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Research Paper

Climate Smart Agriculture Sustainability: A Multidimensional Assessment

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Abstract

Indonesia has a serious problem of climate change that impacts the production of rice in the country, particularly in the climate-sensitive areas of Lombok Tengah. To alleviate the risks of these, the government promotes Climate Smart Agriculture (CSA), which is not commonly practiced. The paper uses the Multidimensional Scaling (MDS) technique of measuring the sustainability of CSA implementation by applying the Rap-CSA method. This method measures five dimensions of sustainability: ecological, economic, social, technological, and institutional. A structured questionnaire was administered in the local language to 75 farmers who participated in field trials at the CSA demonstration sites. These findings demonstrate that three dimensions, including social (79.90%), ecological (75.02%), and institutional (79.73%), are very sustainable. Conversely, the technological (55.75%) and economic (39.33%) performance is moderate and less sustainable, respectively. The sustainability index of CSA has a total mark of 66.14, which is average. The findings imply that economic and technological factors need to be altered to facilitate the implementation of CSA with a more balanced, robust orientation.

Keywords: Climate Smart Agriculture; Multidimensional Scaling; Rice Farming; Sustainable Agriculture

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1. Introduction

Climate change represents a pressing global environmental concern, characterized by rising mean surface temperatures and increasing climate variability, primarily driven by the accumulation of anthropogenic greenhouse gas emissions. According to the Intergovernmental Panel on Climate Change, the global surface temperature has risen by 1.53°C compared to pre-industrial levels (IPCC, 2019). In parallel, the National Oceanic and Atmospheric Administration (NOAA) documented that 2024 was Asia's second-warmest year ever recorded, with temperatures at 2.17°C over the 1991-2020 average. From 1910 to 2024, the general warming trend is 0.18°C per decade, but since 1975, the rate has increased more than twice, to 0.40°C per decade, highlighting the quickening pace of the region's climate change (NOAA, 2024). These weather variations have an immense impact on agriculture, which is an industry that is inherently dependent on the weather consistency and predictability.

Climate change has taken over the centre of the world Sustainable Development Goals agenda of the United Nations (UN). Goal 13 (Climate Action) urges potentially the most immediate action to reduce climate change and its effects, which makes it closely connected with Goal 2 (Zero Hunger) on food security and Goal 15 (Life on Land) on terrestrial ecosystems. To attain these objectives, nations need to work to enhance adaptive capacity, build community resilience, and integrate mitigation and adaptation into national and local policy. Agriculture forms an important part of this agenda, but the risk associated with climate has hampered development, especially in rice-growing areas of Indonesia. The nation is also remarkably susceptible to the effects of climate change, with an increase of one degree Celsius in the temperature by one percent lessening the production of rice by up to 3.85 percent and a 1 percent alteration in rainfall diminishing the output by 0.56 percent (Li et al., 2024). More than 444,000 hectares of rice paddies were damaged during the period between 2015 and 2019 due to floods and droughts. The Government of Indonesia responded by adopting Climate Smart Agriculture (CSA) as a national approach to improve productivity, enhance resilience, and support mitigation in an integrated sustainable agriculture by ratifying the Paris Agreement into Law Number 16 of 2016 (Kementerian Pertanian, 2021).

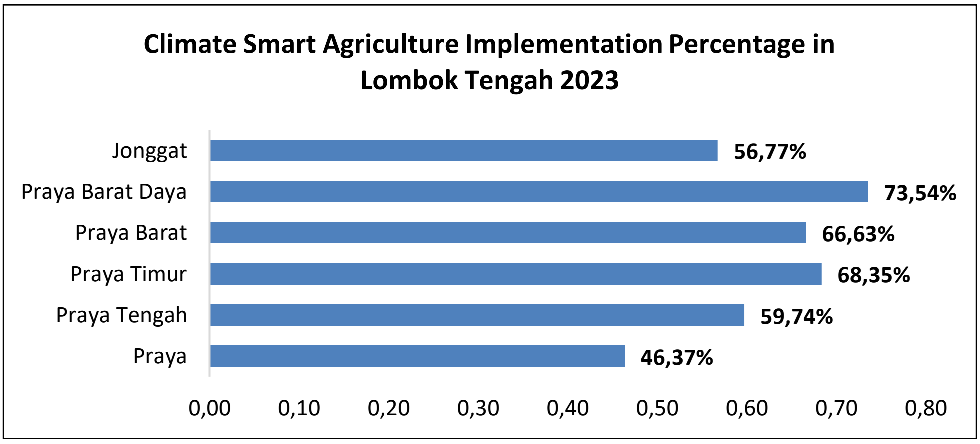


Figure 1. Climate Smart Agriculture Implementation Percentage in Lombok Tengah 2023
Sources: Dinas Pertanian Lombok Tengah, 2024

Lombok Tengah Regency, which is situated in West Nusa Tenggara Province, has been selected as a pilot area in CSA implementation. It was the biggest rice-growing region in 2023 with the harvested area of 72,414 hectares and the total yield of 380,812 tons (BPS Provinsi NTB, 2025). Although this has been a success, the region is exposed to severe climate. According to InaRISK data, 58, 339 hectares are highly vulnerable and 26, 458 hectares are moderately vulnerable to extreme weather events (Florissa et al., 2022). Despite the introduction of CSA technologies using demonstration plots and field schools, there is still a low level of adoption. This is because the adoption rate is low at 46.37 percent in the Praya District, and this means that CSA has not been given a chance to be integrated into the farming activities in the area (Dinas Pertanian Lombok Tengah, 2024).

The challenges notwithstanding, CSA proposes a viable framework for developing food security and climate change resilience in agriculture. It can be effectively operationalized by having coordination between the decision makers and the farmers with the help of the evidence-based decision making, institutional strengthening, the policy harmony, and alignment with the climate finance mechanisms. The holistic strategy leads to innovation and locally responsive solutions to meet changing climatic requirements (Wandayantolis et al., 2024).

Several studies have been carried out on Climate Smart Agriculture (CSA). Various studies have also facilitated the practice of CSA at the international scale. Most recently, Berhanu et al. (2024) analyzed the impacts of the Climate Smart Agricultural Practices (CSAPs) on smallholder farmers' resilience in Ethiopia based on a Multidimensional Livelihood Index (MLI), which incorporates human, social, economic, physical, and natural resources. More so, Djufry et al. (2022) had enumerated some of the principal Climate Smart Agriculture (CSA) techniques of the Indonesian smallholder coffee farmers, like crop diversification and better water management, that could counter the negative effects of climate variability on the crop production and quality. Moreover, Novitasari and Hartono (2025) also investigated the macroeconomic effects of adopting CSA using a Social Accounting Matrix (SAM) setup, but failed to consider social and institutional aspects at the farm level.

On the whole, available research on the topic of CSA in Indonesia has focused primarily on either biophysical or economic outputs, with minimal attention paid to the integrated study of sustainability analysis that is based on environmental, social, institutional, and technological aspects. Thus, the research aims to address this gap in knowledge by evaluating the multidimensional sustainability of CSA practices in rice farming systems in Central Lombok, where CSA is crucial in enhancing local resiliency and food security.

This paper will assess the sustainability of Climate Smart Agriculture (CSA) in rice farmers in Lombok Tengah, Indonesia, using a multidimensional approach. It uses the Multidimensional Scaling (MDS) technique, further developed into Rap-CSA, and leverages Monte Carlo analyses on five dimensions of sustainability: ecological, economic, social, technological, and institutional. What is new about the study is its multidimensional evaluation of the sustainability of CSA, that is, it provides a context-dependent outline that enhances the sustainability of the rice farming system in the long term. It is also unlike other past studies as it has more comprehensive and locally relevant indicators, which are useful in showing the particular conditions of Central Lombok Regency.

2. Methods

2.1 Type of Research

The research employs a quantitative descriptive research design. Ghanad (2023) describes that quantitative descriptive research is utilized to analyze data by describing or graphically demonstrating the data gathered as it is. In this study, the approach is utilized to analyze field data, obtainable facts, and factual data collected directly from the research site to depict the condition of sustainability of Climate Smart Agriculture (CSA) practices in Lombok Tengah Regency.

To measure sustainability quantitatively, the study employs the Modified Multidimensional Scaling (MDS) approach used in the Rap-CSA framework. The method allows for simultaneous assessment of multiple qualitative and quantitative indicators and visualization of sustainability performance along ecological, economic, social, technological, and institutional aspects. The greatest advantage is that it is able to portray the complex socio-ecological interactions in a perceptible form. Whereas MDS does involve professional judgment in its scoring, potential subjectivity was minimized by expert consensus and inter-rater reliability checks. It is not a replication of previous uses but an application and adaptation of the MDS-Rapfish methodology tailored specifically for this aim to measure CSA sustainability using locally relevant indicators for rice farming in Lombok Tengah.

2.2 Location and Population

This study was carried out from March to May 2025, in Lombok Tengah Regency, one of the administrative regions of West Nusa Tenggara Province, Indonesia, geographically located between 8°10'-8°50' South Latitude and 115°46’-116°32' East Longitude (Figure 1). Positioned in the central part of Lombok Island, approximately 30 km southeast of Mataram, the provincial capital, the regency is bordered by West Lombok, East Lombok, and the Indian Ocean. It covers a total area of approximately 1,208.39 km² and has a population of around 1,057,113 people. It has a tropical monsoon climate, with an average temperature recorded in 2023 of 28.25°C, and the region gets rainfall from a long-term annual range of 1,500 to 2,500 mm (BPS Kabupaten Lombok Tengah, 2024). Rice is the main commodity planted on 50,281.81 hectares of its irrigated agricultural land, which covers an area of approximately 41.76% of the regency's expanse (Kementerian ATR/BPN, 2019).

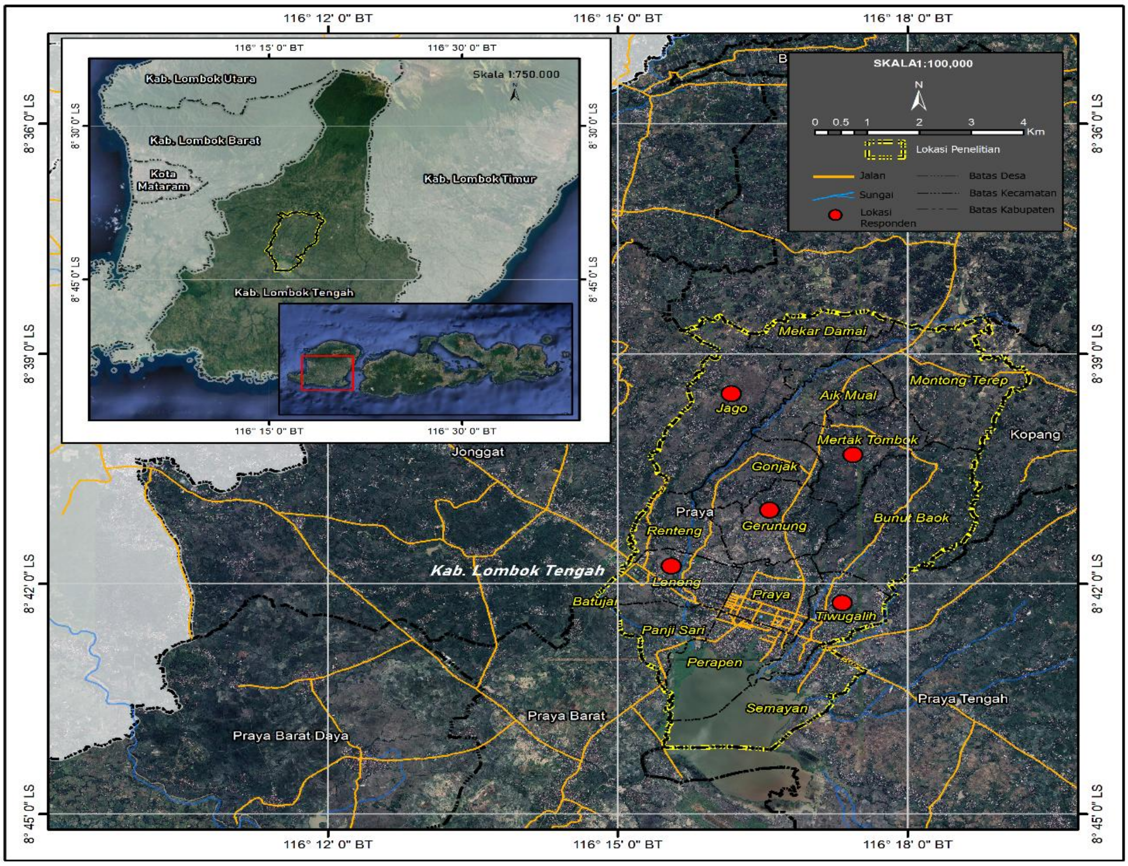


Figure 2. Map showing the study location in Lombok Tengah
Sources: Administrative Map of NTB Province, BPS NTB 2015

The population included all farmers enrolled in the Climate Smart Agriculture (CSA) program in Praya Sub-district, Lombok Tengah Regency. The sample size was 300 farmers; 30 farmer groups, and 10 farmers were chosen in each group. They also participated in the active CSA field schools and demonstration plots that were being conducted by the Lombok Tengah Department of Agriculture. The reason behind selecting this population was that they are farmers with direct exposure and involved in CSA activities, and therefore, a good point of reference in the process of examining the sustainability of CSA practices on the farm level.

2.3 Design and Sampling

The sampling frame consisted of the list of 300 farmers (10 members x 30 farmer groups) officially registered by the Lombok Tengah Department of Agriculture as members of CSA field schools and demonstration plots in Praya Sub-district. This list offers special codes such as name, group, and contact number of each eligible farmer. Simple random sampling was then carried out on the entire list of 300 CSA farmers obtained in the Lombok Tengah Department of Agriculture to select the respondents. In order to predict non-response, five more farmers were randomly picked as substitutes. If a selected respondent could not be contacted or refused to participate, a replacement from the additional list was used, ensuring that the final sample still met the requirements.

The sample size for this study was determined by the Slovin formula with a maximum error margin (E) of 10% (Antoro, 2024). The Slovin method was used because the population of CSA-adopting farmers is known, but the variance of the attributes of CSA is not, and so parameter-based sampling formulas are unsuitable. Slovin provides a practical and statistically acceptable basis for estimating a representative sample with a defined margin of error (Mallapragada & Mignone, 2020). Its use also offers clearer justification and better replicability than the convenience sampling approaches found in some earlier CSA studies. The formula used was:

$$n = \frac{N}{N.E^2 + 1} \qquad (1)$$

With N = 300 and error margin (E) = 10%, the required sample was :

$$n = \frac{300}{300.(0,10)^2 + 1} = 75$$

2.4 Instruments and Measurements

A multidimensional evaluation of the sustainability of rice farming was done across five dimensions (ecological, economic, social, technological, and institutional) to evaluate Climate Smart Agriculture (CSA) implementation in rice cropping. A total of 47 attributes (shown in Table 1) were used for the analysis. Attributes were selected mostly from the literature and modified to the Lombok Tengah rice farming system. Expert inputs and consultations with farmers and extension officers were used to validate the relevance of the attributes being selected.

Table 1. Attributes in Each Dimension of Climate Smart Agriculture (CSA) Sustainability in Lombok Tengah Regency

Attributes	Operational Definition	Criteria	Source
Ecological Dimension			
Rice field area managed	Total rice field area cultivated by farmers per planting season, measured in hectares	(0) 0.1 – 0.5 ha; (1) >0.5 – 1 ha; (2) > 1 ha	(Febriana, 2023)
Rice productivity	Total production of harvested dry grain (GKP) per hectare per planting season.	(0) 1–3 t ha^{-1} ; (1) 3–6 t ha^{-1} ; (2) >6 t $^{ha-1}$	(Sarvina et al., 2022)
Pest attack intensity	Percentage of cultivated area affected by pest attacks per planting season	(0) >30%; (1) 10-29%; (2) <10%	(Febriana, 2023)
Disease attack intensity	Percentage of cultivated area affected by plant diseases per planting season.	(0) >30%; (1) 10-29%; (2) <10%	(Febriana, 2023)
Utilization of agricultural waste	Degree of utilization of agricultural residues for livestock feed, compost, or energy.	(0) Not implemented; (1) Rarely; (2) Always implemented	(Dzikrillah et al., 2017)
Use of organic materials	Level of application of organic inputs to rice fields per planting season.	(0) Not implemented; (1) Rarely; (2) Always implemented	(Dzikrillah et al., 2017)
Land conservation	Implementation of soil and water conservation measures to prevent erosion and maintain fertility.	(0) Not implemented; (1) Rarely; (2) Always implemented	(Sudiono et al., 2017)
Economic Dimension			
Status of paddy management	Land ownership and management status	(0) Wage labor; (1) Profit sharing; (2) Own land	(Febriana, 2023)
Market access	Type of market channel used by farmers	(0) Local trader; (1) Cooperative; (2) Direct marketing	(Sudiono et al., 2017)
Farmer income per planting season per hectare	Net income earned per hectare from rice farming per planting season.	(0) < Rp 25,000,000; (1) = Rp 25,000,000; (2) > Rp 25,000,000	(Febriana, 2023)
Pest and disease control costs	Proportion of pest and disease control expenses to total production cost.	(0) >10% ; (1) 5–10%; (2) <5% of total cost	(Sudiono et al., 2017)
Labor costs	Proportion of labor expenses to total production cost.	(0) >20%; (1) 10–20%; (2) <10% of total cost	(Febriana, 2023)
Price fluctuation	Percentage change in farm-gate rice price compared with the	(0) Increase <5%; (1) 5–9%; (2) >9%	(Nugrahapsari et al., 2021)

Attributes	Operational Definition	Criteria	Source
	previous season		
Market reach	Geographic scope of market coverage	(0) Local; (1) District; (2) Provincial	(Dzikrillah et al., 2017)
Market opportunity	Availability and openness of marketing opportunities for rice products	(0) None; (1) Limited; (2) Open and wide	(Dzikrillah et al., 2017)
Farmers' access to capital.	Frequency and reliance on credit taken per planting season	(0) Frequently borrows >3 times/season; (1) 1–2 times; (2) Never borrows	(Susilawati, 2019)
Social Dimension			
Farmer education	The highest formal education level attained by the farmer	(0) Junior High; (1) High School; (2) Higher Education	(Susilawati, 2019)
Farming management pattern	Type of farm management	(0) Individual; (1) Group; (2) Corporate	(Sudiono et al., 2017)
Membership in a farmer group	Degree of farmers' activeness in farmer group activities	(0) Inactive; (1) Less active; (2) Active	(Sudiono et al., 2017)
Frequency of marketing/post-harvest conflict	Number of conflicts related to marketing or post-harvest processes per planting season	(0) >2 times/season; (1) 1–2 times; (2) Never	(Febriana, 2023)
Frequency of production-related conflict	Number of conflicts related to production inputs per planting season	(0) >2 times/season; (1) 1–2 times; (2) Never	(Febriana, 2023)
Time allocation in farming	Proportion of the farmer's working time devoted to rice farming activities	(0) Part-time; (1) Half-time; (2) Full-time	(Febriana, 2023)
Family participation in farming	Number of household members involved in farming activities	(0) None; (1) 1–2 members; (2) >3 members	(Sudiono et al., 2017)
Extension frequency	Number of agricultural extension sessions attended per month	(0) Never; (1) 1–2 times/month; (2) >2 times/month	(Sudiono et al., 2017)
Farmer motivation	Level of farmers' willingness and enthusiasm to improve production and adopt innovations	(0) Low; (1) Moderate; (2) High	(Sudiono et al., 2017)
Farming experience	Number of years of farming experience in rice cultivation	(0) <5 years; (1) 6–10 years; (2) >11 years	(Nugrahapsari et al., 2021)
Technological Dimension			
Application of Good Agricultural Practices	Degree of compliance with Good Agricultural Practices (GAP) in rice farming	(0) Not applied; (1) Partially applied; (2) Fully applied	(Susilawati, 2019)
Water-saving irrigation (AWD)	Level of adoption of water-saving irrigation techniques such as Alternate Wetting and Drying (AWD)	(0) Not applied; (1) Partially applied; (2) Fully applied	(Mulyani et al., 2024)
Use of improved rice varieties	Level of adoption of recommended stress-tolerant rice varieties.	(0) Not applied; (1) Partially applied; (2) Fully applied	(Mulyani et al., 2024)
Use of the Jajar Legowo planting system	Level of application of the Jajar Legowo planting pattern in rice fields.	(0) Not applied; (1) Partially applied; (2) Fully applied	(Mulyani et al., 2024)
Balanced fertilization	Level of compliance with recommended doses and types of balanced fertilization.	(0) Not applied; (1) Partially applied; (2) Fully applied	(Mulyani et al., 2024)
Use of organic fertilizer	Degree of organic fertilizer use in rice cultivation	(0) Not applied; (1) Partially applied; (2) Fully applied	(Sudiono et al., 2017)
Use of botanical pesticides	Degree of application of plant-based pesticides for pest control	(0) Not applied; (1) Partially applied; (2) Fully applied	(Febriana, 2023)
Integrated pest management	Level of adoption of Integrated Pest Management (IPM) principles	(0) Not applied; (1) Partially applied; (2) Fully applied	(Mulyani et al., 2024)
Reduction in chemical fertilizers	Degree of reduction in chemical fertilizer application compared with previous seasons	(0) Not applied; (1) Partially applied; (2) Fully applied	(Mulyani et al., 2024)
Agricultural waste processing technology	Level of use of technology for agricultural waste processing	(0) None; (1) Conventional; (2) Modern	(Febriana, 2023)

Attributes	Operational Definition	Criteria	Source
Institutional Dimension			
Existence of a farmer group	Availability and functionality of farmer groups in the farmers' area	(0) None; (1) Exists but suboptimal; (2) Optimal	(Sudiono et al., 2017)
Existence of an agricultural extension officer	Presence and activeness of agricultural extension workers supporting farmers	(0) None; (1) Exists but inactive; (2) Active	(Nugrahapsari et al., 2021)
Existence of a training institution	Availability and activeness of agricultural training institutions accessible to farmers	(0) None; (1) Exists but inactive; (2) Active	(Febriana, 2023)
Participation in CSA training	Number of farmer participations in CSA training per season.	(0) Never; (1) 1–2 times/season; (2) >2 times/season	(Sudiono et al., 2017)
Participation in routine group extension	Farmer participation in regular group extension meetings per season	(0) Never; (1) 1–2 times/season; (2) >2 times/season	(Sudiono et al., 2017)
Existence of agribusiness partners	Availability and engagement of agribusiness partners in the area.	(0) None; (1) Exists but inactive; (2) Active	(Dzikrillah et al., 2017)
Existence of credit institutions	Availability and activeness of credit institutions serving farmers	(0) None; (1) Exists but inactive; (2) Active	(Dzikrillah et al., 2017)
Existence of agricultural input suppliers	Availability and activeness of input suppliers providing seeds, fertilizers, pesticides, etc.	(0) None; (1) Exists but inactive; (2) Active	(Nugrahapsari et al., 2021)
Existence of farmer group management	Existence and performance of the farmer group management structure	(0) None; (1) Exists but inactive; (2) Active	(Susilawati, 2019)
Government involvement	Level of government support through programs, subsidies, or assistance in rice farming	(0) None; (1) Exists but inactive; (2) Active	(Febriana, 2023)
University involvement	Engagement of universities in providing research, training, or mentoring to farmers	(0) None; (1) Exists but inactive; (2) Active	(Febriana, 2023)

Sources: various studies and research

All attributes were rated by a team of agricultural extension officers having on-the-ground experience in running and managing rice farm businesses in the target location. The panel was allowed half a day of training in creating a shared feel of the working meaning of the definitions and the rating scale (0 - 2 scale) of each attribute, and then actually going through the rating exercise. To give an assurance as to the validity of the expert opinions, an inter-rater test and the Cohen Kappa coefficient were conducted on a random sample of features. The test received a Kappa of 0.713 ($p < 0.001$, N = 47), which is a measure of a substantial level of consensus among the experts (Landis & Koch, 1977), hence ensuring that scoring was a dependable process.

Equal weights were applied across all attributes within each of the dimensions, and the same applies to the five dimensions (ecological, economic, social, technological, and institutional) that were provided with equal weight in the calculation of the overall CSA sustainability index. This weighting approach takes up the default settings of the Rapfish-based MDS analysis, hence avoiding the possibility of any attribute or dimension influencing the final index too much.

This study used both primary and secondary data sources. Primary data were obtained from official questionnaires filled out by farmers in CSA demonstration farms of rice farming systems in the Lombok Tengah Regency, West Nusa Tenggara. The agricultural statistics (BPS NTB), the reports of the implementation of the CSA program published by the Department of Agriculture Lombok Tengah Regency, the CSA program guidelines, and other scientific publications, including literature reviews and institutional records, were the sources of secondary data. These were supportive sources for the evaluation.

2.5 Analysis Method

The sustainability of the Climate Smart Agriculture (CSA) practice was assessed by applying the RAPFISH (Rapid Appraisal to Fisheries) method that has been tailored and applied to Rap-CSA. Initially, this instrument was created to assess the sustainability of the fisheries sector, but it has since been applied to various other sectors because it is capable of addressing intricate relationships among biophysical, sociocultural, economic, and institutional aspects (Fauzi, 2019). The RAPFISH Excel Add-in with Bray-Curtis distance measure and non-metric multidimensional scaling (MDS) procedure was used to analyze it. To ensure ordination model stability, it was run with multiple random starting points, an iteration number of 100, and a Monte Carlo simulation of 999 permutations. The test of the strength of the results was performed by Monte Carlo, considering the fact that the difference between the MDS and the Monte Carlo sustainability indices must not be larger than 5% (Yusuf et al., 2021). The ordination was also a priori validated with the help of two diagnostic measures: (i) S-Stress values < 0.25, meaning a satisfactory level of stress, and (ii) R^2 coefficients near 1.0, indicating that the ordination accurately represents the data structure (Kavanagh & Pitcher, 2004). The legitimate results that met the conditions above were then further interpreted.

The current paper utilized the multi-stage method of examining the Rap-CSA Ordination (Figure 2). These steps involve: (1) Attributes determination, which involved five dimensions (ecological, economic, social, technological, and institutional) as listed in Table 1; (2) Adding a score to each attribute on an ordinal scale (scoring) according to the sustainability criteria of each of the dimensions; (3) Ordination analysis of Rap-CSA with MDS approach to establish ordination and stress value; (4) The index and sustainability status of CSA implementation in the Lombok Tengah Regency was computed and evaluated with respect to a standardized classification scale (Table 2) (Fauzi, 2019).

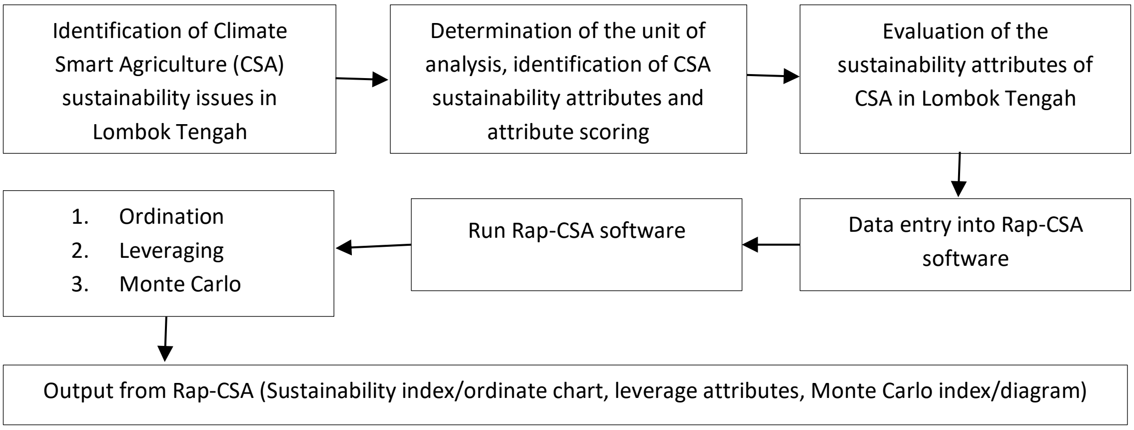


Figure 3. Stages of sustainability analysis (Fauzi, 2019)

Table 2. Sustainability Status Categories

Point	Description
0.00 – 25.00	Not sustainable
25.01 – 50.00	Less sustainable
50.01 – 75.00	Moderately sustainable
75.01 – 100.00	Highly sustainable

Sources: Suharno et al., 2019

2.6 Ethics Approval Statement

The study received formal approval from the Department of Agriculture and Plantation of West Nusa Tenggara Province through Research Permit Letter No. 800.1.4/193/Distanbun/2025. Informed consent was voluntarily provided by each respondent after confirming that they fully understood the information given. To maintain confidentiality, respondents' identities were not disclosed in the research report or any publication, and all data were anonymized to eliminate any possibility of tracing individual participants.

3. Results and Discussions

3.1 Ordination Scale

The ranking of the Rap-CSA approach provides an overview of the general sustainability level of Climate Smart Agriculture (CSA) practices in Lombok Tengah Regency. The output of Multidimensional

Scaling (MDS) provided index values of sustainability for each dimension (ecological, economic, social, technological, and institutional) on a scale of 0–100. These scores enable the performance score of each dimension to be graded in levels. The results of the ordination are therefore the benchmark against which the relative strengths and weaknesses of the dimensions of CSA implementation are evaluated, and which dimensions are resilient and which aspects need to be enhanced specifically. The sustainability status behind each dimension, as well as the multidimensional assessment as a whole, is given below in fine detail.

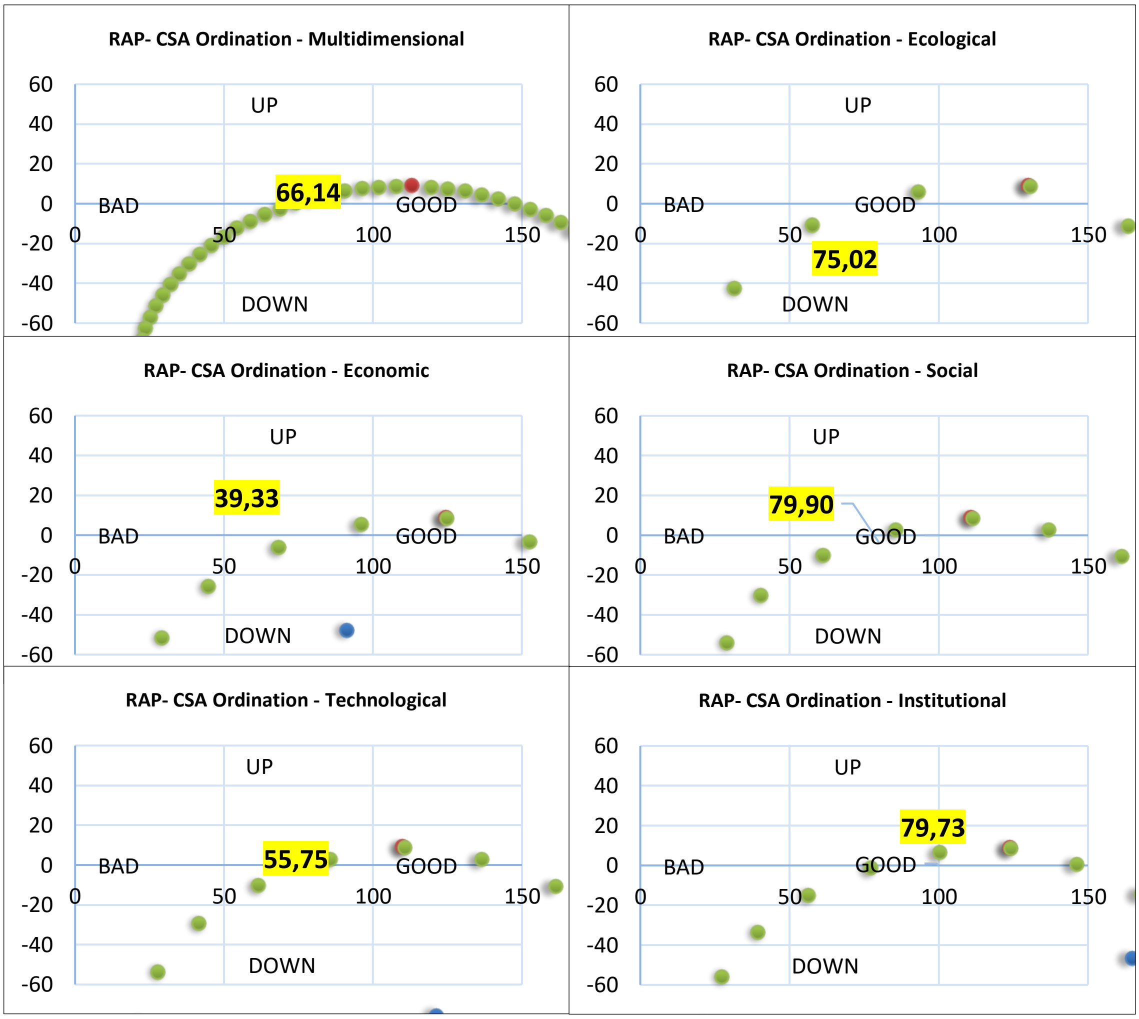


Figure 4. Sustainability Index Values
Sources: Author's Analysis, 2025

The rapid sustainability analysis (Rap-CSA) showed that the multidimensional sustainability index of Climate Smart Agriculture (CSA) in the Lombok Tengah Regency was 66.14%, which was within the category of moderately sustainable. Ecological (75.02%), social (79.90%), and institutional (79.73%) dimensions are in the highly sustainable category, the technological dimension (55.75%) is in the moderately sustainable category, and the economic dimension (39.33%) is in the less sustainable category. This diffusion reflects the fact that the adoption of CSA is not the one that has been balanced through the adoption of the technology and the economic feasibility, as the weaknesses in the technology adoption and economic soundness are limiting the overall performance.

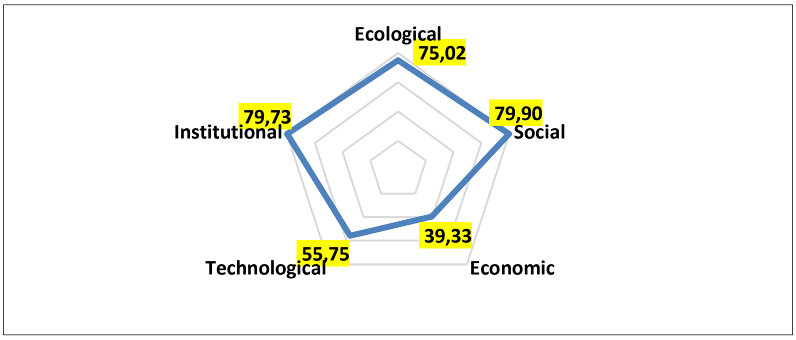
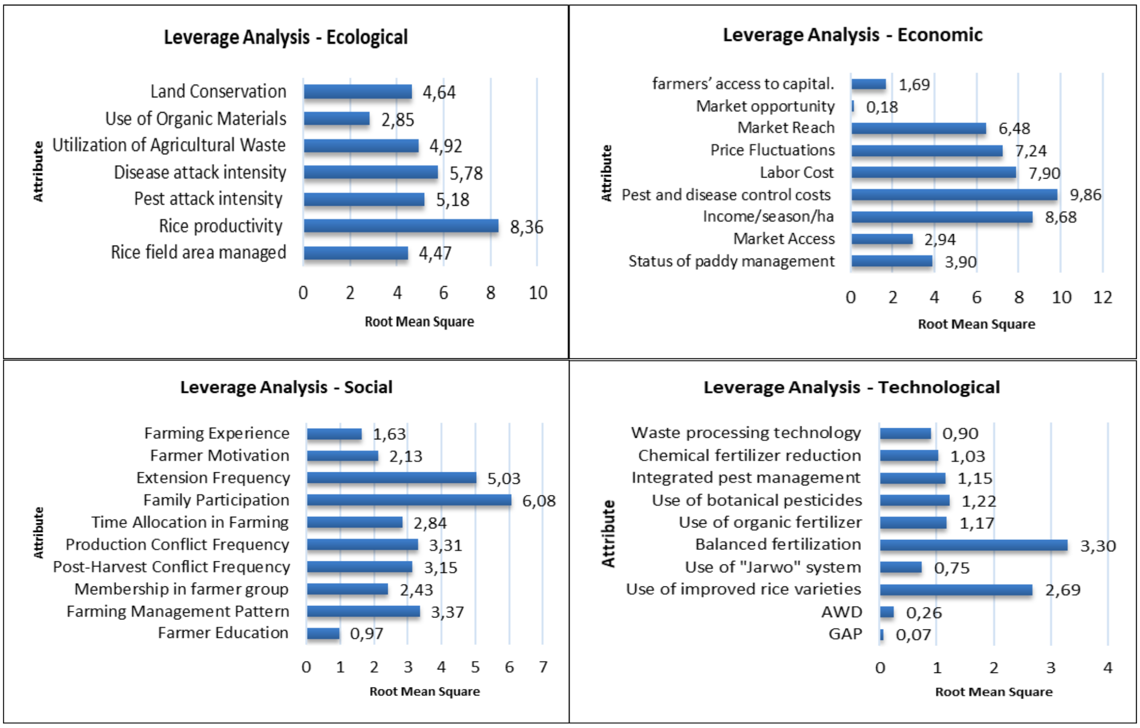


Figure 5. Status Index Diagram
Sources: Author's Analysis, 2025

MDS outcome may also chart visual similarity dimension in a geometric space referred to as a perceptual map to enable relative positions and interdependency of variables to be interpreted (Figure 4) (Borg & Groenen, 2005). The values of the sustainability index of each dimension, as adjusted in the radar chart, show that the more distant the points are from the central point (zero), the greater the level of sustainability. The radar or flyover diagram demonstrates that the further away the dimensions are from the core, the less sustainable the performance is, and the further the dimensions are, the more robust the performance is (Prastiyanto et al., 2024). This distribution shows that CSA implementation is yet to reach the balanced sustainability along all the dimensions, and more efforts are required to make the economic and technological dimensions stronger in order to reach a more integrated and sustainable system of CSA.

3.2 Leverage Analysis

The leverage analysis was conducted to identify the most important attributes driving the sustainability position of Climate Smart Agriculture (CSA) across the five dimensions. The method identifies variables that have the largest Root Mean Square (RMS) values, which are relative sensitivity and possible ability to change index scores in case of an improvement (Mahida, 2020). When such salient leverage points are isolated and analyzed, the analysis provides a strategic foundation of formulating evidence-based, narrow-bound interventions, which can maximise sustainability outcomes. The leverage analysis of each dimension is described in detail, as well as the most sensitive attributes that impact CSA sustainability.



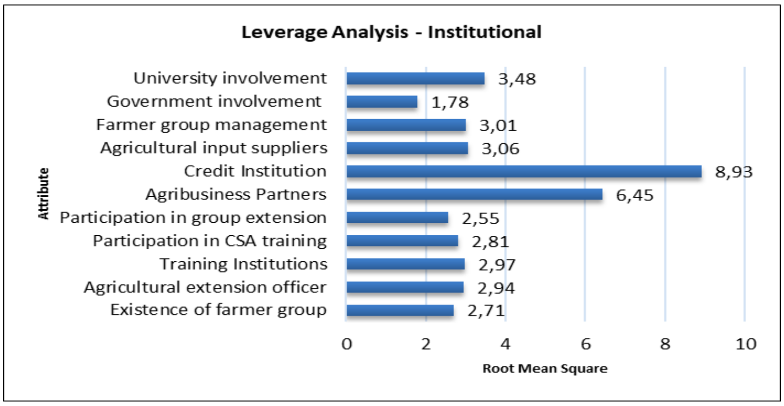


Figure 6. Leverage Analysis
Sources: Author's Analysis, 2025

Table 3. Sensitive Attribute Ranking

No.	Attributes	Root Mean Square (RMS)
A.	**Ecological**	
1.	Rice productivity	8.36
2.	Disease attack intensity	5.78
3.	Pest attack intensity	5.18
4.	Utilization of Agricultural Waste	4.92
5.	Land Conservation	4.64
B.	**Economic**	
1.	Pest and disease control cost	9.86
2.	Income/season/hectare	8.68
3.	Labor cost	7.90
4.	Price fluctuations	7.24
5.	Market reach	6.48
C.	**Social**	
1.	Family participation	6.08
2.	Extension frequency	5.03
3.	Farming management pattern	3.37
4.	Production conflict frequency	3.31
5.	Post-harvest conflict frequency	3.15
D.	**Technological**	
1.	Balanced fertilization	3.30
2.	Use of improved rice varieties	2.69
3.	Use of botanical pesticides	1.22
4.	Use of organic fertilizer	1.17
5.	Integrated pest management	1.15
E.	**Institutional**	
1.	Credit institution	8.93
2.	Agribusiness partners	6.45
3.	University involvement	3.48
4.	Agricultural input suppliers	3.06
5.	Farmer group management	3.01

Sources: Author's Analysis, 2025

The leverage analysis (Figure 5) also revealed that the most sensitive parameters changed according to each dimension as manifested by their Root Mean Square (RMS) values. In the ecological aspect, the leverage factor that had the strongest influence was the rice productivity (RMS = 8.36), followed by the severity of disease and pest attacks, waste utilization, and land conservation. In the economic sector, the most rated costs include pest and disease control (9.86) and income per-hectare per-season (8.68), with labor cost, price instability, and market size having their share. Family participation (6.08) and extension services (5.03) dominated the social domain with little implications of conflict variables.

In the technological category, the influence focused on balanced fertilization (3.30) and better varieties of rice (2.69), as botanical pesticides, organic fertilizer, and integrated pest management had a minor yet significant influence. Institutional sustainability, in its turn, was the most sensitive to the credit institutions (8.93) and agribusiness partnership (6.45), with the other contribution made by universities, input dealers, and farmer group management. These results highlight that the good leverage points are the ecological, social, and institutional aspects, and the operations within the economic and technological features are central to making the overall CSA sustainability more robust.

3.3 Monte Carlo Analysis

Monte Carlo Analysis was applied to assess the stability and reliability of the MDS results through repeated randomization of the data. The simulation results indicate that the ordination bias remained below 5%, confirming the high validity and reliability of the model. Therefore, the MDS configuration can be considered stable and suitable for further interpretation and decision-making, as presented in Table 4.

Table 4. Sustainability status of Climate Smart Agriculture (CSA) in Lombok Tengah Regency

Dimension	Ordination Value (%)	S-Stress	R^2	Monte Carlo (%)	Between Monte Carlo value and Ordination value	Category
Ecological	75.02	0.14	0.95	72.53	2.49	Highly sustainable
Economic	39.33	0.13	0.94	39.99	0.66	Less sustainable
Social	79.90	0.13	0.98	76.85	3.05	Highly sustainable
Technological	55.75	0.14	0.94	55.24	0.51	Moderately sustainable
Institutional	79.73	0.13	0.94	76.60	3.13	Highly sustainable
Multidimensional	66.14	0.12	0.95	64.17	1.97	Moderately sustainable

Sources: Author's Analysis (2025)

Table 4 shows the sustainability index of CSA with five dimensions: ecological, economic, social, technological, and institutional. The low S-Stress values (0.13–0.14) and high R^2-values (0.94–0.98) confirmed the validity of the model for all different behaviors in all settings, reassuring a great fit to the sample data, which we found satisfactory. In all dimensions, the difference between the values of MDS and Monte Carlo was less than 5%, hence indicating the credibility of the results.

3.4 Farmers' Adoption

Climate Smart Agriculture (CSA) practice adoption by farmers is a critical step towards the sustainability of farming, given the climate change situation. However, adoption levels are highly heterogeneous among farming groups and are differentially affected by socioeconomic, institutional, and environmental factors. It is critical to understand the rate of adoption and prevalence of these practices across different farmers in ascertaining the effectiveness of CSA interventions.

Table 5: CSA Adoption by Technology Component in Rice Farming at Lombok Tengah

No.	CSA Technology Component	Full Adopters (%)	Partial Adopters (%)	Non-Adopters (%)
1.	Water-saving irrigation (AWD)	35	48	17
2.	Use of improved rice varieties	68	31	1
3.	Use of Jajar Legowo planting system	36	40	24
4.	Balanced fertilization	63	36	1
5.	Use of organic fertilizer	27	56	17
6.	Use of botanical pesticides	24	49	27
7.	Integrated pest management	39	55	7
8.	Reduction in chemical fertilizers	25	61	13

Sources: Author's Analysis, 2025

In Lombok Tengah, more adopters of CSA practices are headed by improved rice variety (68% full adopters) and balanced fertilization (63%), which strongly affects the technology index. Intermediate adoption of AWD (35%), IPM (39%), and Jajar Legowo system (36%) shows promise to further increase the index if adoption is increased, while low adoption of organic fertilizer (27%), botanical pesticide (24%), and chemical fertilizer reduction (25%) limits their effect. Overall, the technological sustainability of rice farming is currently underpinned by variety improvement and fertilization, but the more extensive application of ecological technologies needs to be strengthened in order to achieve higher resilience and long-term sustainability.

3.5 Impact of Climate Smart Agriculture Practices in Lombok Tengah

The implementation of Climate Smart Agriculture (CSA) methods in Lombok Tengah resulted in measurable variations between CSA demonstration plots and conventional farming systems. Data collected included productivity per hectare, cost of production, net income distribution, and simple break-even analysis.

As shown in Figure 6, during the years 2020–2023, rice production using Climate Smart Agriculture (CSA) in Lombok Tengah consistently surpassed Non-CSA by 0.14–0.85 t ha^{-1} . CSA yield ranged between 5.66 and 6.52 t ha^{-1} , compared to 5.52 and 5.85 t ha^{-1} for Non-CSA, with the obvious advantage of CSA in elevating yields. While there are similar overall expenditures, expenditures between the two systems vary. CSA farms have lower seed costs using high-yielding rice varieties and Jajar Legowo planting, which allows for wider spacing and reduces seed use without lowering output. Fertilizer costs are slightly reduced, reflecting better and more balanced application, while pesticide spending rises modestly as chemical inputs are complemented by plant-based alternatives using Integrated Pest Management (IPM). It is more labor-intensive because of additional labor with Jajar Legowo, IPM, AWD irrigation, and the use of organic fertilizer, all of which involve more monitoring and intensive management. It also has higher fixed costs, which reflect investment in infrastructure and equipment to enable CSA practice.

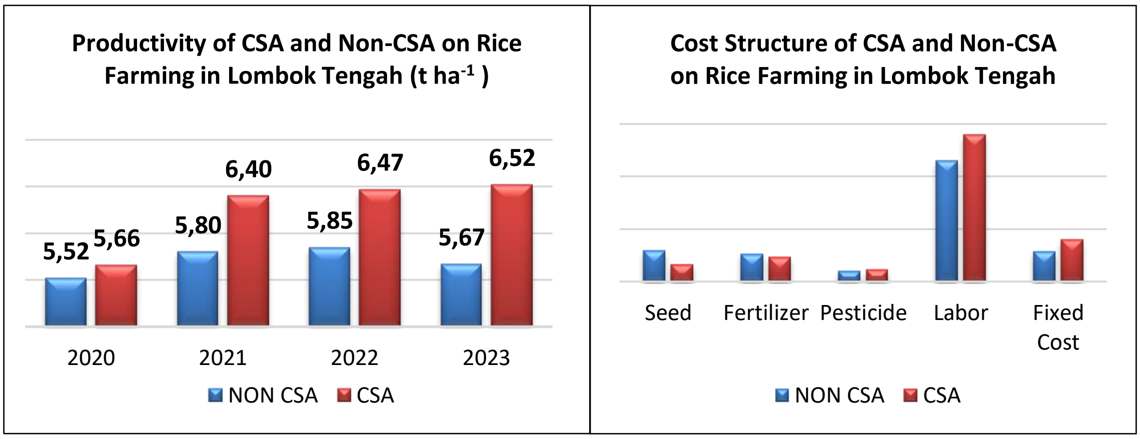


Figure 7. Productivity and Cost Structure of CSA and Non-CSA on Rice Farming in Lombok Tengah
Sources: Dinas Pertanian Lombok Tengah, 2024

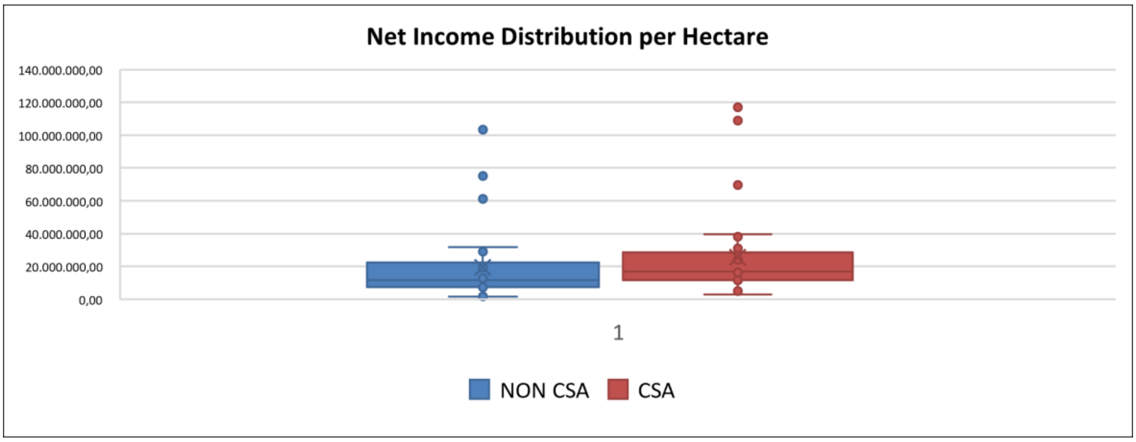


Figure 8. Net Income Distribution per Hectare of CSA and Non-CSA on Rice Farming in Lombok Tengah
Sources: Author's Analysis, 2025

Table 6. Break-even Analysis of CSA Interventions

No.	Cost Component	Additional Cost (IDR/ha)	Break-Even Yield (t ha^{-1})
1.	Pesticide	56.916	0,01
2.	Labor	984.608	0,18
3.	Fixed Cost	460.000	0,08

Sources: Author's Analysis (2025)

Figure 7 indicates that CSA farmers' net income per hectare is more spread out than that of non-CSA farmers. Although their median is lower, the increased mean and outliers ensure that some farmers earn significantly more, which raises the average overall. Table 5 supports this by showing that labor is the most substantial additional cost of CSA adoption, requiring a moderate increase in yields to reach the break-even point. These findings suggest that CSA practices are capable of increasing farm profitability, provided increases in yields are large enough to offset greater demand for labor. However, the benefits are not yet across the board for all farmers.

3.6 Discussion

3.6.1. Sustainability of Climate Smart Agriculture in Rice in Lombok Tengah

One of the principal challenges of the twenty-first century is the sustainable management of agrosystems under conditions of climate change. Sustainable development seeks to maintain all three dimensions: economic growth (economic dimension), protection of the environment (ecological dimension), and social justice (social dimension) in a well-balanced relationship. Over time, this approach has developed to include both technological and institutional dimensions, which are essential for maintaining long-term agricultural resilience. Even though the concept still develops in respect to the global developments, its key principles of integration, equity, and sustainability have been preserved.

Many studies have examined rice farming systems with respect to their sustainability by employing the Multidimensional Scaling (MDS) method. As an example, Arief et al. (2025) tested the sustainability of rice farming in Kutai Kartanegara and determined the multidimensional index of 43.90%, which is less sustainable. In the meantime, Rachman et al. (2022) measured the sustainability of expanding rice production in West Java and determined the major influential factors, and the index achieved in Bandung was 50.08%. In the same way, Ismail et al. (2024) assessed sustainable rice farming in Pancur Batu Sub-district, North Sumatra, and got a more significant index of 72%, which is defined as moderately sustainable. All of these findings reiterate the fact that with the ecological and social dimensions tending to show higher levels of sustainability performance, due to the high degree of community involvement and environmental consciousness, the economic and technological dimensions are rather weak due to the lack of accessibility to markets, production factors, and agricultural innovations.

In the current research in Lombok Tengah, the overall sustainability index appears mediocre (66.14%), which is consistent with the overall tendency in past results. The social (79.90%), ecological (75.02%), and institutional (79.73%) dimensions are very much sustainable, and this validates the previous findings that social cohesion and environmental consciousness enhance sustainability performance. Nonetheless, the economic (39.33%) and technological (55.75%) dimensions are still not as strong and legitimize the previous issues found by other researchers. Analysis of leverage revealed the presence of important sensitive attributes, namely; rice productivity and pest and disease attack intensity (ecological); pest and disease control costs, income per hectare, and labor costs (economic); family participation and frequency of extension (social); balanced fertilization and improved rice varieties (technological); and presence of credit institutions and agribusiness partners (institutional).

This implies that even though CSA in Lombok Tengah boasts of good social networks, environmental stewardship, and institutional support, more needs to be done to enhance the economic performance and fast-track the adoption of technology. The priorities of the policy should be to improve access to markets, stabilize the prices of rice, and increase the use of major CSA technologies, including AWD irrigation, organic fertilizers, and IPM. Enhancing these will facilitate a more robust and sustainable rice economy and be used as an example to other climate-susceptible countries in Indonesia.

3.6.2. Ecological Dimension of CSA in Rice Farming

The ecological aspect of Climate Smart Agriculture (CSA) in Lombok Tengah has been evaluated through the Rap-CSA approach, with the index of 75.02, indicating a highly sustainable ecological dimension. This is significantly greater than the results of Arief et al. (2025), who recorded an ecological sustainability index of 37.18% (less sustainable) in paddy farming systems in Kutai Kartanegara. Their research noted excessive use of chemical fertilizers and pesticides, low uptake of water-saving irrigation methods, and low levels of organic farming activities as the key ecological restraints. Likewise, Dzikrillah et al. (2017) have noted 49.02% as an ecological index in Soreang District, Bandung (less sustainable).

Among the crucial ecological problems, the overuse of pesticides, the decrease in soil fertility, and the poor rates of waste use could be noted. The value of the index is high in the present study, which means that the agroecosystem is approaching long-term ecological sustainability.

Previous studies have found that productivity, pest and disease pressure are some of the most important ecological issues that characterize agricultural sustainability. According to Sarvina et al. (2022) the, productivity was the most vulnerable quality of the coffee production system sustainability in West Lampung, which means that productivity reflects the ecological efficiency and stability of agroecosystems. Similarly, Rachman et al. (2022) emphasized that pest and disease control are important leverage factors affecting the sustainability of rice farming in Bandung District. In line with these findings, the present study revealed that rice productivity, severity of disease attack, and severity of pest attack are the most sensitive attributes in the ecological dimension. Although the ecological index was high (75.02%), the low productivity and the recurring pest and disease pressure indicate that ecological balance is yet to be achieved fully, with the necessity to strengthen integrated pest and disease management (IPM) and soil fertility enhancement for enhancing long-term ecological sustainability.

These are corroborated in Lombok Tengah by recent agricultural statistics. Total rice output in 2024 decreased by 6.12%, and the harvested area fell by 2.26%, and average harvests from 5.26 t ha^{-1} in 2023 fell to 5.05 t ha^{-1} in 2024 (BPS Provinsi NTB, 2025). Farmer surveys also supported that 68% of farmers provided returns of below 5 t ha^{-1}, due primarily to drought stress that affected 2,985 hectares of paddy. Pest infestation is also on the rise, which has expanded from 2,013 ha in 2023 to 2,346 ha in 2024, and it is followed by stem borers, rats, and other insect pests. These stresses threaten to promote excessive reliance on chemical pesticides, thus compromising soil and water quality in the long run.

To address these challenges, numerous studies have demonstrated that CSA technologies can significantly enhance productivity and environmental efficiency in rice-based ecosystems. Stress-tolerant crop varieties and balanced fertilization up-scaling in Ethiopia improved soil fertility, input use efficiency, and yields by up to 0.564 t ha^{-1} (Assaye et al., 2022). In South Sulawesi, IPM adoption was effective in terms of decreasing the pests and disease cases, pesticide application, and production expenses and augmenting the yields (Bulkis et al., 2020). Measures applied by CSA to enhance productivity, efficiency of resource use, and ecological resilience to stress (e.g,. stress-tolerant crop varieties, alternate wetting and drying (AWD) irrigation, and balanced fertilization) were effective in Central Java (Connor et al., 2021). As such, it is important to scale up CSA-based interventions to strengthen the ecological and long-term sustainability of rice-based farming in Lombok Tengah.

3.6.3. Economic Dimension of CSA in Rice Farming

The Lombok Tengah economic aspect of Climate Smart Agriculture (CSA) was less sustainable, with an index value of 39.33. This is very low due to financial constraints background especially the high cost of controlling pests and diseases, and low income per hectare of farmland,s and this indicates that though there is improvement in ecology, the financial performance of the rice-based farming systems is low.

The same Rapid Appraisal (RAPFISH) method was also applied in another similar comparative analysis by Ismail et al. (2024) in Pancur Batu Sub-district, North Sumatra, with an economic sustainability index of 43.58, which is less sustainable. The high prices of fertilizers and pesticides, the labor prices, and the low availability of inputs were reported to be the most sensitive and expensive forces depressing the economic sustainability. In line with this, Rachman et al. (2022), when evaluating the sustainability of rice farming in the Bandung District (West Java), indicated that the economic aspect had a value of 35.25% index, which was classified as being less sustainable. It was demonstrated in the study that high production costs, low selling price, and limited access to capital had a significant influence on the economic factor, which led to decreased economic viability of the rice farming systems. These results have been consistent with the state of affairs in Lombok Tengah, which suggests that the problem with structural and input-based constraints is not new to the Indonesian systems of smallholder rice.

According to a field survey, there is low profitability for the farmers; 5 percent of them do not get incomes of less than IDR 25 million per hectare per season. The average production costs are IDR 9,8 million per hectare, with 71 percent of the farmers incurring less than 5 percent of the cost of controlling pests anddiseases, showing a relatively efficient current use. Nonetheless, excessive use of chemical pesticides enhances costs over the long term and environmental hazards, and the transition to the integrated, low-cost, and ecological approach.

Rachman et al. (2022) identified capital access constraint as among the primary factors that make the economic viability of rice growing in Bandung District lower. They found that access to the Kredit Usaha Rakyat (KUR) program, which is a low-cost micro credit program in Indonesia, is significant in capital constraint reduction of farmers and also enables them to adopt sustainable farming technologies. Having the data, the technology, institutional, and policy interventions are essential to enhance the economic sustainability of CSA in Lombok Tengah. Farm level intervention may involve the marketing of Integrated Pest Management (IPM), balanced fertilization in order to reduce the cost of inputs and maximize the efficiency. An area of priority in terms of improving farmers' cooperatives, group marketing, and access to affordable credit, like KUR, is done institutionally. Supply of more KUR to CSA-scaled investments, such as organic inputs and irrigation systems, can also be used to improve the profitability of farms and their financial stability and sustainability in the long term.

3.6.4. Social Dimension of CSA in Rice Farming

The social aspect of CSA in Lombok Tengah was discovered to be very sustainable, as it had an index value of 79.90. This outcome means that there is high community engagement, good interaction between farmers and institutions, and communication of knowledge among the rice farmers. Family participation in agriculture and the frequency of extension were found to be the most sensitive attributes.

Comparative analysis reveals that there are different degrees of social sustainability in different regions. According to Rachman et al. (2022), the social sustainability index in Bandung District was low (30.79% less sustainable) because of low education rates, high-aged farmers, and poor access to extension services, which diluted the social pillar of rice production. Equally, Dzikrillah et al. (2017) established a social dimension index of 45.87% (less sustainable) in the Soreang District, Bandung, due to poor farmer motivation, low membership in farmer groups, and poor training. Conversely, the social sustainability index measured at 75.13% (quite sustainable) in Pancur Batu Sub-district, North Sumatra, where the primary contributor to social performance was regular agricultural counseling and high attendance of people, was observed by Ismail et al. (2024) These results are quite consistent with the present study since they proved that frequency of extension and family involvement are the core of enhancing social resilience in rice-based CSA systems. The large index in Lombok Tengah thus indicates the good influence of active family participation and the good working extension services, which implies that further strengthening of these variables will continue to maintain as well as enhance social sustainability in the region.

Earlier studies highlight the importance of family and social networks as the way to make CSA adoption possible. Wang et al. (2024) determined that family and friendship ties have positive impacts on the adoption of CSA among farmers through informal household communication. In line with this, the present research found family participation as a critical social attribute, where 60% of farmers used 1–2 family members, 23% used over three, and only 17% worked individually. Furthermore, the frequency of agricultural extension also plays a crucial role in sustaining CSA practices. Bhatnagar et al. (2024) reported that regular participatory extension accelerates technology adoption and mutual learning among farmers. Similarly, this study found that 64% of the farmers were participating in extension sessions 1–2 times a month, 32% over once a month, and 4% never, which assured permanent access to information and innovation. Collectively, high family engagement and long extension participation also resulted in a high social sustainability index of CSA in Lombok Tengah.

This is due to the Strategic Irrigation Modernization and Urgent Rehabilitation Project (SIMURP), which encourages family engagement, promotes Women Farmer Groups (KWT), and doubles the frequency of extension to strengthen knowledge sharing and adoption of climate-smart technologies. SIMURP engages women and youths in resource-sustainable management and diversified household incomes through small agri-based ventures under CSA Learning Centers and Climate Field Schools. These interventions foster social networks, community resilience, and the overall social sustainability of CSA in Lombok Tengah.

3.6.5. Technological Dimension of CSA in Rice Farming

The technological dimension of CSA in Lombok Tengah is currently moderately sustainable, with a sustainability index of only 55.75%. The value of the sustainability index is slightly lower than the technological sustainability index of 61.76% for rice farming in Bandung District, West Java (Rachman et al., 2022). However, these values are both still in the same level of category. But it still has a lot of room for improvement, particularly through the application of balanced fertilization and improved rice varieties, which are the strongest technological drivers.

The moderate technological sustainability in Lombok Tengah reflects ongoing developments in CSA-related technology, particularly in crop improvement and nutrient management. Balanced fertilization is practiced quite well, with 63% of farmers implementing it fully, 36% partially, and only 1% not yet implementing it, indicating increased awareness of the effective use of nutrients, but full implementation is not yet complete. Likewise, the adoption of improved rice varieties has been 68% complete adoption, 31% partial adoption, and 1% non-adoption, resulting in enhanced yield stability in the face of climate variability. These results are consistent with those of Rachman et al. (2022), who observed that the high rate of new high-quality varieties and planting innovations increased the productivity of rice in Bandung District. In the same vein, Bhatnagar et al. (2024) have highlighted that the use of strengthening the supply chain of seeds, enhancing field demonstrations, and facilitating participatory varietal testing are the key measures to ensure the building of trust in farmers and quicken the adoption of technology.

3.6.6. Institutional Dimension of CSA in Rice Farming

The institutional sustainability of Climate Smart Agriculture (CSA) of Lombok Tengah is highly sustainable, with the sustainability index at 79.73%, which is higher than the 60.19% for traditional Adan rice farming in Krayan, North Kalimantan. The critically sensitive institutional variables in the Krayan study were capital loans from financial institutions, cooperatives' presence, cooperatives' provision of capital assistance, and indigenous forum participation, underlining the role of financial and social institutions in sustaining farming systems (Khaerunnisa et al., 2023). Similarly, credit institution access and agribusiness partnership were listed in Lombok Tengah as the most critical factors, building farmers' institutional capacity and market access. They all point out that institution building through financial access, cooperatives, and business partnerships is one of the major drivers of long-run agricultural sustainability.

Darma et al. (2025) in the region of Wajo, South Sulawesi, emphasize the importance of having strong farmer institutions and access to microfinancing for improved agricultural sustainability. Farmer organizations formed either through cooperative memberships or irrigation service provision (ISPs) can provide farmers access to credit for inputs and mutual financial support for embracing sustainable agricultural production strategies. However, in Lombok Tengah, results from the interviews indicate that the availability of credit services for CSA on behalf of the farmers is still limited, where only 17% of the farmers benefit from the active services, while 16% benefit from limited institutional participation, and 67% lack access to credit institutions. The poor financial access hinders investments in good seeds, organic farm inputs, and irrigation systems. Moreover, only 34% benefit from partnership participation, suggesting that strengthening farmer cooperatives and improving access to microcredit are essential to enhance investment capacity and promote CSA adoption in the region.

Conclusion

Climate change still poses a risk for rice crops in climate-exposed areas like Lombok Tengah, and there is a need for more sustainable agriculture practices. This study aims to evaluate the sustainability level of Climate Smart Agriculture (CSA) on the rice farmers in Lombok Tengah and analyse factors affecting it. Applying the quantitative descriptive method and Multidimensional Scaling (MDS) algorithm based on the Rap-CSA methodology. The results show that ecological (75.02%), social (79.90%), and institutional dimensions (79.73%) maintain a highly sustainable situation. The findings suggest a great relationship among customers or tourists' perception gap with the intensity of domestic tourism development, sociocultural diversity promotion, and nature preservation/maintenance at the confidence level. But technological (55.75%) and even more so economic (39.33%) aspects are still in a poor state. Although the multidimensional analysis is currently at 66.14%, indicating a moderate sustainability level.

Nine vulnerable attributes for the sustainability of Climate Smart Agriculture (CSA) have been identified, with one attribute for ecological and two attributes each for economic, social, technology and institutional. Rice productivity constitutes an ecological aspect. The economic aspect includes cost of pest and disease control, and income per hectare. The impact of the social dimension is influenced by family involvement and frequency of extension programs. The technology aspect is addressed through balanced fertilization and the use of superior rice varieties, while the institutional aspect is driven by credit institutions' provision as well as agribusiness partnerships. Farmers should implement Alternate Wetting and Drying (AWD) irrigation, Integrated Pest Management (IPM) practices, and utilize stress-tolerant varieties of rice in order to remediate low-performing dimensions. Stronger cooperatives, better access to microcredit, and the development of value-added products will help achieve a level of economic sustainability.

Limitations

The study was carried out in Lombok Tengah Regency and thus may not be generalisable to other areas with different agroecological and socioeconomic contexts. Self-reporting of data and peer rating in the Rap-CSA method also added a level of subjectivity and variability. Additionally, the amount of time and resources dedicated to the study limited the sample size and the depth with which qualitative analyses could be conducted. Therefore, future studies have to enlarge the area of investigation (in geographical terms) in order not only to consider comparator countries as well, but also to perform data triangulation for better validity and incorporate a mixed panel of experts or apply the Delphi approach sequence for a more homogeneous evaluation. Future employment of a bigger sample size and longer duration is also warranted. Overall, this will make CSA sustainability assessments stronger and more representative.

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