47) is an important factor because many farmers have difficulty obtaining capital to purchase environmentally friendly inputs or access new technologies (Harudin, 2025). Yoko & Prayoga (2019) explains that low-interest microcredit schemes can help small farmers innovate. In Ngawi, despite the existence of the People's Business Credit (KUR) program, not all farmers have access to it due to limited collateral or information.

The effectiveness of government policy (RMS = 3.30), despite having the lowest influence, remains an important attribute. PRLB policies often still focus on normative aspects and are not yet fully integrated with the needs of farmers at the local level (Juwenie *et al*., 2024). Handayani *et al*. (2024) stating that policies are only effective if their implementation is consistent and accompanied by monitoring in the field. Therefore, there needs to be adaptation of government policies to be more responsive to local conditions in Ngawi. Improving the sustainability of the institutional dimension of PRLB in Ngawi Regency can be achieved by strengthening the role of PPL, building strong farmer groups/cooperatives, encouraging partnerships with the private sector, expanding access to capital, and ensuring that government policies can be implemented effectively in the field.

4. CONCLUSION AND RECOMMENDATIONS

4.1. Conclusion

This study shows that the sustainability status of Sustainable Environmentally Friendly Agriculture (PRLB) in Ngawi Regency is in the moderately sustainable category with an average index value of 67.28. The social dimension is the strongest, supported by the active participation of farmer groups and the role of women, while the ecological dimension is the weakest due to the low adoption of organic fertilizers and conservation practices. Sensitive factors that affect the sustainability of PRLB include the use of organic fertilizers, agricultural waste management, added value of by-products, farmer participation, regeneration of young workers, and the role of field agricultural extension workers. The Monte Carlo validation results showed a very small difference, indicating that the analysis results are stable and reliable. The Multidimensional Scaling (MDS) approach proved to be effective as a quantitative model for assessing and mapping the sustainability of PRLB at the regional level.

4.2. Recommendation

Based on the results of the study, it is recommended that efforts to improve the sustainability of PRLB in Ngawi Regency focus on strengthening the ecological and institutional dimensions, particularly through increased use of organic fertilizers, integrated agricultural waste management, and the development of added value for agricultural by-products. In addition, the capacity of farmer groups and the role of agricultural extension workers in the field need to be continuously optimized to encourage the adoption of sustainable agricultural practices. Going forward, the development of environmentally friendly agricultural systems needs to be directed towards the use of digital technology, efficient use of resources, and climate change mitigation strategies in order to achieve resilient and sustainable agriculture.

AUTHOR CONTRIBUTION STATEMENT

Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
RP	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
ASL	✓	✓		✓				✓		✓			✓	✓
AA	✓	✓		✓				✓		✓				✓
Soe	✓	✓		✓				✓		✓				✓
AAS	✓	✓		✓				✓		✓				✓

C: Conceptualization	Fo: Formal Analysis	O: Writing - Original Draft	Fu: Funding Acquisition
M: Methodology	I: Investigation	E: Writing - Review & Editing	P: Project Administration
So: Software	D: Data Curation	Vi: Visualization	
Va: Validation	R: Resources	Su: Supervision	

ACKNOWLEDGEMENTS

The authors would like to express their sincere gratitude to the Graduate School of Universitas Brawijaya, Malang, for the financial support provided for this research through Grant No. 4/UN10.F4001/B/PT/2025.

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