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The role of the madura cattle-field crops integration system model in increasing farmers' income

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ABSTRACT

Introduction: The integration between cattle farming and agricultural crops has long been known as a strategy to improve efficiency in the use of natural resources. The cattle-crop integration system model enables synergy between these two sectors and plays a significant role in increasing farmer income in Madura. This research aims to analyze the role of the Madura cattle-field crop integration model in increasing farmer income. **Methods:** Samples were selected using purposive sampling technique, with criteria for farmers who have implemented the integration system for at least five years. The sample size was determined based on the availability of data that could be obtained and statistical analysis needs. The analysis method used Structural Equation Modeling-Partial Least Square (SEM-PLS). This design was chosen because SEM-PLS can handle latent variables and test relationships between variables simultaneously. **Results:** The analysis results show that both cattle maintenance and field crop management contribute significantly to increasing farmer income, with path coefficient values of 0.392 and 0.502 respectively, and T-statistic values > 1.96 (p-value < 0.05). **Conclusion:** An R^2 value of 0.370 indicates that about 37% of farmers' income variations are explained by this integrated system, while the rest is influenced by external factors outside the model, this result is strong enough to illustrate the strategic role of the integration model in sustainable agribusiness systems.

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INTRODUCTION

Madura Island is geographically located to the east of Java Island and is part of the administrative region of East Java Province, possessing unique ecological, social, and economic characteristics. One of the most prominent local assets is the Madura cow, which is not only known for its unique genetic quality but also holds high economic and cultural value (Hopid & Rahman, 2025) This cow has long been a symbol of Madura's identity and plays a significant role in various aspects of life, including as a living savings, a medium of exchange, and a component in traditional ceremonies. However, the economic potential of Madura cows has not yet been fully optimally utilized by local farmers.

Most farmers in Madura still rely on conventional and fragmented farming systems, which result in low production and income efficiency (Sugandi et al., 2023). The monodisciplinary business pattern, both in agriculture and livestock farming, leads to the underutilization of natural resources (Icahyaningrum et al., 2024). This is exacerbated by limited access to technology, market information, and adequate policy support. As a result, despite having valuable assets such as Madura cattle, many farmers remain in vulnerable economic conditions.

Field land, which is dry land with limited fertility, dominates land use in Madura. This land is usually used for monoculture agriculture, such as corn or soybeans, without considering the potential for integration with the livestock sector. However, integrated land use between crops and livestock can create a more efficient and sustainable resource utilization cycle (Suhartini et al., 2022). This approach not only increases land productivity but also reduces dependence on external inputs such as chemical fertilizers and imported livestock feed.

The integrated livestock-plant system is an agroecological model that has proven effective in various agricultural contexts in the tropics. In this model, livestock waste such as cattle manure can be utilized as organic fertilizer to enhance soil fertility, while agricultural byproducts such as straw, corn stalks, and bean leaves can be processed into animal feed (Novra et al., 2023). Such synergy allows farmers to reduce production costs while increasing income through the diversification of products generated.

In Madura, particularly in Sumenep Regency, the implementation of the integrated Madura cattle-vegetable system is still very limited. Several inhibiting factors include farmers' lack of understanding of the principles of integration, limited initial capital, and the absence of suitable pilot models that match local conditions. Additionally, socio-cultural aspects, such as the habit of selling cattle before reaching optimal weight or using cattle more as a status symbol than as a productive business unit, also influence the adoption of this model (Bonewati et al., 2024; Zenda, 2025).

While extensive research has been conducted on crop-livestock integration systems, a significant research gap persists as prior literature tends to be generalized and has yet to address the specific context of Madura cattle integration within dryland farming. For comparison, Grinnell et al. (2022) utilized a mixed-methods approach to demonstrate the effectiveness of integration within the palm oil sector, while Wantasen et al. (2024) employed Linear Programming optimization to measure productivity in arid regions more broadly. Furthermore, although ecological intensification through soybean-livestock integration has been proven to enhance profitability (de Albuquerque Nunes et al., 2021), and integrated systems are recognized as more environmentally friendly than conventional ones (Shanmugam et al., 2024), these studies leave a void regarding the complex causal mechanisms within Madura's specific ecosystem. The fundamental distinction of this study lies in its use of an explanatory quantitative design utilizing Structural Equation Modeling-Partial Least Squares (SEM-PLS). Whereas previous research predominantly focused on long-term field experimental outcomes, this study aims to bridge the literary gap by statistically validating inter-variable relationships to map the primary determinants of increased farmer income through the Madura cattle-dryland crop integration model.

These studies have not taken into account the typical characteristics of the Madura region which include unique agroecological, social, and cultural conditions. The role of the integration model between Madura cattle which have high cultural value and local adaptation to the dryland plant system has not been adequately explored in the scientific literature. Therefore, this research aims to fill this gap while making an original contribution to the development of contextual and sustainable integrated agricultural systems in the Madura region.

This study aims to analyze the role of the Madura cattle-field crop integration system model in accelerating the increase in farmers' income and to assess its contribution to the economic well being of farming households using a systems approach (crop-livestock integration).

The urgency of this research is even higher considering the pressure on food security, climate change, and the need to transform the agricultural system towards a more inclusive and environmentally friendly approach. The cow-plant integration model offers a holistic solution that is aligned with the principles of circular economy and sustainable agriculture. The results of the research are expected to provide concrete policy recommendations for local governments, extension institutions, and business actors in the agribusiness sector.

More broadly, the findings of this study can also be a reference for other regions in Indonesia that have similar ecological and socio-economic conditions to Madura. Thus, the integration model developed is not only locally relevant, but also has the potential for national replication in order to support sovereign, just, and sustainable agricultural development.

METHODS

Research location

This research was conducted in Pakandangan Sangra Village, Bluto District, Sumenep Regency, East Java, Indonesia, from August to September 2025. The area was selected purposively because it represents one of the regions where farmers commonly implement an integration system between Madura cattle and dryland crop farming. The village is characterized by dryland agricultural systems dominated by crops such as corn, peanuts, mung beans, and other seasonal crops.

Research design

This study employed a quantitative explanatory research design aimed at analyzing the causal relationships between variables within the Madura cattle-field crop integration system. The analysis was conducted using Structural Equation Modeling-Partial Least Squares (SEM-PLS) with the assistance of SmartPLS version 3 software. SEM-PLS was selected because it is suitable for analyzing complex relationships between latent variables, particularly in studies with relatively small sample sizes and non-normal data distributions. In addition, SEM-PLS enables simultaneous evaluation of both measurement models (outer models) and structural models (inner models) (Al-Rikabi et al., 2024; Sarstedt & Liu, 2023).

Population and sample

The population of this study consisted of farmers who implement the Madura cattle–field crop integration system in the research area. Samples were selected using a purposive sampling technique, with the following criteria:

1. Farmers who raise Madura cattle.
2. Farmers who cultivate dryland crops.
3. Farmers who have implemented the livestock–crop integration system for at least five years.

Based on these criteria, a total of 37 farmers were selected as respondents.

The sample size follows the ten-times rule commonly applied in SEM-PLS, which states that the minimum sample size should be at least ten times the largest number of structural paths directed at a latent variable in the model. Since the model contains two predictor variables influencing farmers' income, the sample size used in this study satisfies the recommended requirement.

Data sources and data collection

This study used primary data collected directly from farmers in the research area.

Data collection was conducted through:

1. Structured questionnaires, used to measure research variables based on predetermined indicators.
2. Field observations, conducted to obtain information about farming practices, livestock management, and crop cultivation systems.
3. Informal interviews, carried out to clarify responses and obtain contextual information related to integrated farming practices.

The questionnaire was designed using a Likert scale to measure respondents' perceptions and practices related to the integration system. Besides primary data, secondary data obtained from a review of the literature in various journals relevant to this study was also used

Research variables and indicators

This study involved three latent variables, consisting of two exogenous variables and one endogenous variable. The variables include:

1. Cattle Farming (S), Indicators: Number of cattle owned by farmers; Frequency of livestock feeding; Availability of livestock housing; Sustainability of cattle maintenance; Availability of feed reserves; Utilization of agricultural waste as animal feed
2. Field Crops (T), Indicators: Area of cultivated land; Types of crops cultivated; Frequency of fertilization; Utilization of livestock manure as fertilizer
3. Farmers' Income (P) Indicators: Income from cattle farming; Income from crop farming

Data analysis

The collected data were analyzed using Structural Equation Modeling–Partial Least Squares (SEM-PLS).

The analysis procedure consisted of two main stages:

1. Measurement Model Evaluation (Outer Model)

The outer model evaluation aims to test the validity and reliability of the indicators used to measure latent variables. The assessment includes:

- Convergent Validity, measured using loading factor values and Average Variance Extracted (AVE). Indicators are considered valid if the loading factor exceeds 0.70 and AVE exceeds 0.50.
- Composite Reliability, used to measure internal consistency of constructs. A value above 0.70 indicates good reliability.
- Discriminant Validity, evaluated by comparing the square root of AVE with the correlation between latent variables.

2. Structural Model Evaluation (Inner Model)

The inner model evaluation aims to analyze the relationship between latent variables. This evaluation includes:

- Path Coefficient Analysis, to measure the direction and strength of relationships between variables.
- Bootstrapping Analysis, to test statistical significance using T-statistics and p-values.
- Coefficient of Determination (R^2), used to measure the explanatory power of the model in explaining variations in farmers' income.

A relationship between variables is considered significant if:

- T-statistic > 1.96
- p-value < 0.05

RESULTS AND DISCUSSION

Outer model measurement

Structural Equation Modelling (SEM) consists of two main components, namely the outer model (measurement model) and the structural model. The analysis stage begins with evaluating the quality of the outer model, which in this research was conducted using SmartPLS software version 3. The outer model describes the relationship between indicators (manifest variables) and the latent variable they represent (table 1), which is measured through the loading factor value. According to the standards applicable in the SEMPLS approach, an indicator is considered to have good (adequate) convergent validity if its loading factor value exceeds 0.70. If this criterion is met, the indicator is considered capable of validly representing the latent construct and is worth retaining in the measurement model.

Table 1. Latent Variables and Manifest Variables

Latent Variable	Manifest Variable (Indicator)	Symbol
Cattle Farming (S)	Number of cattle owned by farmers	S1
	Frequency of livestock feed provision	S2
	Sufficiency of available stalls	S3
	Implementation of modern technology	S4
	Sustainability of cattle maintenance	S5
	Availability of feed reserves (feeders)	S6
	Utilization of agricultural waste for feed	S7
Field crops (T)	Area of managed crop land	T1
	Main crop type planted	T2
	Frequency of plant fertilization	T3
	Utilization of livestock manure (cattle)	T4
Farmer's income (P)	Income from cattle produce	P1
	Income from vegetable cultivation	P2

Source: Primary data processed (2025)

The initial step in evaluating the outer model's quality is to test the convergence validity, which is usually assessed based on the loading factor values of each indicator. The acceptance criteria state that an indicator is considered to have good convergence validity if its loading factor value exceeds the threshold or is greater than 0.70 (Pratomo et al., 2023). Based on the results of the outer model testing (figure 1), most indicators in this study meet this criterion, with the average loading factor value being above 0.70. However, there is one exception, namely indicator S4 (implementation of modern technology) which shows a loading factor value of -0.087 (boxed red in Figure 1). This value is far below the established threshold and even negative, indicating that this indicator is unable to represent the construct validly (not valid). Therefore, in accordance with the principles of the outer model testing, indicator S4 (implementation of modern technology) must be removed from the model to improve the quality of measurement and ensure the convergence validity of all indicators used. The application of modern technology is not implemented by farmers because of the high costs that must be incurred, which affects the income that will be obtained.

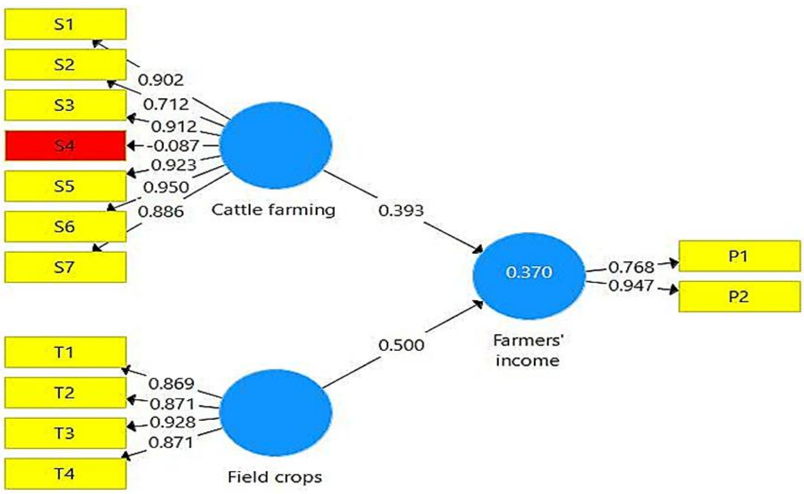

Figure 1. Initial results of outer model measurements

The reason why indicator S4 was removed from the model is because it has a loading factor below 0.7, even with a negative value of -0.087 (Figure 1). This is also reinforced by the behavior of farmers at the research location, most of whom do not apply modern technology in Madura cattle breeding; everything is done traditionally using local wisdom, especially when dealing with health problems in cattle, as they still primarily use herbal medicine that has been passed down through generations. However, although cattle breeding is still traditional, most farmers have already used artificial insemination (insemination) with various cattle seeds adapted to the condition of the female cattle.

Calves from artificial insemination have different characters from Madura calves from pure breeding. Artificially inseminated calves tend to grow faster with a high appetite from an early age than calves from purebred matings that tend to continue to suckle their mothers until they are several months old, this is felt by most farmers who keep cows (Ediset et al., 2024).

After retesting (calculate-pls algorithm) by eliminating indicators (S4) that do not meet the test criteria with an outer loading value below 0.70, then the loading factor value of all latent variable indicators greater than 0.7 is obtained. This value (outer model) indicates that all indicators already have a good convergent validity value (figure 2).

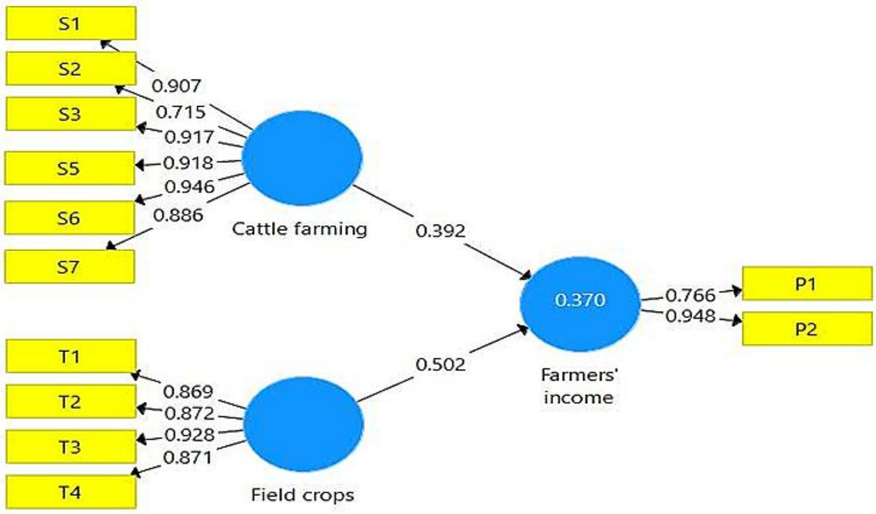

Figure 2. The second result of the outer model measurement

In Figure 2, it appears that the loading factor value ranges from 0.715-0.946 in the latent variable of cattle rearing, while in the latent variable of field crops ranges from 0.869-928 and the latent variable of farmer income ranges from 0.766-0.948, all of these loading factor values show a greater value of 0.7, meaning that they are qualified and have a good convergent validity value.

The S6 indicator (availability of feed reserves) shows the highest loading factor value in the cattle maintenance variable, which is 0.946. These findings reveal that the aspect of the availability of reserve feed has the most significant role in shaping the construct of cattle rearing. The value of the loading factor that is close to 1 indicates that the indicator is very strong in representing these dimensions, as well as reflecting its high validity and reliability as a measure in this study.


Figure 3. Livestock feed store

Farmers have intuitively implemented preventive feed management strategies to mitigate the risk of nutritional deficits during the dry season. This strategy is executed by converting agricultural waste, specifically corn stover, into feed reserves that are systematically stored in feed barns (Figure 3) during the harvest or rainy seasons. This biomass conservation effort aims to ensure the availability of fodder stocks when the productivity of fresh forage declines drastically, thereby ensuring that the fundamental nutritional requirements of cattle are met sustainably.

The implementation of this feed reserve management has proven crucial in maintaining the stability of physiological conditions and the growth rate of livestock body weight, preventing fluctuations caused by seasonal climate changes (Mekonnen et al., 2021). This phenomenon is consistent with the findings of Azine et al. (2024) who assert that the utilization of crop residues, such as corn stover, is a common practice in rural areas to strengthen feed security. Through the integration of these harvest by-products, farmers can minimize the negative impacts of drought on livestock productivity while simultaneously optimizing the efficiency of local resources.

Figure 4. Madura cows with simple cages

In the latent variable of dryland plants, the T3 indicator (frequency of plant fertilization) showed the highest loading factor value, which was 0.928. These findings indicate that the aspect of fertilization frequency has the greatest contribution in shaping the construction of field plants. Farmers always fertilize regularly with manure (organic) and chemical so that optimal plants can produce abundant harvests so that the income obtained is also large to meet family needs. The commodities planted by farmers are corn, green beans, peanuts, tobacco and herbal peppers, cayenne peppers with an intercropping system or turns. Diversification of food crops is very helpful for farmers in increasing food security and the economy (Appiah-Twumasi & Asale, 2022; Yusriadi et al., 2024).

Meanwhile, the highest loading factor for the latent variable of farmers’ income is found in P2 (income from dryland crops), with a value of 0.948 (Figure 2). This indicates that the income obtained from dryland farming is sufficient to meet household needs. Dryland crops represent the main source of income for farmers, while additional income is obtained from cattle raising (Figure 4), which is considered an asset or savings that can be sold at any time when urgent financial needs arise. Dryland crops such as maize play a significant role in supporting the food security of farmers’ households. The maize produced is stored in granaries for household consumption throughout the year, while the remaining portion is sold to meet other family needs (Imran et al., 2025; Sugiarti et al., 2022).

Evaluation of path coefficients (inner model)

After analyzing the loading factor value in the outer model, the next step is to evaluate the path coefficients to understand the influence of exogenous latent variables on endogenous latent variables. In this context, the variables of cattle and field crops play a role as predictors of farmers' income.

Table 2. Path Coefficients

	Farmers' income
Cattle farming	0.392
Field crops	0.502

Source: Primary data processed with SmartPls (2025)

The results of the path coefficient analysis (Table 2) demonstrate that cattle ranching contributes 0.392 to farmers' income, implying that an increase in cattle rearing activities tends to enhance total earnings. Meanwhile, dryland cultivation exerts a more substantial influence, with a coefficient of 0.502. These findings indicate that dryland management practices have a relatively stronger impact compared to cattle ranching in determining the income levels of farmers.

The magnitude of these path coefficients reflects the strength and direction of the causal relationships between the latent variables within the tested structural model. Consequently, although both sectors contribute positively, the statistical evidence suggests that agricultural productivity in dryland areas serves as a more dominant predictor of economic outcomes in this specific model.

In empirical reality, the productivity of drylands plays a crucial role in the economic stability of farmers who concurrently function as livestock breeders. Dryland commodities, such as mung beans, bird's eye chilies, and Javanese long peppers, offer the advantage of multiple harvest cycles within a single season, with Javanese long peppers specifically yielding significant economic value in the market. Consequently, the income generated from these crops serves as the primary pillar for meeting the daily operational and consumption needs of the farming household.

In contrast, Madura cattle function as medium to long term liquid assets. These livestock can only be converted into cash after a maintenance period of at least 1.5 to 2 years. This discrepancy in income realization timelines indicates that while dryland cultivation serves as a vital source of daily cash flow, Madura cattle ranching acts more as a formal savings or investment instrument, requiring a longer retention period before providing a financial return for the farmers.

Figure 5. Javanese long pepper plants along the field margins

Income from the dryland sector is significantly derived from the sale of dried Javanese long pepper, which maintains a high economic value ranging from IDR 80,000 to IDR 90,000 per kilogram, with the potential to escalate further during periods of increased market demand. As a strategic commodity, Javanese long pepper serves a dual role: supplying the domestic herbal medicine industry and acting as a vital export raw material for various global manufactured products (Aswar et al., 2022; Prameswari et al., 2021). Characterized as a perennial crop, it is efficiently cultivated along field margins (Figure 5) by utilizing Moringa trees (*Moringa oleifera*) as climbing supports. This integration creates an ecological and economic synergy, as the Moringa foliage is simultaneously utilized as a high-quality nutritional feed source for cattle (Abdoun et al., 2022; Amad & Zentek, 2023).

The financial contribution from Javanese long pepper cultivation is substantial for the economic stability of farming households. Revenue from this commodity does not merely support daily consumption needs but also serves as a crucial financing instrument for long-term investments, particularly in children's education and healthcare services. Consequently, Javanese long pepper is not merely a secondary crop; it represents a pillar of economic resilience that integrates land productivity with livestock sustainability and family welfare (Marwaty et al., 2022).

Reliability test results

The reliability of the latent variables in the outer model was evaluated using two main indicators, namely Cronbach's Alpha and Composite Reliability. In general, a construct is considered reliable when the value of either indicator exceeds the recommended threshold of 0.70. In this study, the reliability assessment primarily refers to Composite Reliability. The Composite Reliability values for all constructs were 0.955, 0.851, and 0.935 (table 3, third column), respectively, all of which exceed the recommended threshold (> 0.70). These results indicate that the three latent variables demonstrate strong internal consistency and reliably measure the role of the Madura cattle dryland crop integration system in improving farmers' income.

Table 3. *Construct Reliability and Validity*

	Cronbach's Alpha	*Composite Reliability*	*Average Variance Extracted (AVE)*
Cattle farming	0.943	0.955	0.783
Farmers' income	0.686	0.851	0.743
Field crops	0.912	0.935	0.784

Source: Primary data processed with SmartPls (2025)

Reliability and loading factors were also analyzed using Average Variance Extracted (AVE). According to the existing standards, a construct meets the criteria for convergent validity if its AVE value is greater than 0.5. The test results show that the AVE values for each latent variable are 0.783; 0.743; and 0.784 (table 3, fourth column) all exceeding the minimum threshold. This finding confirms that the indicators used are capable of explaining more than 50% of the variance of the measured construct, thus meeting the criteria for convergent validity as presented in Table 3.

Discriminant validity

To measure the outer model, in addition to convergent validity and reliability, there is also what is called discriminant validity, as can be seen in table 4 below. The criterion is that if the AVE root value is greater than the correlation between its latent variables, then it can be said that the variable has good discriminant validity.

Table 4. *Discriminant Validity*

	Cattle farming	Farmers' income	Field crops
Cattle farming	0.885		
Farmers' income	0.346	0.862	
Field crops	-0.092	0.466	0.885

Source: Primary data processed with SmartPls (2025)

Based on the results presented in table 4, the AVE value for the cattle maintenance latent variable of 0.885 exceeds its correlation with farmer income (0.346) and dryland crops (-0.092). Similarly, the AVE value of farmer income (0.862) is higher than its correlation with dryland crops (0.466). Meanwhile, the dryland crops latent variable also shows an AVE value of 0.885 that is greater than its correlation with the other two latent variables. These findings indicate that each construct has a unique measurement identity and does not overlap, thus satisfying the requirements for good discriminant validity within the framework of this research model.

T-statistics and p-value test results

To determine whether the relationship between these latent variables is significant or not, it is necessary to look at the T-statistic value. The criterion is that if the T-statistic value is greater than 1.96, it can be concluded that the relationship between these latent variables is significant. Based on the calculate-bootstraping results, the T-statistic values were obtained as shown in Figure 6 and Table 5 below.

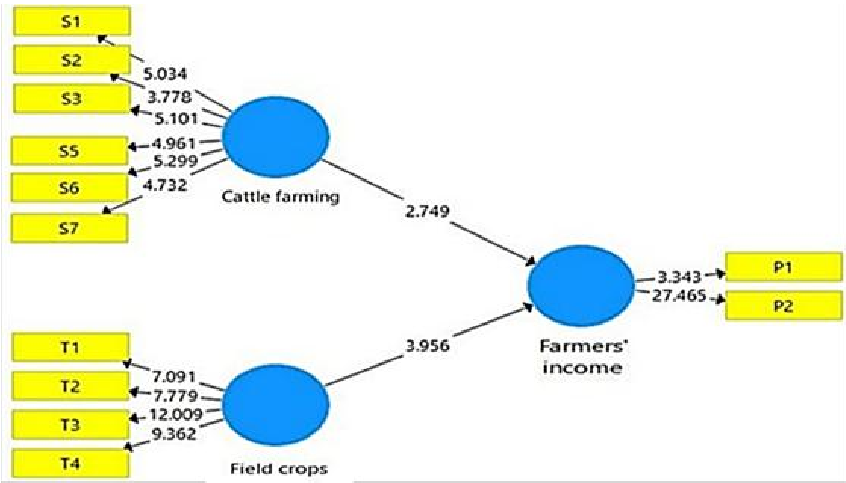

Figure 6. T-Statistical Model

The hypothesis test results show that the influence of cattle maintenance on farmer income has a T-statistic value of 2.749 (table 5), which exceeds the critical value of 1.96 at a 5% significance level. This indicates that the influence is statistically significant, leading to the conclusion that cattle maintenance practices contribute significantly to increasing farmer income.

Similarly, the relationship between dryland plants and farmer income yields a T-statistic value of 3.956, far above the critical threshold of 1.96. This finding confirms that field crop management also significantly influences farmer income improvement. Overall, both exogenous variables in this model are proven to play a meaningful role in increasing farmer income within the Madura cattle-field crop integration system.

Besides the T statistic, the significance of the relationship between variables can also be seen from the P value (table 5) with the criterion that the P value must be smaller than 0.05. This is in accordance with what is stated in Table 5 with P values of 0.006 and 0.000, which are already smaller than 0.05, meaning that the integration of cattle maintenance and dryland plants plays a role in increasing farmers' income. Similarly, the Original Sample value of the path coefficients has a positive value or relationship (0.392, 0.502), meaning that the greater the income from cattle maintenance and dryland plants, the greater the income that will be obtained by farmers. In other words, the greater the value of the path coefficient, the greater its role in increasing farmers' income.

The combination of income from cattle maintenance and field crops provides greater income than relying solely on one agricultural enterprise, as the two complement each other, leading to improved farmer economy and welfare (Dhehibi et al., 2023).

Table 5. *T-Statictics* and *P-Values*

	Original Sample	*T Statistics*	*P Values*
Cattle farming → Farmers' income	0.392	2.749	0.006
Field crops → Farmers' income	0.502	3.956	0.000

Source: Primary data processed with SmartPls (2025)

The goodness of the model (goodness of fit) in statistical analysis, especially in the approach of structural equation modeling (Structural Equation Modeling with Partial Least Squares-SEMPLS) can be assessed through various indicators, one of which is the coefficient of determination, known as the value of R^2 (R-square). The R^2 value as shown in table 6, describes the proportion of variation in dependent (endogenous) variables that can be explained by one or more independent (exogenous) variables in the model. The criterion is that the R Square value must be greater than 0.26 which indicates that the model is already good (Mohammadi et al., 2023).

Table 6. R Square

	R Square
Farmers' income	0.370

Source: Primary data processed with SmartPls (2025)

The R Square value of 0.370 (table 6) in this study shows that around 37% variation in the increase in farmers' income can be explained by the Madura cattle-field crop integration system model studied. In other words, the variables covered in the integration model (such as the number of livestock, the area of farmland, the frequency of use of agricultural waste as feed, or the synergy between livestock and crop components) have a significant contribution to changes in farmers' incomes. The remaining 63% are influenced by factors outside of the model studied, such as commodity market prices, government policies, access to financing, farmers' education levels, or climatic conditions.

Although the value of R Square is not relatively high, in the context of agricultural socio-economic research, especially involving complex agroecosystem systems such as livestock-plant integration, it can still be considered meaningful, especially if the model shows a statistically significant influence. This indicates that the implementation of the Madura-plant-plant-herb integration system does have a real role, although it is not the only major determinant in increasing farmers' incomes, it also reinforces the argument that an agroecosystem approach based on livestock-crop integration is feasible to be developed and encouraged as part of a sustainable rural agribusiness development strategy.

The integration of cattle with crops is not only an economic improvement but will also be very beneficial for agricultural sustainability, because the direction of agriculture in the future is towards organic farming so that what is produced is safer and avoided from chemical content (Shanmugam et al., n.d.; Triono et al., 2024).

CONCLUSION

This research demonstrates that the integrated Madura cattle–dryland crop system exerts a significant influence on increasing farmer income in the arid regions of Madura, particularly within the Sumenep Regency. Structural Equation Modeling-Partial Least Squares (SEM-PLS) analysis reveals that both cattle husbandry and dryland crop management contribute significantly to income enhancement, yielding path coefficients of 0.392 and 0.502, respectively, with T-statistic values exceeding 1.96 (p value < 0.05).

An R^2 value of 0.370 indicates that approximately 37% of the variance in farmers' income is explained by this integration model, while the remainder is influenced by external factors beyond the scope of this study, such as market price fluctuations, government policies, and climatic variability. Nevertheless, these empirical results sufficiently illustrate the strategic importance of this integration model within sustainable agribusiness systems.

Furthermore, the Madura cattle–dryland crop integration system not only bolsters the household economy but also promotes agricultural sustainability through efficient waste utilization, enhanced land productivity, and reduced reliance on external inputs. Consequently, this model warrants broader implementation as a strategic approach to strengthening local economies and conserving agricultural resources in arid environments such as Madura.

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