



# Compound Cropping Innovation for Enhancing Farmers' Terms of Trade in Calcareous Drylands: A Low-Input Agroforestry Approach



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**Abstract:** Dryland agriculture faces multiple challenges, particularly extreme environmental conditions and institutional constraints, which increase the vulnerability of farming households. Despite the availability of agricultural land, sustainable solutions are required to improve land productivity and farmer welfare. This study aims to analyze the effectiveness of compound cropping innovation in enhancing Farmers' Terms of Trade (FTT) in calcareous drylands. A mixed-methods approach was employed, integrating qualitative and quantitative techniques through surveys, field observations, and participatory farmer empowerment using a demonstration plot. The study introduced a compound polyculture system combining maize (*Zea mays*) and jack bean (*Canavalia ensiformis*) as a low-input agroforestry innovation. The results indicate that major constraints in the Kendeng Mountains include pest attacks (particularly rats), drought-induced soil degradation, limited capital, and restricted access to agricultural inputs and markets. The introduction of the maize–jack bean system improved land productivity and increased FTT from 69.24 to 74.13. These findings demonstrate that jack bean-based compound cropping is agronomically suitable and economically beneficial in dryland conditions. The model also contributes to sustainable agriculture by improving soil fertility, reducing production risk, and enhancing farmer resilience. Therefore, this innovation has strong potential for wider adoption in the Kendeng region and similar dryland ecosystems.

**Keywords:** Sustainable agriculture; Low-input agroforestry; Legume cover crop; Agroecological innovation; Compound cropping; Farmers' Terms of Trade; Jack bean

## 1. Introduction

Dryland agriculture faces various challenges, mainly related to extreme environmental conditions such as drought, limited water availability, poor soil fertility, high seasonal variability, and soil quality degradation (Bantilan et al., 2006). In addition to biophysical pressures, increasingly unpredictable climate dynamics also pose a serious threat to the sustainability agriculture (Altieri & Nicholls, 2017; Intergovernmental Panel on Climate Change, 2023) including a dryland agriculture. The combination of these factors not only limits land productivity but also reduces the efficiency of agricultural input use and increases the vulnerability of local farming businesses. Meanwhile, farming businesses in this region are a key sector driving the rural economy, with a direct impact on farmers' incomes and household welfare.

In addition to biophysical factors, institutional dimensions, particularly those related to land tenure security, also play an important role in the sustainability of farming (Barrett et al., 2010) and farm household poverty (Miller et al., 2021). Property rights theory holds that the stronger the land management rights, the greater the incentive for managers to invest in the land (Kurbanov et al., 2025). In Indonesia, the social forestry scheme grants local residents management rights for up to 35 years. Theoretically, the certainty of management rights should

encourage optimization of the production system. However, despite this tenure certainty, improvement in agricultural yields and household welfare have not yet been fully realized, indicating the need for complementary technical, social, economic interventions.

At the research site in the dry Kendeng hills, specifically in Kedungtuban Subdistrict, Blora, the land currently managed by farmers is the result of an agrarian reform (*Reforma Agraria*, RA) scheme within the social forestry (*Perhutanan Sosial*, PS) framework. Despite long-term certainty of management rights, the prevailing cultivation system is still dominated by a single crop, maize (monoculture), at the end of the rainy season. After harvest, some of the land tends to be underutilized during the dry season due to water limitations and the high risk of crop failure. This pattern results in relatively low planting intensity, concentrated income distribution in a single harvest period, and high vulnerability to price and production fluctuations. These conditions have implications for the low Farmers' Terms of Trade (FTT) as an indicator of the relative welfare of farming households.

The vulnerability of dry-land farming households requires long-term solutions, even amid adequate agricultural land availability. Empowerment based on land and non-land (social and economic) activities is one of the efforts to improve the productive management of increased utilization value (Barrett et al., 2010; Suminah et al., 2023) and an important strategy for promoting sustainable forest resource management among farmers who are recipients of redistribution agreement (BPS-Statistics Indonesia Blora Regency, 2024b; Robinson et al., 2014). PS in Kedungtuban Subdistrict is generally of the Grumusol type, which is alkaline and has almost no organic activity, making this soil infertile (BPS-Statistics Indonesia Blora Regency, 2024b). Under such conditions, low-input and ecologically adapted farming innovations become particularly important.

Innovations that empower farmers in terms of land use technology include: (1) a series of harvest calendars, (2) a compound cropping system in accordance with the cycle (Banowati & Prajanti, 2017; Beiküfner et al., 2019; Lechner et al., 2020), (3) selection of legume crops, such as peanut (*Arachis hypogaea* L.) as a companion crop to maize (*Zea mays*), which may help maintain production continuity and improve land-use efficiency (Feng et al., 2021), (4) improving soil fertility (Banowati & Prajanti, 2017; Vanlauwe et al., 2010) play an important role in enhancing agricultural productivity and sustainability. Peanut root nodules are the result of mutualistic symbiosis between *Rhizobium* bacteria and plants as a process of nitrogen fixation (Zhang et al., 2024). Due to its ability to fix nitrogen, *Rhizobium* has been widely used as a biofertilizer (Zhang et al., 2024). In addition, the demand for peanuts continues to increase in line with the development of the food industry and the growth in the number of consumers (Variath & Janila, 2017), and this plant can grow across various agroclimatic environments with varying temperatures, rainfall, and soil types. Such legume-based systems are particularly relevant to organic farming, sustainable agriculture, and low-input agroforestry, as they can improve soil cover, support biological nitrogen fixation, and contribute to more efficient nutrient cycling (Drinkwater et al., 1998; Peoples et al., 2009). (5) Another promising innovation is the introduction of jack bean (*Canavalia ensiformis*), locally known as *koro pedang*, a type of legume that can replace soybeans (*Glycine max*) and is resistant to rat pests. Jack bean is a diversified crop with several advantages, including drought tolerance, resistance to pests and high productivity (Prasetyo et al., 2025; Safarov et al., 2025). As a legume cover crop, jack bean has the potential to support agroecological innovation by improving land productivity while remaining consistent with low-input and sustainable agricultural practices (Safarov et al., 2025). The urgency of research on empowering subject farmers to increase the value of PS land redistribution in accordance with existing land on the FTT, and on how the compound system innovation model significantly increases FTT, thereby reducing structural poverty, therefore deserves greater attention. This study contributes to the existing literature by integrating agroecological innovation with socio-economic indicators, particularly FTT, as a proxy for rural welfare. Unlike previous studies that focus primarily on productivity, this research emphasizes the combined impact of ecological adaptation and economic resilience in dryland farming systems.

## 2. Methodology

### 2.1 The Study Area

This study was conducted in the Kendeng Mountains, specifically in Sogo Village, Kedungtuban District, Blora, Indonesia. The dominant vegetation in the study area is teak (*Tectona grandis*), which is generally found on grumusol soil, a soil type internationally classified as a Vertisol. This soil type is characterized by a heavy clay texture, high expansion-contraction properties, and a soil pH that tends to be neutral to alkaline. Agroclimatically, based on data from the Center for Watershed Management of Solo (*Balai Pengelolaan Daerah Aliran Sungai Solo*, BPDAS Solo), the annual rainfall in Kedungtuban District amounted to 2,157 mm in 2022, decreased to 1,764 mm in 2023, and subsequently increased to 1,909 mm in 2024, indicating interannual variability in precipitation patterns. At the research location, rainfall occurred over five months (January to March, June, and December), and in 2025, rainfall was 0.2 mm in May. Oldeman's climate classification, which is based on the number of wet months, humid months, and dry months, was used to identify the agroclimatic zone of the study area. Based on rainfall data from four local weather stations, the research location was classified as C3, an Oldeman agroclimatic

type characterized by 4–5 wet months and 5–6 dry months. Areas with a C3 climate type are generally suitable for secondary food crops, such as maize and beans. Consideration of agroclimatic conditions is also very useful for determining planting times and crop types (Safarov et al., 2025).

## 2.2 Research Design

The analysis in this study used a mixed-methods approach, combining qualitative and quantitative methods. Survey research and data exploration were conducted by empowering subject farmers through an innovative compound cropping system implemented in the Production Forest Area—specifically in Kedungtuban Subdistrict, Blora Regency, as the PS location (Dinas Lingkungan Hidup Kabupaten Blora, 2022). At the research location, the subject farmer community had received a land redistribution management agreement. Data exploration techniques used field observations to obtain data on land cultivation and utilization after redistribution. The overall research design and analytical framework of the study are presented in Figure 1.

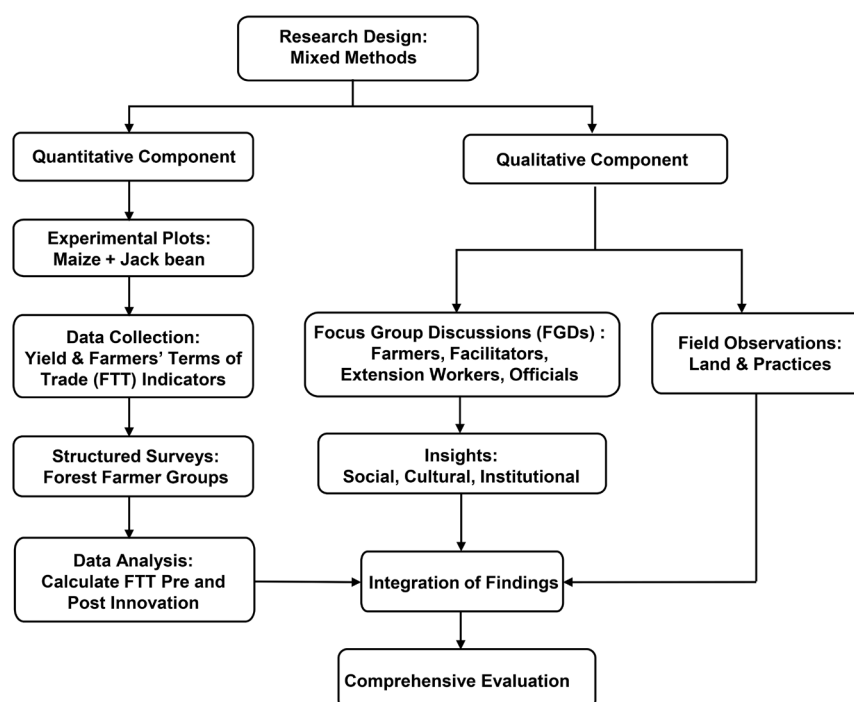


**Figure 1.** Research framework

## 2.3 Study Population and Sample

The population area was located in Sogo Village and Galuk Village (Kedungtuban Subdistrict), Blora Regency, Indonesia. The communities in these villages have received PS land redistribution under Land Management Rights (LMR) and Social Forestry Decrees. The location was selected based on the following considerations: rehabilitation has been carried out, facilitation from BPDAS Solo in 2024, and the economic transaction value of seasonal crops. For the FTT calculation, the farmer sample was selected by random sampling, with 12 farmers and a total managed land area of 4.866 ha.

## 2.4 Data Collection Technique

Landsat 8 OLI (Operational Land Imager) imagery was accessed on the [earthexplorer.usgs.gov](https://earthexplorer.usgs.gov) website as the source of initial mapping data for the research location because it has a spatial resolution of 30 m. Spatial analysis was also supported by drone data and field surveys, which provided more accurate, targeted data. Data collection from research subjects was conducted through focus group discussions (FGDs) and in-depth interviews to obtain information on current land use and farmers' knowledge of agricultural challenges or constraints, the design of models to improve farm income through FTT, and other relevant topics. FGDs were conducted with stakeholders, including farmers, the Village Forest Community Institution, the village government, and the Technical Implementation Unit of the Environmental and Forestry Department of Blora Region I. Empowerment and agricultural education activities were carried out together with the subjects in a bottom-up innovation process.

## 2.5 Design Demonstration Plot: Compound System

Based on measurement results and field interviews, polygons were created to cover the demonstration plot area or the trial area for planting jack bean in the forest plot at the PS location in Sogo Village (Figure 2). These polygons were used to identify the planting area, monitor plant development, and support the reporting and tracking of land productivity. The compound cropping system was implemented in a demonstration plot under the guidance of field instructors, including resource persons from agricultural agencies and/or the Indonesian Agency for Meteorology, Climatology, and Geophysics (*Badan Meteorologi, Klimatologi, dan Geofisika*, BMKG). The activities in this demonstration plot are primarily intended as a medium for educating farmers to strengthen their understanding of the compound system, as an experiment to test the suitability of plants to the physical conditions at the research site, and as input for measuring the potential to improve the welfare of local farmers. The demonstration plot is located at 7° 09' 53" S and 111° 28' 56" E, covering 0.2 ha. Administratively, it is located in Sogo Village, Kedungtuban District, Blora (Figure 2).

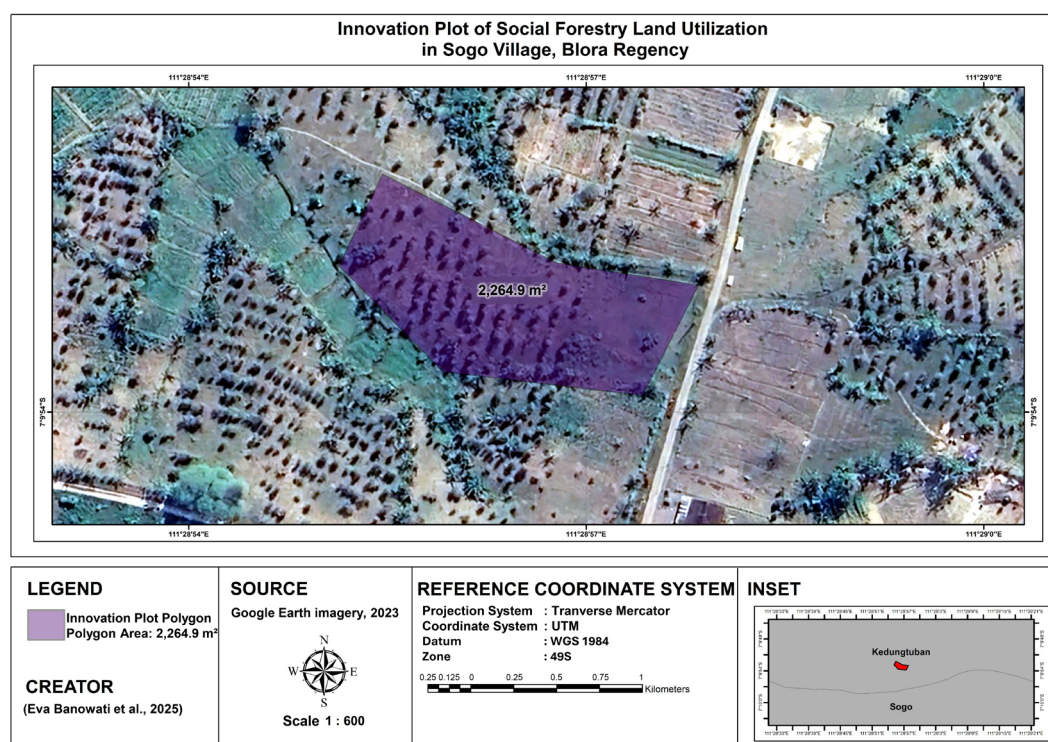


**Figure 2.** Innovation plot of social forestry land utilization in Sogo Village, Blora Regency

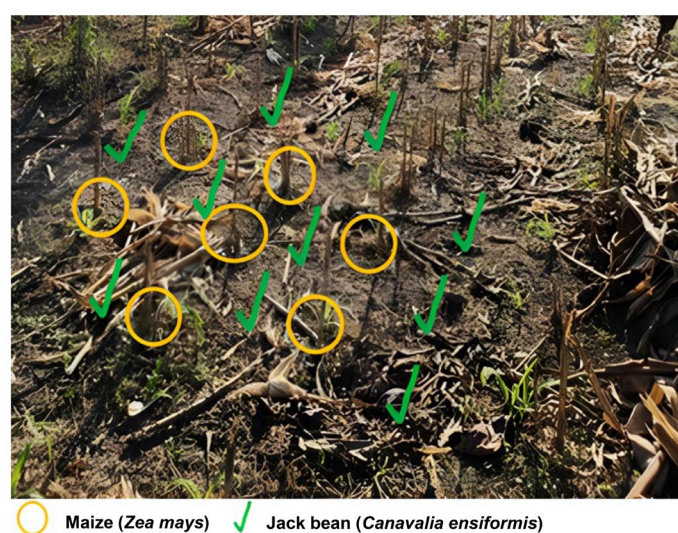


**Figure 3.** Innovative design for redistributed land utilization

The design is illustrated in Figure 3, where, in a compound cropping system, existing maize plants are interspersed with jack bean plants in an alternating pattern with a spacing of about 30 cm. The procedure is to plant jack bean seeds in planting holes between the maize rows, ensuring they do not overlap. The land is prepared without plowing or hoeing, since the maize had already been planted. The jack bean seedlings were observed at 7–18 days after planting, as shown in Figure 3. Maintenance and fertilization were carried out after the seedlings were more than 2 weeks old. Irrigation still relies on rainwater; later, these plants will need stakes for support. Pest and disease control on plants must still be considered, with crop rotation activities to prevent pest outbreaks.

## 2.6 Data Analysis

Geographic Information System (GIS) analysis was conducted using land use mapping and management information from the community and forestry authorities. Spatial land-use information was used as input for mapping and as a basis for determining the appropriate strategy for designing a model to increase FTT. GIS analysis was carried out through visual interpretation of remote sensing data using Landsat 8 OLI imagery to observe land cover and produce a tentative land-use map, followed by validation using drone observations and terrestrial surveys.

The results of the FGD were then used in a SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis to determine the actual position of the dryland agriculture sector in the research location for further development and as a basis for developing an empowerment model. To quantitatively measure the economic conditions of local farmers and estimate their improvement, this study also calculated the FTT of farmers before and after the implementation of the innovation. The FTT calculation was performed using the following formula (BPS-Statistics Indonesia, 2022).

$$FTT = \frac{It}{Ib} \times 100 \quad (1)$$

where,

$FTT$  = Farmers' Terms of Trade;

$It$  = total value received by farmers from agricultural production (Indonesian Rupiah, IDR), calculated as total production multiplied by the commodity price;

$Ib$  = total value paid by farmers (IDR), representing total household expenditure, consisting of:

1. Production costs (e.g., seeds, fertilizers, labor)
2. Household consumption expenditure based on the Decent Living Needs (DLN) standard for each farming household).

Therefore, this approach aligns with the definition of FTT, which defines  $Ib$  as all expenses farmers must pay, including production activities and household consumption. Thus, in this study, FTT is calculated using actual monetary values rather than price indices, in order to better reflect the real economic condition and purchasing power of farming households.

## 3. Results and Discussion

As an agricultural country, Indonesia has several regions whose management includes agricultural activities. The survey conducted by the research team was carried out in Blora Regency, specifically in Kedungtuban District, covering approximately 106.86 km<sup>2</sup>, which accounts for 5.87% of the regency's total area. This subdistrict comprises 17 villages, including Sogo, Galuk, and Temengeng. One of the locations surveyed was Sogo Village, which has an area of 3.80 km<sup>2</sup> (BPS-Statistics Indonesia Blora Regency, 2024a). The research findings presented in this section are based on secondary data from authorized institutions, primary data collected through interviews and field observations, in-depth interviews with selected respondents, and the analysis of land-use innovation.

Issues related to land ownership, land control, and community land management are important in this agrarian context, where many people depend on farming for their livelihoods. In the study area, members of the Forest Farmers Group (*Kelompok Tani Hutan*, KTH) obtained approval from the Community Forest manager to cultivate the land in order to strengthen the participation and empowerment of KTH members and institutions, with the aim of improving welfare. In accordance with the provisions, optimal and sustainable forest land use can be managed by farmers who have obtained access approval for up to 30 years, with an extension of up to 20 years. While maintaining environmental sustainability, this is carried out by forming Social Forestry Business Groups (*Kelompok Usaha Perhutanan Sosial*, KUPS). Business groups are formed by Social Forestry permit holders or Social Forestry Rights holders to improve community welfare by utilizing non-timber forest products. KUPS plays an important role in forest management, including land preservation and utilization, and may further support the development of forest product-based businesses and low-input sustainable agricultural practices. Figure 4 shows the distribution of social forestry land area, membership, and average landholding across the three KUPS in Blora

Regency. The total managed land area was 76.316 ha, with 144 permitted farmers and an average landholding of 0.529 ha per farmer. These conditions highlight the importance of social forestry land management as a basis for improving farmer welfare and strengthening sustainable rural livelihoods in the study area. This is also relevant to SDG 1, particularly in relation to reducing rural poverty through improved access to productive land and more secure land tenure.

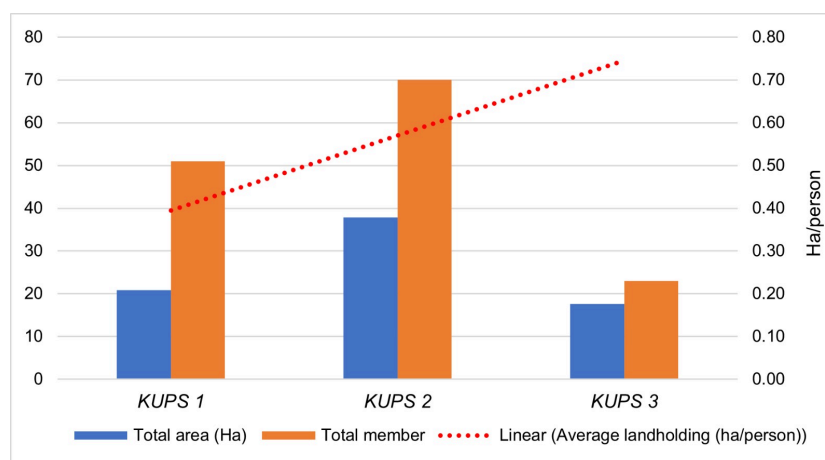


**Figure 4.** Distribution of social forestry land and membership across three Social Forestry Business Groups (KUPS) in Blora Regency

In this study, empowerment was used to support activities aimed at optimizing land use and agricultural products, increasing land productivity, and providing environmental protection services. Respondent attributes were determined by the research team based on indicators relevant to the research topic, to interpret data collected from respondent actors, and ensure the research was relevant to the target.

Based on information from the Blora Forestry Service Branch Office (*Cabang Dinas Kehutanan*, CDK) 1, the FGD was held with the forest management team in the Sogo Village area, accompanied by the CDK 1 team, on Wednesday, April 23, 2025. The FGD results showed that the local community in the area uses a social forestry system to promote community welfare. The discussion involved three Forest Farmer Groups (KTH), namely: Sendang Agung Rejo II in Sogo Village, KTH Wono Berkah in Galuk Village, and KTH Gilang Maju Mulyo in Kutukan Village. The farmers reported that several pests are currently attacking the area, including rats and termites. The farmers reported that several pests, including rats and termites, were attacking maize and other productive crops, thereby reducing yields. In addition, dry and windy conditions were reported to contribute to the thinning of the soil surface layer.

In November 2024, the government, through BPDAS Solo, implemented the Forest and Land Rehabilitation (RHL) program to restore, maintain, and improve the function of forests and land, thereby increasing their carrying capacity. This program applies the Multi-Purpose Tree Species (MPTS) system by planting sweet orange (*Citrus sinensis* L.) and jackfruit (*Artocarpus heterophyllus*) trees. This system primarily produces wood, while non-wood products offer benefits, such as fruits, leaves, food, and green fodder for livestock, including greening, reforestation, increased income, and reduced risk of crop failure due to pests or diseases in a single crop type. However, these plants are long-term crops, so they are not yet optimal for water retention or for protecting the soil from wind erosion.

Empowerment of farmers managing PS land was carried out to increase farm income and improve farmers' understanding of possible solutions to declining yields caused by rat pests. In addition, the FGD identified various strengths, weaknesses, challenges, and opportunities of dryland farming at the research site. The aspirations and outcomes of the discussion were then analyzed using the SWOT analysis and quantified to identify the current position/situation of agriculture and to serve as a basis for formulating a strategic plan for its future development. The following are the results of the SWOT analysis presented in Table 1 and Figure 5.

The SWOT analysis results in Table 1 indicate that the internal strengths of the agricultural system at the research site outweigh its weaknesses. The total strength score was 3.37, while the total weakness score was 2.51, resulting in a positive Internal Factor Analysis Summary (IFAS) value of 0.86. Among the strengths, the highest score was recorded for predominantly productive-age human resources (0.70), followed by adequate land area (0.60), and both land management transfer to farmers and support from field extension officers (0.57 each). These findings suggest that the study area has relatively favorable internal resources for agricultural development. However, several weaknesses remain important, particularly limited market access (0.68), limited access to capital (0.55), and insufficient agricultural inputs (0.49), indicating that institutional and financial constraints still limit

the optimal use of these strengths.

In terms of external factors, the total opportunity score was 3.45, which was substantially higher than the total threat score of 1.96, resulting in a positive External Factor Analysis Summary (EFAS) value of 1.49. The most important opportunities were institutional support from BPDAS Solo and CDK agencies (1.13), support from the local government (1.10), and increasing market demand for food products (0.63). At the same time, the main threats were limited market access (1.31) and competition from products in neighboring regions (0.65). These results indicate that, although external challenges remain, the study area has stronger development opportunities than threats. Therefore, as shown in Figure 5, the study area falls into Quadrant I, which supports the adoption of an aggressive growth strategy. In this context, the introduction of jack bean as part of a compound cropping system can be understood as a strategic response that builds on existing land resources, institutional support, and market opportunities while addressing production risks and improving land use.

**Table 1.** SWOT analysis for agrarian development potential

| Factors                                       |               | Category                                                                                                                                                                                                                       | Weight | Rating | Score |
|-----------------------------------------------|---------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|--------|-------|
| Internal factor                               | Strengths     | 1 Land management has been transferred to farmers                                                                                                                                                                              | 0.19   | 3.00   | 0.57  |
|                                               |               | 2 Adequate land area                                                                                                                                                                                                           | 0.17   | 3.50   | 0.60  |
|                                               |               | 3 Established Social Forestry Business Groups ( <i>Kelompok Usaha Perhutanan Sosial</i> , KUPS)                                                                                                                                | 0.15   | 3.40   | 0.51  |
|                                               |               | 4 Soil fertility can still be improved                                                                                                                                                                                         | 0.14   | 3.00   | 0.42  |
|                                               |               | 5 Support from field extension officers                                                                                                                                                                                        | 0.15   | 3.80   | 0.57  |
|                                               |               | 6 Predominantly productive-age human resources                                                                                                                                                                                 | 0.20   | 3.50   | 0.70  |
|                                               |               | Total                                                                                                                                                                                                                          | 1.00   | –      | 3.37  |
|                                               | Weakness      | 1 Limited openness to innovation (conventional practices)                                                                                                                                                                      | 0.21   | 2.10   | 0.44  |
|                                               |               | 2 Limited access to capital                                                                                                                                                                                                    | 0.17   | 3.22   | 0.55  |
|                                               |               | 3 Insufficient agricultural inputs                                                                                                                                                                                             | 0.19   | 2.60   | 0.49  |
|                                               |               | 4 Limited market access                                                                                                                                                                                                        | 0.25   | 2.70   | 0.68  |
|                                               |               | 5 Multi-Purpose Tree Species (MPTS) not yet productive                                                                                                                                                                         | 0.18   | 1.95   | 0.35  |
|                                               |               | Total                                                                                                                                                                                                                          | 1.00   | –      | 2.51  |
| Total Internal Factor Analysis Summary (IFAS) |               |                                                                                                                                                                                                                                | –      | –      | 0.86  |
| External factor                               | Opportunities | 1 Increasing market demand for food products                                                                                                                                                                                   | 0.20   | 3.17   | 0.63  |
|                                               |               | Institutional support from Center for Watershed Management of Solo ( <i>Balai Pengelolaan Daerah Aliran Sungai Solo</i> , BPDAS Solo) and Blora Forestry Service Branch Office ( <i>Cabang Dinas Kehutanan</i> , CDK) agencies | 0.32   | 3.54   | 1.13  |
|                                               |               | 3 Support from local government                                                                                                                                                                                                | 0.30   | 3.66   | 1.10  |
|                                               |               | 4 Opportunities for developing agricultural commodities of high economic value                                                                                                                                                 | 0.18   | 3.25   | 0.59  |
|                                               |               | Total                                                                                                                                                                                                                          | 1.00   | –      | 3.45  |
|                                               | Threats       | 1 Competition from products in neighboring regions                                                                                                                                                                             | 0.43   | 1.50   | 0.65  |
|                                               |               | 2 Limited market access                                                                                                                                                                                                        | 0.57   | 2.30   | 1.31  |
|                                               |               | Total                                                                                                                                                                                                                          | 1.00   | –      | 1.96  |
| Total External Factor Analysis Summary (EFAS) |               |                                                                                                                                                                                                                                | –      | –      | 1.49  |

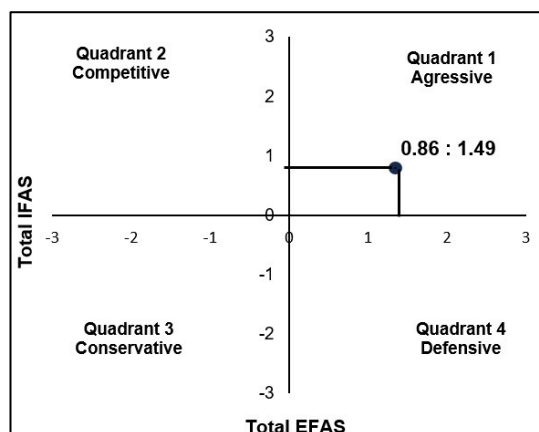


**Figure 5.** SWOT analysis result

Note: IFAS: Internal Factor Analysis Summary; EFAS: External Factor Analysis Summary

Based on the FGDs results, jack bean was selected for planting because rats do not usually attack this plant according to the information obtained. In addition to its resistance to rat pests, this plant can help protect the soil surface from erosion because of its creeping and climbing growth habit. This plant can be used as ground cover crop in forest areas. Subsequently, community planting was carried out in April 2025, at the end of the rainy season, although the community still had difficulty obtaining F1 jack bean seeds. The FGD and interview results also indicated that limited farmer knowledge regarding agricultural land management and utilization could greatly affect agricultural productivity. Therefore, it is necessary to improve crop planning, from seed selection to crop maintenance, in order to ensure product quality and marketability and thereby support poverty alleviation and the welfare of forest farmers.

Jack bean is a type of legume that is widely cultivated and used as an alternative source of protein, especially as a substitute for soybeans. Various literature sources (Kessler, 1990; Prasetyo et al., 2025; Safarov et al., 2025) and interviews with farmers in Kebumen (May 2025) indicate that this plant is very easy to cultivate. Jack bean seeds can grow in all types of soil, even sandy soil. Planting at the end of the rainy season is more labor-efficient, and the crop can continue growing during the dry season. However, irrigation depends on water availability and the capacity of farmers. Efforts to obtain seeds are done online and directly from farmers. Jack beans are indeed edible, but it is not recommended to consume them directly. Jack bean seeds contain toxic compounds such as HCN and Concanavalin A (Con A), which can cause dizziness or other side effects. Jack beans need to be processed first, for example, by boiling or fermenting them into tempeh, to reduce the levels of these toxic compounds (Ramdani, 2017). Young jack bean pods can be used as vegetables, while the seeds can be processed into tempeh or bean sprouts (Widiantara & Cahyadi, 2017).

The community's aspiration is to choose jack bean plants, which are planted alongside maize in a compound -cropping system. This is a mixed farming system that integrates several types of plants in one field, taking into account the interaction between plants and the environment. This system aims to increase productivity, reduce the risk of pests and diseases, and improve agricultural sustainability to obtain maximum results from optimal land use. Jack bean plants will grow optimally when they receive full sunlight, as in this experimental demonstration plot. However, these plants are still adaptable to shaded conditions and can even produce good seeds (Prasojo et al., 2025). Growth optimization was successfully achieved by applying organic fertilizer in the form of animal manure.

Furthermore, a cropping calendar was developed to provide information on crop types, planting and harvesting schedules, and crop maintenance (Ramdani, 2017; Widiantara & Cahyadi, 2017). The resulting cropping calendar is presented in Figure 6.

| Research Area | Month                                |   |   |   |   |           |   |   |   |           |    |    |
|---------------|--------------------------------------|---|---|---|---|-----------|---|---|---|-----------|----|----|
|               | 1                                    | 2 | 3 | 4 | 5 | 6         | 7 | 8 | 9 | 10        | 11 | 12 |
|               | Wet Month                            |   |   |   |   | Dry Month |   |   |   |           |    |    |
| Sogo Village  | Compound system: maize and jack bean |   |   |   |   |           |   |   |   | Jack bean |    |    |

**Figure 6.** Cropping calendar for agroforestry systems in the study area

The cropping calendar tool helps farmers understand and visualize the patterns and processes of crop cultivation. In this study, the crops cultivated were maize and jack bean, which formed the compound cropping system. At the research site, the rainy season lasts from mid-December to May (approximately six months). At the beginning of the year, farmers are instructed to plant maize and jack beans simultaneously using an alternating planting pattern (see Figure 3). The difference in plant age makes this system effective in avoiding idle land. In the eighth month, the maize has generally been harvested, while the jack bean is just beginning to be harvested. Harvesting can be done periodically, 3–4 times, until the end of the year. On the experimental land, jack bean was introduced primarily as a medium for farmer education; therefore, observations could not be continued comprehensively until the final harvest stage. The plants were planted in April 2025 in 210 planting holes. By September 2025, 98% of the plants were growing well and in the fruit growth stage. This indicates that these plants are suitable for planting at the research site and have the potential to increase the income of local farmers.

Innovation to increase the FTT uses demonstration plots (demplots) as a focused information medium, serving as a contextual empowerment measure to utilize the idle time between planting/harvesting or post-harvesting. The idle time is presented in Figure 3 and Figure 6, which show the application of the innovative land redistribution design. Through the demonstration plot, farmers were able to observe planting schedules, crop characteristics, and crop diversity under the compound cropping system. This also serves as an alternative solution for fruit crops from the forest and land rehabilitation program that are not yet productive because they are only 2 years old.

Empowerment encourages farmers to plant diverse crops and produce a range of agricultural products, so they do not depend solely on maize. Creating innovation plots can increase farmers' knowledge, skills, and/or understanding of compound cropping systems, thereby boosting land productivity and potentially farmers' income. The use of this jack bean cultivation innovation plot is not only for testing a technology but also as an instrument

for empowerment and strategic social data collection in efforts to develop sustainable agriculture. From the total population, farming data were collected from 12 randomly selected respondents to assess changes in FTT before and after the innovation's implementation. The total area managed by the 12 respondents was 4.866 ha. Measures to increase production and productivity in this study were oriented toward land optimization and agricultural diversification to reduce the risk of crop failure, particularly due to rats, a major concern for farmers during harvesting. Table 2 presents the actual FTT values of the 12 farmer respondents in Sogo Village, Blora Regency. The results show that the average FTT was 69.24, indicating that, on average, farmers' receipts were still lower than their total household and production expenditures. Only three respondents recorded FTT values above 100 (Respondents 2, 3, and 9), while the remaining nine respondents were below 100. The lowest FTT value was recorded for Respondent 11 (20.84), whereas the highest value was recorded for Respondent 3 (126.39). These findings indicate that most farmers were still in a relatively weak economic position and that reliance on maize-based farming alone had not yet provided sufficient economic security.

**Table 2.** Maize farming yields and Farmers' Terms of Trade (FTT) in Sogo Village

| Respondent ID  | Total Value Received by Farmers from Agricultural Production (IDR) | Production Cost (IDR) | Household Consumption Expenditure (Estimated DLN) (IDR) | Total Value Paid by Farmers (IDR) | FTT    |
|----------------|--------------------------------------------------------------------|-----------------------|---------------------------------------------------------|-----------------------------------|--------|
| 1              | 8,400,000                                                          | 5,000,000             | 7,076,604                                               | 12,076,604                        | 69.56  |
| 2              | 12,100,000                                                         | 4,800,000             | 7,076,604                                               | 11,876,604                        | 101.88 |
| 3              | 14,000,000                                                         | 4,000,000             | 7,076,604                                               | 11,076,604                        | 126.39 |
| 4              | 10,500,000                                                         | 14,000,000            | 7,076,604                                               | 21,076,604                        | 49.82  |
| 5              | 10,500,000                                                         | 4,400,000             | 7,076,604                                               | 11,476,604                        | 91.49  |
| 6              | 7,000,000                                                          | 4,600,000             | 7,076,604                                               | 11,676,604                        | 59.95  |
| 7              | 2,800,000                                                          | 4,000,000             | 7,076,604                                               | 11,076,604                        | 25.28  |
| 8              | 4,200,000                                                          | 2,000,000             | 7,076,604                                               | 9,076,604                         | 46.27  |
| 9              | 14,000,000                                                         | 6,000,000             | 7,076,604                                               | 13,076,604                        | 107.06 |
| 10             | 7,000,000                                                          | 6,000,000             | 7,076,604                                               | 13,076,604                        | 53.53  |
| 11             | 2,100,000                                                          | 3,000,000             | 7,076,604                                               | 10,076,604                        | 20.84  |
| 12             | 7,000,000                                                          | 1,800,000             | 7,076,604                                               | 8,876,604                         | 78.86  |
| Average of FTT |                                                                    |                       |                                                         |                                   | 69.24  |

Note: DLN = Decent Living Needs; IDR = Indonesian Rupiah

The utilization of Social Forestry land currently relies solely on maize crops with two harvests per year. This condition is influenced by the area's dry, low-irrigation conditions. The next step in land-use innovation carried out on demonstration plots is to provide information through farm business analysis, intended to provide an overview of the comprehensive evaluation of prospects for increasing land productivity, leading to increased income, and to identify opportunities and challenges.

Several studies show that white jack bean, as planted in the demonstration plot to replace soybeans for the tempeh industry, is a solution to reduce dependence on imported soybeans, whose prices are increasing. The harvest of this crop can also be processed into various other products, such as milk, flour, and meal (Chen et al., 2013). The average production of jack bean ranges from 4–7 tons/ha, which is much higher than that of soybeans, which only produce 1.3–2 tons/ha. In this study, the estimated average productivity of jack bean was 4 tons/ha.

The total actual maize yield of the selected respondents was 16.10 tons on 4.866 ha, yielding 3.31 tons per year over two harvests (Table 3). Under the innovation scenario, maize production was estimated at 8.05 tons from one harvest, while jack bean production was estimated at 19.46 tons in total, with an average productivity of 4.00 tons/ha. Although this sacrifices maize production on the land, the competitive price of jack beans makes this acceptable. Compared with the initial total production of 16.10 tons of maize, the innovation scenario indicates a higher total output and better land-use efficiency. Secondary data from various sources indicate that jack bean prices for tempeh vary by quality, type (organic or non-organic), and seller. However, in general, the price of raw jack beans per kilogram ranges from IDR 8,000 to IDR 10,000. The estimated productivity of jack beans in this study was 4 tons/ha, in line with the research conducted by Soedarjo (2021), who also found similar results.

This productivity value was then used to estimate the increase in the FTT of local farmers if they applied the same system. Table 4 presents the FTT calculation results after implementing the innovation. Based on these results, it is estimated that FTT will increase from 69.24 to 74.13. This indicates an average increase of 7.56 points in FTT after the adoption of the innovation. In addition, all 12 respondents showed positive growth in FTT, with the highest increase recorded for Respondent 4 (42.89%) and the lowest for Respondent 7 (2.45%). However, despite the improvement in FTT values among all respondents, most remained below 100, indicating a relatively vulnerable economic position. Nevertheless, these findings reveal a positive trend in farmers' purchasing power, suggesting that intercropping systems may serve as a transitional strategy toward economic resilience, particularly in marginal dryland areas. The harvested jack bean can be processed into a variety of food products and used as a

substitute for soybeans, mung beans, and wheat flour in processed foods. Among other things, it can be used as a filling for bakpia cakes or to make tempeh and soy sauce. The selling price of each product is competitive and may create additional income opportunities for farming households.

The analysis of jack bean farming covers several important aspects, including crop potential, cultivation techniques, and the utilization of harvests. Jack beans have the potential to serve as an alternative protein source, a green fertilizer, and a raw material for products such as tempeh, plant-based milk, and animal feed. These findings suggest that jack bean cultivation is promising not only in terms of agronomic adaptation and land productivity, but also in terms of its potential contribution to farm income diversification and livelihood improvement. The analysis of farming businesses identifies opportunities and challenges in jack bean cultivation and in business sustainability. Furthermore, the integration of jack bean as a legume cover crop contributes to nitrogen fixation and soil improvement, aligning with agroecological principles and sustainable land management practices (Drinkwater et al., 1998; Peoples et al., 2009).

**Table 3.** Estimated production and productivity from innovation

| Respondent ID                  | Land Area (Hectares) | Initial Production (Tons) | Estimated Production from Innovation Based on Planting Calendar (Tons) |           |
|--------------------------------|----------------------|---------------------------|------------------------------------------------------------------------|-----------|
|                                |                      | Maize (2 Harvests)        | Maize (1 Harvest)                                                      | Jack bean |
| 1                              | 0.63                 | 1.20                      | 0.60                                                                   | 2.51      |
| 2                              | 0.61                 | 1.10                      | 0.55                                                                   | 2.44      |
| 3                              | 1.04                 | 4.00                      | 2.00                                                                   | 4.16      |
| 4                              | 0.45                 | 1.50                      | 0.75                                                                   | 1.82      |
| 5                              | 0.46                 | 1.50                      | 0.75                                                                   | 1.84      |
| 6                              | 0.34                 | 1.50                      | 0.75                                                                   | 1.34      |
| 7                              | 0.07                 | 0.40                      | 0.20                                                                   | 0.28      |
| 8                              | 0.16                 | 0.60                      | 0.30                                                                   | 0.64      |
| 9                              | 0.54                 | 2.00                      | 1.00                                                                   | 2.15      |
| 10                             | 0.26                 | 1.00                      | 0.50                                                                   | 1.04      |
| 11                             | 0.06                 | 0.30                      | 0.15                                                                   | 0.25      |
| 12                             | 0.25                 | 1.00                      | 0.50                                                                   | 0.99      |
| Total                          | 4.87                 | 16.10                     | 8.05                                                                   | 19.46     |
| Overall productivity (tons/ha) |                      | 3.31                      | 1.65                                                                   | 4.00      |

**Table 4.** The impact of innovation adoption on Farmers' Terms of Trade (FTT)

| Respondent ID  | Total Value Received by Farmers from Agricultural Production in a Compound Cropping System (IDR) | Household Consumption Expenditure (Estimated DLN) (IDR) | Total Value Paid by Farmers with Implementing Innovation (IDR) | FTT Value Pre-Innovation | FTT Value Post-Innovation | Growth in FTT (%) |
|----------------|--------------------------------------------------------------------------------------------------|---------------------------------------------------------|----------------------------------------------------------------|--------------------------|---------------------------|-------------------|
| 1              | 9,007,150                                                                                        | 7,076,604                                               | 12,076,604                                                     | 69.56                    | 74.58                     | 7.22              |
| 2              | 12,689,748                                                                                       | 7,076,604                                               | 11,876,604                                                     | 101.88                   | 106.85                    | 4.88              |
| 3              | 15,005,472                                                                                       | 7,076,604                                               | 11,076,604                                                     | 126.39                   | 135.47                    | 7.18              |
| 4              | 15,005,472                                                                                       | 7,076,604                                               | 21,076,604                                                     | 49.82                    | 71.19                     | 42.89             |
| 5              | 10,943,761                                                                                       | 7,076,604                                               | 11,476,604                                                     | 91.49                    | 95.36                     | 4.23              |
| 6              | 7,324,845                                                                                        | 7,076,604                                               | 11,676,604                                                     | 59.95                    | 62.73                     | 4.64              |
| 7              | 2,868,643                                                                                        | 7,076,604                                               | 11,076,604                                                     | 25.28                    | 25.90                     | 2.45              |
| 8              | 4,354,689                                                                                        | 7,076,604                                               | 9,076,604                                                      | 46.27                    | 47.98                     | 3.70              |
| 9              | 14,519,172                                                                                       | 7,076,604                                               | 13,076,604                                                     | 107.06                   | 111.03                    | 3.71              |
| 10             | 7,251,368                                                                                        | 7,076,604                                               | 13,076,604                                                     | 53.53                    | 55.45                     | 3.59              |
| 11             | 2,160,908                                                                                        | 7,076,604                                               | 10,076,604                                                     | 20.84                    | 21.44                     | 2.88              |
| 12             | 7,238,800                                                                                        | 7,076,604                                               | 8,876,604                                                      | 78.86                    | 81.55                     | 3.41              |
| Average of FTT |                                                                                                  |                                                         |                                                                | 69.24                    | 74.13                     | 7.56              |

Note: DLN = Decent Living Needs; IDR = Indonesian Rupiah

#### 4. Conclusion

At the research site, empowerment was carried out through demonstration plots, which served as a medium for educating farmers to increase land productivity and farmer welfare by raising the FTT value. The study identified several obstacles to farming in the Kendeng Mountains, particularly in Sogo Village, Blora Regency. Some of these include the threat of rats that destroy maize production, drought on the soil surface, which causes the soil to become thinner, and low farmer income from agricultural products. Other weaknesses include a lack of business capital and poor access to agricultural facilities and infrastructure. To address these issues, farmers were introduced to the innovation of planting jack bean in a low-input compound cropping system with maize. Based on land

productivity calculations, this innovation increased land productivity. In addition, the FTT value also increased from 69.24 to 74.13. These various improvements indicate that the application of jack bean cultivation in a compound cropping system is feasible in the study area and has the potential to be adopted more widely in the Mount Kendeng region as a sustainable agricultural practice.

### Author Contributions

Conceptualization, E.B., J., and M.; methodology, E.B., J., and M.; software, T.M.; validation, E.B., J., and S.M.; formal analysis, J., M., and T.M.; resources, M. and S.M.; writing—original draft preparation, E.B., J., and M.; writing—review and editing, S.M. and U.I.; visualization, T.M.; project administration, E.B. and T.M.; funding acquisition, E.B. All authors have read and agreed to the published version of the manuscript.

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### Informed Consent Statement

Written informed consent was obtained from all participants.

### Data Availability

The data used to support the research findings are available from the corresponding author upon request.

### Conflicts of Interest

The authors declare no conflicts of interest.

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