INDONESIAN TREASURY REVIEW
JURNAL PERBENDAHARAAN, KEUANGAN NEGARA DAN KEBIJAKAN PUBLIK

ANALYSIS OF GOVERNMENT INTERVENTIONS TO ADDRESS CLIMATE CHANGE IMPACTS ON THE AGRICULTURAL SECTOR IN WEST NUSA TENGGARA

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ABSTRACT

Research Originality — Existing studies on climate change and agriculture primarily focus on the physical impacts and food security outcomes. However, how local governments prioritize budget allocations between mitigation and adaptation strategies in the agricultural sector remains underexplored.

Research Objective — This study aims at evaluating whether the government's budget policy is appropriate in addressing impacts of climate change by focusing the climate change budget only on mitigation budget without allocating a budget for climate change adaptation.

Research Methods — This study adopts a mixed methods approach that integrates both quantitative and qualitative techniques. Many studies have analyzed the impact of climate change on the agricultural sector, but studies using forecasting models such as the autoregressive integrated moving average (ARIMA) to predict this impact combined with policy evaluation are still rare.

Empirical Results — The forecasting results using the ARIMA (12,1,1) model reveal a continued decline in paddy production in West Nusa Tenggara from 2025 to 2028. Furthermore, it also shows a negative monthly production trend between 2021 to 2024. The evaluation results using the ARIMA model and the large number of cases of drought data and pests indicate that in dealing with climate change in West Nusa Tenggara, the government should not only allocate budgets for climate change mitigation, but also for adaptation to the impacts of climate change.

Implications — The optimal strategy for addressing the impacts of climate change on the agricultural sector require prioritizing a combination of adaptation measures across key areas such as crop management, farming systems, water resources, soil health, and pest control.

Keywords: ARIMA; Budget Policies; Climate Change; Climate Change Impacts; Climate Change Mitigation; Evidence-Based Policy

JEL Classification: Q18, Q54, Q58, H53, R58, C53, O21

How to Cite: Akbar, S. A., & Utomo, D. M. (2025). Analysis of government interventions to address climate change impacts on the agricultural sector in West Nusa Tenggara. *Indonesian Treasury Review: Jurnal Perbendaharaan, Keuangan Negara, dan Kebijakan Publik, 10*(4)*, 411-426. https://doi.org/10.33105/itrev.v10i4.1201

INTRODUCTION

Agriculture is the largest contributor to West Nusa Tenggara's gross regional domestic product, although its contribution has fluctuated in recent years. The contribution fell from 17.85% in 2021 to 16.63% in 2022, followed by a rebound to 17.48% in 2023 (Statistics Indonesia, 2024). Agriculture is also one of the largest labor-absorbed sectors in the region. Based on Statistics Indonesia (2024), the agriculture, forestry, and fishery sectors absorb approximately 33.54% of the total labor force in West Nusa Tenggara. Additionally, the agricultural sector in West Nusa Tenggara plays a crucial role in supporting the province's food security.

According to the Indonesian Meteorology, Climatology, and Geophysical Agency, agriculture is the sector most sensitive to climate change. Extreme climate events, such as floods and droughts, lead to increased crop failures. According to the National Research and Innovation Agency (2024), climate change has a substantial impact on agriculture, jeopardizing food security, livelihoods, and ecosystems. The World Meteorological Organization (2024) also found that agriculture is the most sensitive sector to climate change. Evidence shows that climate change is increasing the frequency of extreme weather events such as droughts and dry spells.

The preceding discussion highlights the critical need to address the impacts of climate change on the agricultural sector. Based on budget data from the West Nusa Tenggara Provincial Government (2024), the local government does little to address how climate change is affecting agriculture in West Nusa Tenggara.

The legal basis for the division of roles and responsibilities related to climate change adaptation and mitigation is Law No. 32 of 2009 on Environmental Protection and Management and Minister of Environment and Forestry Regulation No. 12 of 2024 on the Implementation of Nationally Determined Contributions in Climate Change Management.

Article 45 of Law No. 32 of 2009 stipulates that the government, the House of Representatives of the Republic of Indonesia, regional governments,

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APPLICATIONS FOR PRACTICE

- Local governments, especially in areas most affected by climate change such as West Nusa Tenggara, need to allocate sufficient budgets for climate change adaptation.
- A comprehensive integration of innovation and adaptive technologies in crop management, farming systems, water management, soil management, and integrated pest management offers the most effective response to climate change impacts on the agricultural sector.
- Local governments must allocate funds to encourage innovation and adaptation technologies in the agricultural sector, while also promoting their adoption among farmers.

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and regional legislative councils shall allocate an adequate budget to finance environmental protection and management activities. Minister of Environment and Forestry Regulation No. 12 of 2024 regulates the implementation of climate change mitigation and adaptation, which includes planning, implementation, monitoring, and evaluation of mitigation and adaptation activities.

The Minister of Environment and Forestry Regulation Number 12 of 2024 further stipulates that the implementation of climate change mitigation shall be carried out by ministries or agencies, regional governments, enterprises, and the public. The regulation emphasizes that climate change adaptation efforts will be carried out at different levels of government: ministries at the national level, governors at the provincial level, and mayors at the city level. It also states that adaptation efforts should be prioritized in key sectors such as food security, water resources, energy, and health.

Based on these regulations, both the central and regional governments have different roles and responsibilities in mitigating and adapting to climate change within their respective jurisdictions. Therefore, they need to allocate an adequate budget to support both climate change adaptation and mitigation. Based on the analysis of the 2024 local government budget, as shown in Table 1, the only available funds related to climate change initiatives are those allocated for mitigation, notably funds for rehabilitation of forest areas.

Table 1 Local Government Budget Related to Mitigation of Climate Change

Program	3.28.03 Forest Management Programs	
Output Indicator	Land Area Reforested Outside State Forest Areas	
ACCOUNT CODE	DESCRIPTION	AMOUNT (Rp)
5.1.02.01.01.0008	Expenditure for Plant Seeds	24,990,000

Source: West Nusa Tenggara Provincial Government (2024)

Table 2 Local Government Budgets Related to Adaptation of Climate Change

Program	3.27.05 Program for Control and Management of Agricultural Disasters	
Activity	3.27.05.1.01 Control and Management of Provincial Agricultural Disasters	
Sub-Activity	3.27.05.1.01.0001 Control of Plant Pest Organisms (PPO) in Food Crops, Horticulture, and Plantations	
Output Indicator	Total Area Affected by Plant Pest Organisms (PPO) in Food Crops, Horticulture, and Plantations Controlled	
ACCOUNT CODE	DESCRIPTION	AMOUNT (Rp)
[object Object]	null	0.00
Sub-Activity	3.27.05.1.01.0002 Management of Climate Change Impacts on Food Crops, Horticulture, and Plantations	
Output Indicator	Total Area Affected by Climate Change in Food Crops, Horticulture, and Plantations Handled	
ACCOUNT CODE	DESCRIPTION	AMOUNT (Rp)
[object Object]	null	0.00

Source: West Nusa Tenggara Provincial Government (2024)

Meanwhile, as shown in Table 2, there are no funds available in the local government budget for climate change adaptation. Based on the analysis of the 2024 budget of the central government units in West Nusa Tenggara, namely Tambora National Park Office, West Nusa Tenggara Natural Resources

Conservation Office, Dodokan Moyosari Watershed Management Office, and Mount Rinjani National Park Office, most of the funds for climate change are allocated for climate change mitigation such as rehabilitation of forest areas (Table 3). There are no funds in the central government budget for climate change adaptation, especially in the agricultural sector, which is the most vulnerable sector to climate change.

Table 3 Central Government Budgets Related to Climate Change

No.	Unit	Activity	Budget (Rp)
1	Tambora National Park Authority	Ecosystem Restoration	272,500,000
2	West Nusa Tenggara Natural Resources Conservation Agency	Ecosystem Restoration	80,000,000
3	Dodokan Moyosari Watershed Management Agency	Inland Water Rehabilitation	180,527,000
4	Dodokan Moyosari Watershed Management Agency	Forest Tree Breeding	300,000,000
5	Dodokan Moyosari Watershed Management Agency	Soil and Water Conservation	50,000,000
6	Mount Rinjani National Park Authority	Ecosystem Restoration	115,500,000

Source: Ministry of Finance of the Republic of Indonesia

Table 1 and Table 2 demonstrate the need to evaluate the government's budget policy which allocate climate-related funds exclusively to mitigation and provides no budget for adaptation. Furthermore, based on the evaluation results, policy recommendations are formulated using an evidence-based approach. This research is of critical importance for two key reasons. First, analyzing budget allocation strategies of local governments is crucial to addressing climate change in the region. These analyses can provide valuable insights to other local governments, particularly those in areas affected by climate change. Second, few studies have examined how local budgets in Indonesia are allocated between climate change mitigation and adaptation, particularly within the agricultural sector.

Numerous studies on climate change and agriculture have predominantly focused on the physical impacts of climate change, such as changes in rainfall patterns, increased frequency of droughts, and declining agricultural productivity (e.g., Ansari et al., 2021; Vaghefi et al., 2016; Xie et al., 2023). Additionally, a substantial body of literature has examined the implications of climate change for food security through its effects on agricultural production, food availability, access, and stability (e.g., Campbell et al., 2016; Hasegawa et al., 2018; Ray et al., 2019). However, limited attention has been given to how local governments prioritize budget allocation between climate change mitigation and adaptation strategies, particularly in the agricultural sector. Existing studies on climate-related fiscal policies in agriculture tend to assess the overall impact of agricultural public expenditures on addressing climate change impacts, without explicitly distinguishing between mitigation and adaptation (Hao et al., 2024; Zhang et al., 2023). This study aims to address this gap by integrating ARIMA-based forecasting of agricultural production with a policy evaluation framework to assess whether local government climate budgets that emphasize mitigation in the absence of sufficient adaptation measures are aligned with the actual climate risks faced by the agricultural sector.

LITERATURE REVIEW

Several studies have shown that climate change reduces agricultural production. These studies have found that climate change negatively impacts rice yield (Ansari et al., 2021; Tan et al., 2021; Vaghefi et al., 2016; Xie et al., 2023). Malhi et al. (2021) found that the consequences of climate change include increased rates of crop respiration and evapotranspiration, increased pest infestation, changes in weed flora, and reduced harvest duration. Climate change also affects soil microbial populations and their enzyme activities, which will ultimately affect global food security.

Habib-ur-Rahman et al. (2022) found that climate change has had a significant impact on agricultural productivity in Asia, particularly on rice and wheat yields. According to model simulations, rice yields are expected to decline by 15.2% based on the DSSAT model and by 17.2% based on the APSIM model under projected mid-century climate conditions. Similarly, wheat yield reductions are estimated at 14.1% and 12% for the two models, respectively. In addition, increased temperature and erratic precipitation patterns have been identified as major contributors to yield reductions. The study found that under the RCP 8.5 scenario, maximum temperatures in Pakistan are projected to increase by 2.8°C, while minimum temperatures are projected to increase by 2.2°C. This temperature increase will adversely affect crop growth stages, resulting in lower grain weight and reducing overall productivity.

Skendžić et al. (2021) argue that temperature increases can accelerate insect development, leading to higher pest populations and a greater risk of crop damage. The study also points out that changes in precipitation patterns, such as increased summer rainfall, can create favorable conditions for the growth of certain pest populations, such as wireworms, which may exacerbate pest problems in the future. In

addition, numerous studies have consistently demonstrated that climate change poses significant risks to food security by impacting agricultural production, food availability, access, and stability. Changes in temperature and precipitation patterns, as well as an increased frequency of extreme climate events, have been shown to negatively impact crop yields and global food production systems (Campbell et al., 2016; Ray et al., 2019). Furthermore, empirical and multi-model assessments indicate that climate change exacerbates food insecurity by increasing yield variability, disrupting food supply chains, and raising food prices, particularly in vulnerable regions (Hasegawa et al., 2018).

The National Research and Innovation Agency (2024) explain that climate variables such as temperature and rainfall cause changes in crop yields such as paddy and soybeans. If the temperature increases by 1°C to 2.5°C and rainfall decreases by 5% to 25%, paddy production decreases by 50%. Moreover, a 50 mm/month increase in rainfall raises soybean productivity by 27.31%. Based on climate change projection data for the periods 2020-2049 compared to the periods 1976-2005 from the Indonesian Meteorology, Climatology, and Geophysical Agency West Nusa Tenggara is among regions vulnerable to climate change. Most areas in West Nusa Tenggara are projected to experience a decrease in rainfall and an increase in temperature with significant changes.

Figure 1 portrays a projected seasonal precipitation change map for the September–October–November periods from 2020 to 2049, compared to the baseline periods of 1976–2005, based on the RCP4.5 scenario. The map shows that West Nusa Tenggara Province is predominantly shaded in red and orange, indicating a significant decline in precipitation and an increased risk of drought. Lombok Island is largely represented by red-orange shades, indicating a reduction in rainfall ranging from approximately 10% to more than 25%. Sumbawa Island exhibits a broader range of variability, with most regions experiencing a similar decline of 10% to over 25%, particularly in the southern and central areas.

Figure 1 Projected Seasonal Precipitation
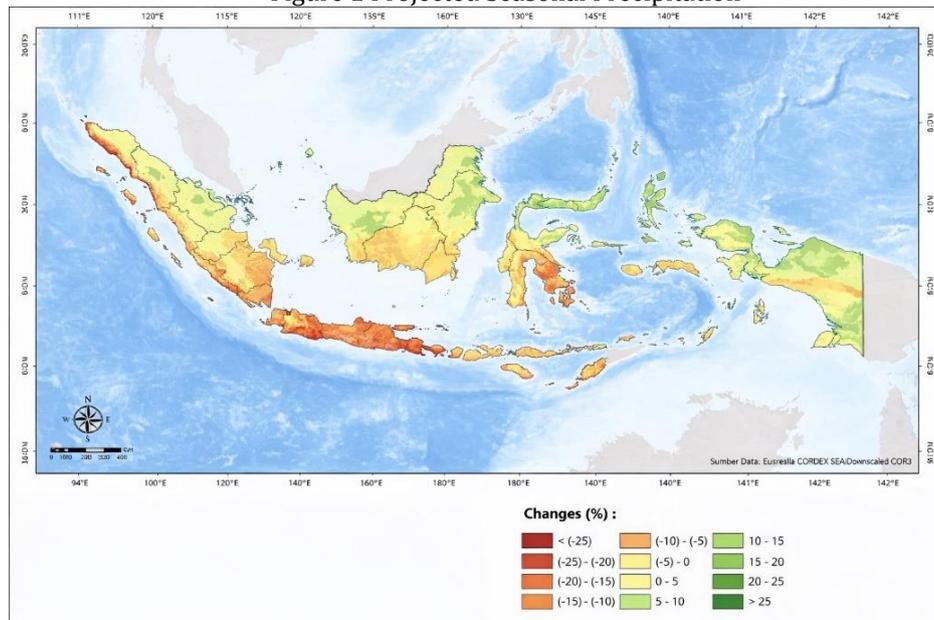
Source: Indonesian Meteorology, Climatology, and Geophysical Agency (2024)

The projected precipitation data for 2020–2049 closely align with actual rainfall recorded in December 2023, as shown in Figure 2. These observations confirm that most regions in West Nusa Tenggara experience low precipitation levels. Notably, North Lombok, West Lombok, and Bima City recorded extremely low rainfall, while precipitation levels in West Sumbawa and Sumbawa exhibited greater variability.

Figure 3 illustrates projected changes in diurnal temperature variation for the 2020-2049 periods relative to 1976-2005 under the RCP8.5 scenario. The map indicates that West Nusa Tenggara is expected to experience an increase in diurnal temperature variation, particularly in southern Sumbawa and parts of Lombok. Greater changes in diurnal temperature (red and orange shades) indicate an increased temperature difference between daytime and nighttime. An increase in diurnal temperature suggests that daytime temperatures are expected to rise, while nighttime temperatures remain stable or decrease further. Conversely, a decrease in diurnal temperature variation (blue and green shades) indicates a smaller temperature gap between day and night, possibly due to the greenhouse effect of trapping heat during nighttime hours.

Figure 2 Actual Seasonal Precipitation
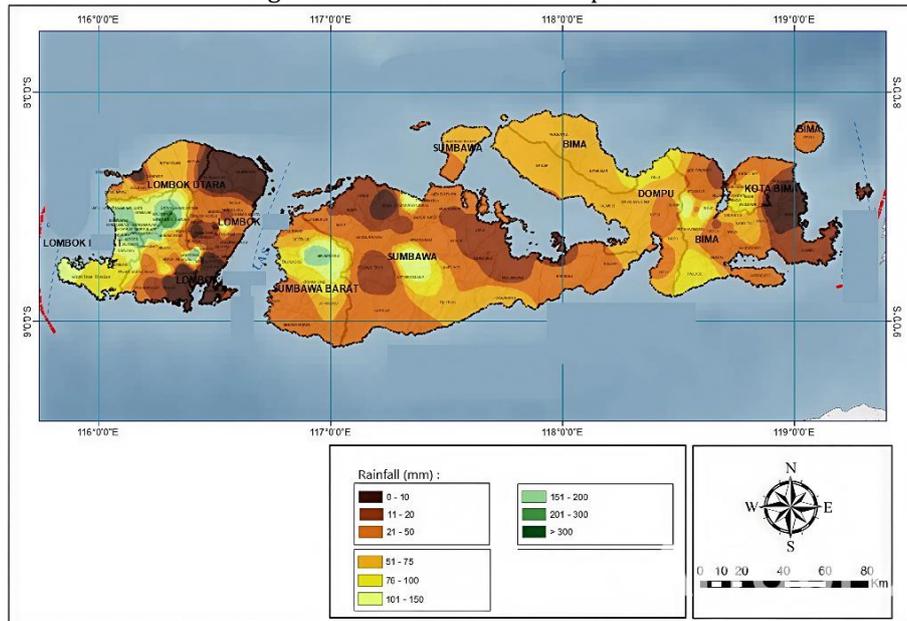
Source: Indonesian Meteorology, Climatology, and Geophysical Agency (2024)

Figure 3 Projected Diurnal Temperature
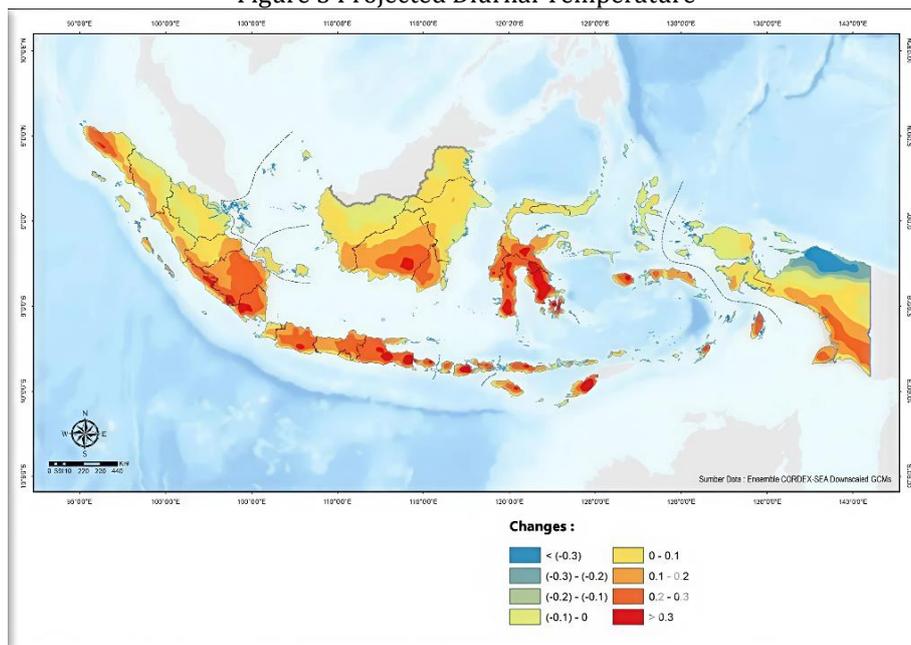
Source: Indonesian Meteorology, Climatology, and Geophysical Agency (2024)

Projected changes in diurnal temperature for West Nusa Tenggara range from 0.1°C to over 0.3°C, as represented by shading in yellow, orange, and red on the map. Coastal and lowland areas tend to experience more pronounced increases (>0.3°C, orange red) compared to mountainous regions. These variations in temperature may have significant implications for agricultural productivity, as extreme temperature fluctuations can induce thermal stress in plants. Certain crops are particularly sensitive to nighttime temperature changes, which may affect their growth and yield potential.

This study uses ARIMA to predict impacts of climate change on the agricultural sector combined with policy evaluation. Predicting future numbers allows the identification of trends and patterns that show past and ongoing performance in handling climate change impacts. Using historical data patterns, ARIMA, which is a statistical model, can forecast future values. Based on the ARIMA model projections, this study hypothesizes that climate change budget allocations focusing solely on mitigation, without complementary adaptation measures, contribute to declining agricultural productivity in climate-sensitive regions such as

rice-producing areas. This is grounded in the climate-resilient development framework (CRDF) articulated by the IPCC (2022), which emphasizes the necessity of integrating mitigation, adaptation, and sustainable development to avoid maladaptation and ensure long-term resilience. The framework suggests that prioritizing only mitigation without adequate adaptation can lead to maladaptation, especially in climate-sensitive sectors such as agriculture. This study is structured around two hypotheses.

H_1: Government climate change budget policies that allocate funds exclusively to mitigation, without parallel investment in adaptation, are associated with a decline in agricultural production in climate-sensitive regions.

This study examines policy opportunities that could be implemented using an organized methodology based on the evidence-based policy approach, in addition to the assessment mechanism. The lexicographic ordering method and the systematic literature review method are combined to create evidence-based policy approach used in this study.

METHODS

This study adopts a mixed methods approach that integrates both quantitative and qualitative techniques (Johnson et al., 2019; Mertens et al., 2016; Molina-Azorin, 2016). As shown in Figure 4, a quantitative method was conducted at the evaluation stage to analyze the impact of climate change on the agricultural sector and to forecast future food crop production in West Nusa Tenggara. Simultaneously, a qualitative method was used to develop policy alternatives and to select policy priorities.

This research was conducted in two stages. The first stage involved an evaluation by predicting rice production for the coming years based on past trends using the ARIMA model. Based on the results of this evaluation, specific policies were formulated for West Nusa Tenggara. Policy formulation began with the development of policy alternatives using the systematic literature review method. The second stage involved selecting the results of the systematic literature review using several criteria with the lexicographic ordering method.

In the first stage, an evaluation was conducted to assess whether the budget for climate change adaptation, especially in the agricultural sector, was unnecessary. The evaluation was conducted by analyzing how climate change affects the agricultural sector in West Nusa Tenggara. Furthermore, we explored the paddy production outlook over the next few years, which showed the performance of paddy production over the last few years.

Forecasting is important in public policy because it determines the social and economic conditions in the future (Subarsono, 2022). Based on the forecasting results, interventions can be made through government policies. The autoregressive integrated moving average (ARIMA) model is a statistical model used to analyze and forecast time series data. This model uses past patterns of the same data to predict the future. By predicting future numbers, it is possible to identify trends and patterns that indicate good or bad performance. In other words, this model can show the quality of performance produced in the past. Compared to other statistical models' data, ARIMA can yield lower forecast errors for certain time series datasets, suggesting higher predictive accuracy (Misiurek et al., 2025; Rubio et al., 2021).

Despite the advent of increasingly sophisticated forecasting techniques, the ARIMA model continues to be a pervasive choice due to its robust theoretical underpinnings and tangible benefits. Empirical evidence indicates that ARIMA demonstrates superior forecasting accuracy, particularly for short-term horizons and relatively stable in univariate time series, while preserving model parsimony and interpretability. Furthermore, ARIMA-based models have been demonstrated to be effective in capturing temporal dependence and lag structures, providing a transparent statistical framework that supports inference and explanation. In the context of hybrid modeling approaches, ARIMA is frequently employed as the primary linear component. This is due to its ability to effectively model linear dynamics prior to the application of machine learning techniques, which address nonlinear patterns. This underscores the persistent relevance of ARIMA as a resilient baseline model in the field of time series forecasting (Ilyés-Vincze et al., 2025; Perone, 2022; Smyl, 2020). The second stage of this research is policy analysis. Based on the results of the policy evaluation, alternative policies are generated using a systematic literature review. After policy alternatives are determined, the final process in the second stage is to select policies that need to be prioritized for implementation. The selection of policy alternatives is carried out using the lexicographic ordering method.

In policy formulation, the generation of policy alternatives is recognized as a fundamental step that shapes the quality of subsequent policy choices. Ferretti et al. (2019) argue that alternative generation should be treated as a deliberate and structured process in public policy making, emphasizing the importance of producing a sufficiently broad set of feasible alternatives rather than prematurely converging on a single solution. Pluchinotta et al. (2019) further explain that design-oriented approaches can support the systematic generation of policy alternatives by integrating analytical reasoning with

creative and deliberative mechanisms, enabling policymakers to explore multiple options, including baseline or status quo scenarios.

Complementing this perspective, Hämäläinen et al. (2024) highlight that the inclusion of a "do-nothing" or no-action alternative is essential as a reference point for evaluating the added value and effectiveness of policy interventions. They also acknowledge the influence of behavioral and cognitive factors on the generation and evaluation of alternatives. Furthermore, El-Jardali et al. (2023) demonstrate that evidence synthesis methods, particularly literature reviews, play a crucial role in identifying policy options grounded in existing empirical knowledge, which can subsequently be refined through stakeholder engagement and contextual analysis to enhance their applicability in real-world policy settings.

The literature review involves searching for alternative problem-solving strategies in various literature, such as books and journals that publish specific research findings. A systematic literature review employs strict and predefined procedures for searching and selecting studies, enabling the synthesis of evidence from multiple studies to address a specific research question and support policy and practice decisions (Snyder, 2019).

The subsequent step in the policy formulation is the selection of various available alternatives. The selection of policy alternatives is based on clear criteria. The rationality and acceptability of an alternative are important considerations in their selection. Subarsono (2022) shows several methods that can be used to select several policy alternatives, including comparison method, satisfying method, lexicographic ordering method, non-dominated alternatives method, may method, pros-cons method, and cost-benefit analysis.

The lexicographic ordering method compares and ranks all policy alternatives based on several criteria, from the most important to the least important. The criteria are arranged based on certain assumptions. The results of the selection on the first criterion are compared again using the second criterion, which has a lower weight until the best alternative is obtained (Subarsono, 2022). This lexicographic logic, which prioritizes the most significant criterion first and utilizes the subsequent criterion to resolve ties, has been implemented in public-sector decisions, including the determination of public micro transit service zones and the allocation of public resources through lexicographic goal programming (Erdoğan et al., 2024; Lozano & Contreras, 2022). This method also has been widely applied in economic and multi-criteria policy analysis to support transparent and priority-driven government interventions (Mandler, 2021; Safarzadeh & Rasti-Barzoki, 2018).

Figure 4 Research Stages
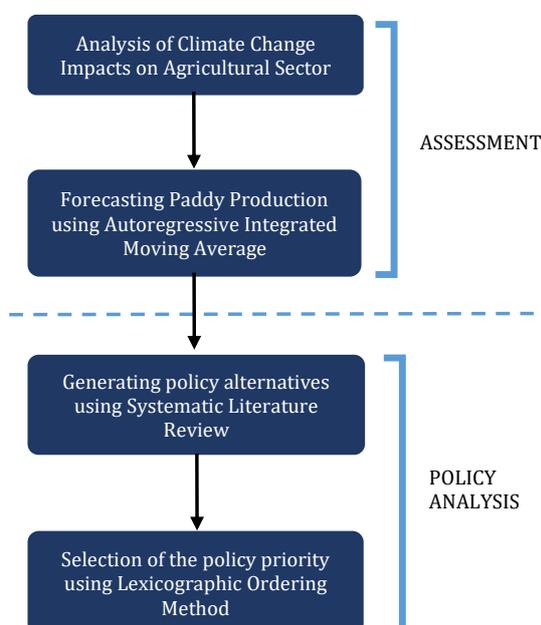
Source: Processed by the authors

The first analysis at the evaluation stage was conducted by identifying the impacts of climate change on the agricultural sector in West Nusa Tenggara. The effects of climate change on paddy production are floods, droughts, and pests (National Research and Innovation Agency, 2024). A representative of the Agriculture Department in West Nusa Tenggara stated that the biggest impact of climate change on the agriculture sector in West Nusa Tenggara was the increase in drought-affected land and the rise in the number of crop pests. Accordingly, the analysis used data on plant-disturbing organisms and droughts, sourced from the West Nusa Tenggara Agricultural Plant Protection Center.

The second analysis in the evaluation stage was conducted by forecasting paddy production in West Nusa Tenggara from 2025 to 2028, which also showed the performance of paddy production in recent years. The data for the forecast were sourced from the report on monthly paddy production from 2021 to 2024 published by the Statistics Indonesia. The data showed four seasonal cycles. As sufficient data were not available for corn and soybean production, only paddy production was forecasted. Petropoulos & Spiliotis (2021) emphasize that estimating seasonality reliably requires data spanning multiple seasonal repetitions. In the context of periodic series, analysts generally retain a minimum of two seasonal cycles to ensure the preservation of sufficient information for

the identification and forecasting of seasons. In some applications, more cycles may be needed for seasonal models to adequately learn seasonal patterns (Duangchaemkarn et al., 2022).

ARIMA models the relationship between a time series and its lagged values and lagged forecast errors, while also accounting for nonstationary through differencing. It is a generalization of the simpler autoregressive (AR) and moving average (MA) models. ARIMA is used when the data show evidence of nonstationary, meaning that the data have trends, seasonal effects, or varying variance over time (Box et al., 2015).

A key assumption of ARIMA modeling is the stationarity of the time series data. A stationary series exhibits constant statistical properties over time, such as consistent mean and variance. However, real-world time series data often exhibit non-stationarity due to trends, seasonality, or varying variance. Therefore, before applying ARIMA, it is necessary to transform the data to make it stationary. This transformation is typically accomplished by differencing, which takes the difference between successive observations (Box et al., 2015).

Box et al. (2015) state that an ARIMA model is expressed as ARIMA (p,d,q). The parameters p, d, and q are crucial components of the ARIMA model, which plays a central role in modeling and forecasting time series data. An important decision when using an ARIMA model is the choice for the value of d (Petropoulos et al., 2022). The autoregressive (AR) component of the ARIMA model is represented by the parameter p, which indicates the number of lagged observations in the model. Essentially, p specifies how many past values of the series are used to predict the current value. The autoregressive process assumes that the current value of the series is linearly dependent on its previous values. This means that the past observations influence the current value.

The AR(p) model is expressed as:

$$Yt = \phi 1 Yt - 1 + \phi 2 Yt - 2 + \cdots + \phi p Yt - p + \epsilon t \; Yt \ldots (1)$$

where: Yt is the observed value at time t; φ1, φ2, …, φp are the autoregressive parameters; and εt is the error term. The parameter d (degree of differencing) represents the number of times the time series needs to be different to make it stationary. A stationary time series has constant statistical properties over time, including constant mean and variance. However, many real-world time series datasets are nonstationary because they exhibit trends, seasonal effects, or other time-dependent behaviors. Differencing is a technique used to transform a nonstationary series into a stationary one.

The differenced series ∇Yt is computed as:

$$\nabla Yt = Yt - Yt - 1 \ldots (2)$$

The moving average (MA) is represented by the parameter q, which determines the number of lagged forecast errors to include in the model. The moving average process assumes that the current value of the time series is influenced by the errors (or residuals) from previous observations. The MA(q) model can be expressed as:

$$Yt = \mu + \epsilon t + \theta 1 \epsilon t - 1 + \theta 2 \epsilon t - 2 + \cdots + \theta q \epsilon t - q \ldots (3)$$

μ is the mean of the series; θ1, θ2, …, θq are the moving average parameters; and εt is the residual error term at time t. The first step for forecasting the time series data using the ARIMA method is determining the ARIMA model that best fits the existing data. The ARIMA (p,q,d) model is determined using simulations based on AIC (Akaike information criterion) and BIC (Bayesian information criterion), which are estimation tools for predicting error values. The lower the AIC and BIC values, the superior the model. AIC is an information criterion used to select the best model by considering the number of parameters in the model. The AIC formula is:

$$AIC = 2k - 2ln(L) \ldots (4)$$

Where k is the number of parameters in the model, and L is the likelihood value of the model. The BIC is an information criterion used to select the optimal model from a finite set of candidate models. It is based on the likelihood function and is used to compare models with different numbers of parameters. BIC helps choose the best model among several proposed models. The BIC formula is:

$$BIC = k \, ln(n) - 2 \, ln(L) \ldots (5)$$

Where k is the number of parameters in the model, n is the number of observations, and L is the likelihood value of the model. The simulation of the ARIMA model produced the AIC and BIC values presented in Table 4 and Table 5. Based on the simulation, ARIMA (12,1,1) has the lowest AIC and BIC values; therefore, this model is chosen as the best model for this study.

Table 4 Simulation Results of the ARIMA Model

Model	AIC	BIC
ARIMA (12,0,0)	523.95	551.17
ARIMA (12,1,0)	519.08	546.09
ARIMA (12,0,1)	519.08	546.09
ARIMA (12,1,1)	480.02	511.18
ARIMA (11,1,1)	528.53	557.86
ARIMA (13,1,1)	514.60	547.56

Source: Processed by the authors

Table 5 Simulation of the ARIMA Model using Real Statistics Software

p	12	12	12	12
q	1	1	0	1
d	1	0	1	2
res mean	42	-0.084	0.000	3.915
res s.d.	17.176	63.775	65.840	72.268
sqrt mse	45.321	63.241	73.931	71.750
data mean	-0.307	-1.124	-0.207	-0.585
data s.d.	127.937	129.054	127.937	178.727
size	59	60	59	58
LL	-308.730	-333.954	-330.260	-330.143
AIC	**480.025**	**527.634**	**519.085**	**525.689**
BIC	**511.188**	**559.050**	**546.093**	**556.596**
p	12	12	13	11
q	2	0	1	1
d	1	0	1	1
res mean	-0.768	0.000	-0.016	-0.163
res s.d.	65.426	63.945	64.654	65.338
sqrt mse	64.874	71.644	64.094	64.791
data mean	-0.355	-0.774	-0.697	-0.248
data s.d.	127.937	129.054	129.036	126.849
size	59	60	58	60
LL	-329.892	-334.113	-323.599	-335.406
AIC	**524.348**	**523.953**	**514.601**	**528.540**
BIC	**557.589**	**551.180**	**547.568**	**557.861**

Source: Processed by the authors

In time series forecasting, using ARIMA models, statistical significance can be evaluated through external comparisons between forecasted outcomes and historical benchmarks. The confidence interval (CI) of a forecast is central to this inference.

The following step in this research is the policy analysis, formulated based on the results of the assessment. The policy analysis in this study is intended to provide inputs on budget allocation and policies to deal with the impacts of climate change on the agricultural sector. The initial analysis in the policy analysis phase was conducted by generating policy alternatives using the systematic literature review. Several studies, including Connor et al. (2021) conducted in Yogyakarta, indicate that farmers who employ technological and innovative adaptation strategies towards climate change achieve better harvests and consequently higher incomes than those who do not. Thus, the development of alternative policies in this study focuses on the use of innovation and technology to adapt to the impacts of climate change on the agricultural sector.

The systematic literature review analysis of this study used PRISMA (preferred reporting items for systematic reviews and meta-analyses). Figure 5 shows a PRISMA flowchart generated at this stage. The journal databases used in this systematic literature review research are Scopus and IEEE. We applied asterisk connectors (*), "OR" and "AND" to develop search strings in the database. The search string used in this study is ("Innovation" OR "technology") AND ("overcome" OR "adaptation") AND ("impact*" OR "effect*") AND ("climate change") AND ("agriculture*" OR "farm*").

The inclusion criteria used in this research were articles published from 2019 to 2024, in English, journal or conference papers, and relevant to the discussion. The exclusion criteria were books, theses or dissertations, working papers, predatory journals, and articles not relevant to the discussion. The lexicographic ordering method was used to select among alternatives that can be prioritized for implementation in West Nusa Tenggara. The data for the selection of policy alternatives was from

interviews with the West Nusa Tenggara Agriculture Office and relevant secondary documents. The criteria used to select policy alternatives include, first, the impact of the adaptation mechanism on addressing drought and plant disruptive organisms, which are the main impacts of climate change on the agricultural sector in West Nusa Tenggara; second, the cost of implementation; and third, whether the adaptation mechanism has not yet been widely implemented in West Nusa Tenggara.

Figure 5 PRISMA Flowchart
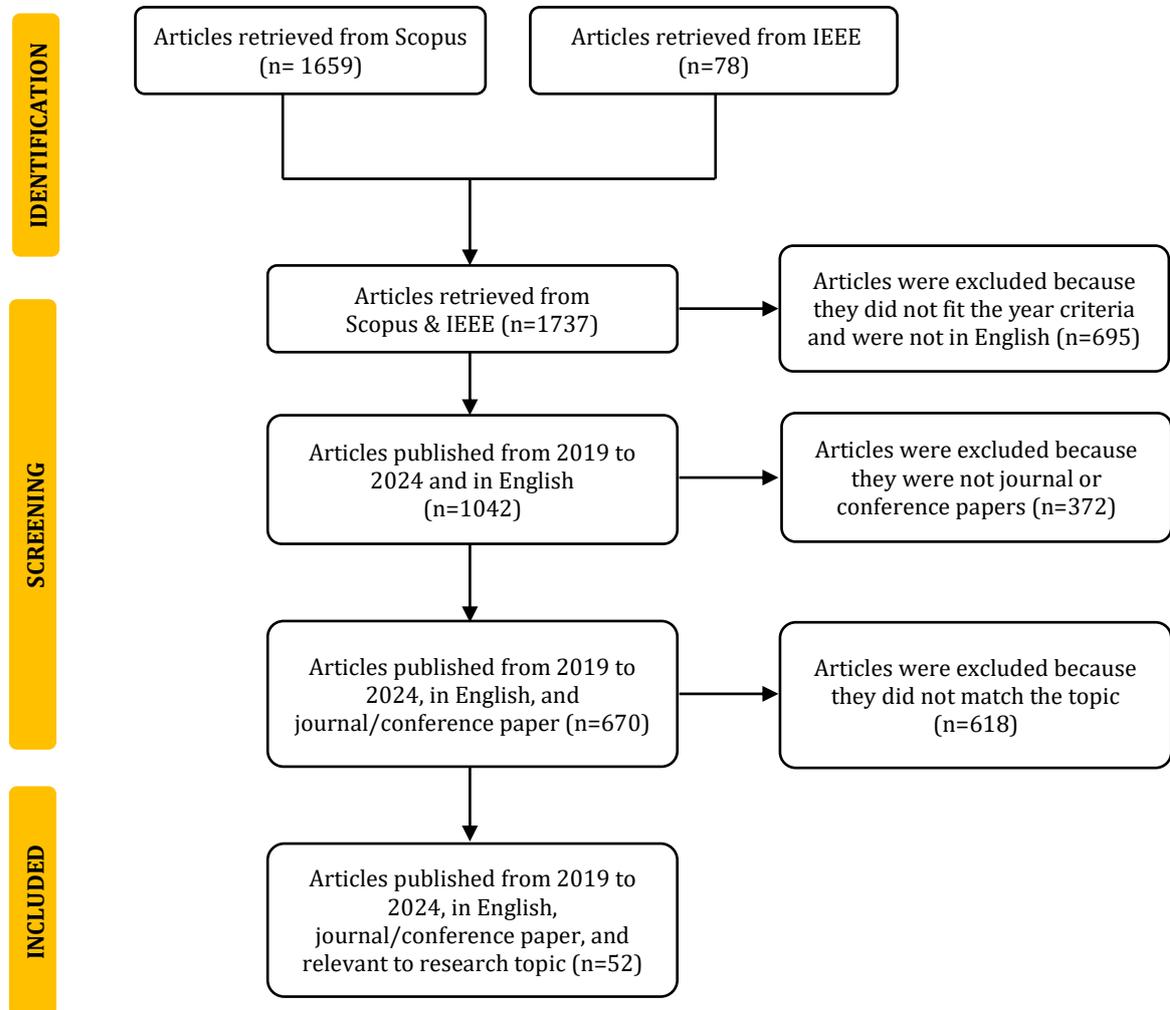
Source: Processed by the authors

RESULTS AND DISCUSSION

The first result of the analysis is related to the impact of climate change on the agricultural sector in West Nusa Tenggara. Table 6 present data on agricultural land affected by plant-disturbing organisms in West Nusa Tenggara, based on records from the Agricultural Plant Protection Center for 2018–2024.

Table 6 Land Affected by Plant-Disturbing Organisms from 2018 to 2024

Food Crops	Area of Land Affected (Hectares)						
	2018	2019	2020	2021	2022	2023	2024
Paddy	4,208	3,293	7,104	9,376	7,347	5,757	4,030
Corn	499	1,359	12,893	4,981	2,515	1,588	1,438
Soybeans	158	172	137	195	106	130	119

Source: Agricultural Plant Protection Center (2024b)

Based on the data, we can see that the area of land affected by plant-disturbing organisms is substantial. The area of land affected by plant-disturbing organisms from year to year tends not to experience a significant decrease Table 7 is the data related to the area affected by drought from the West Nusa Tenggara Agricultural Plant Protection Center in the year 2024 up to the June period. In addition,

based on the data on drought-affected agricultural land, we can also see that the area of agricultural land affected by drought in 2024 until June is still substantial. Both of these indicate that the government needs to pay more attention to the impacts of climate change in the agricultural sector, primarily related to drought and plant-disturbing organisms.

Table 7 Land Affected by Drought

District/City	Area of Land Affected (Hectares)
Bima	10
Dompu	165
West Lombok	1,418
Central Lombok	2,972
North Lombok	12
Sumbawa	467
West Sumbawa	132
TOTAL	**5.175**

Source: Agricultural Plant Protection Center (2024a)

The second result of the analysis is related to the forecast of rice production in West Nusa Tenggara from 2025 to 2028 using the ARIMA (12,1,1) model. To forecast paddy production, we used Orange, a data mining software. The results for ARIMA (12,1,1) show that paddy production in West Nusa Tenggara from 2025 to 2028 is expected to decline. Figure 6 shows the forecasting results using the ARIMA (12,1,1) model.

Figure 6 Forecast Results of Paddy Production from 2025 to 2028
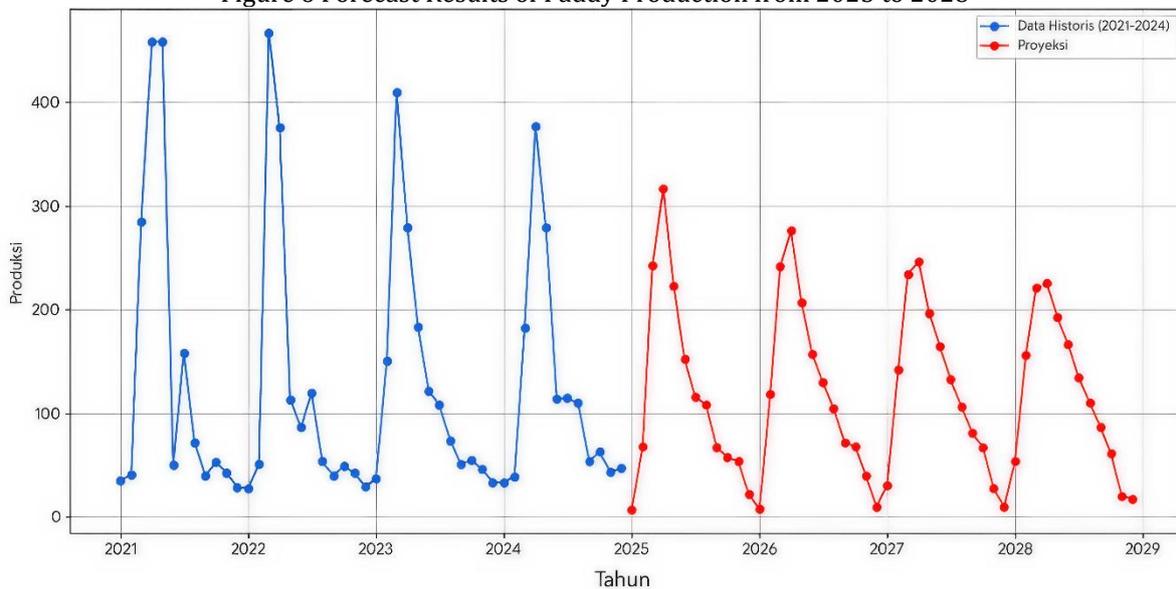
Source: Processed by the authors

The forecasted mean production for 2025–2028 is 1434.26, with a 95% confidence interval of [1424.15, 1444.37]. Since this interval does not contain the historical mean of 1543.12 (2021–2024), the difference between past and projected production is statistically significant. By contrast, a wider historical interval [1343.28, 1742.96] encompasses the forecasted mean, which reflects greater variability in past data but does not negate the significance of future decline.

From the standpoint of hypothesis testing, these results provide sufficient evidence to reject the null hypothesis (H0), which posits no significant association between climate budget policy and agricultural production. Instead, the findings lend support to the research hypothesis (H1), confirming that budget policies allocating funds exclusively to mitigation, without corresponding adaptation measures, are associated with a measurable decline in agricultural production in climate-sensitive regions. The evaluation results for the ARIMA model, as well as the large number of reported cases of drought and pests, indicate that the regional government must pay close attention to the impacts of climate change on the agricultural sector. Therefore, the local government must allocate adequate funds to both mitigation and adaptation of investments to minimize the impacts of climate change in the coming years.

Based on the evaluation results, recommendations were made on budget allocations and other policies needed to address the impacts of climate change on the agricultural sector. The first stage of the policy formulation mechanism generates policy alternatives related to innovations and technologies for climate

change adaptation. Based on the inclusion of results using the PRISMA, 52 articles relevant to the topic of this study were identified from Scopus and IEEE. Table 8 shows the results of the generation of policy alternatives related to climate change adaptation innovations through a systematic literature review. Innovations that can be developed to address the impacts of climate change on the agricultural sector fall into five categories: crop management innovations, cropping system innovations, water management innovations, soil management innovations, and integrated pest management.

Table 8 Innovations Related to Climate Change Adaptation

Adaptation Category	Innovation
Crop Management	Development and utilization of climate-resilient superior varieties with the following characteristics: • resistant to drought • resistant to flooding • resistant to temperature changes • resistant to pests and diseases • high yielding • fast harvest
Farming System	• adjustment of planting time to climatic conditions • mixed farming • crop rotation • optimization of fertilizer application intensity • biotic environmental strategies • agroforestry • greenhouse
Water Management	• smart irrigation • rainwater harvesting technologies • water-saving technologies • micro-irrigation • managed aquifer recharge
Land Management	• appropriate application of organic fertilizer • precision farming
Integrated Pest Management	• utilization of natural predators and parasitoids • implementation of crop rotation and pest-repellent crops varieties • utilization of plant-based pesticides (biopesticides) • use of pheromone-based pest control

Source: Processed by the authors

The most important innovation in crop management is the development and use of high-yielding and climate-resilient varieties. Climate-resilient varieties are those that can withstand drought, flooding, high temperatures, and pests. High-yielding varieties are those that have high yields and can be harvested quickly. Innovations or adaptation methods that can be developed related to agricultural systems include adjusting planting time with climatic conditions, mixed farming, crop rotation, adjusting the intensity of fertilizer use, biotic environmental strategies, agroforestry, and greenhouses. Biotic environmental strategies refer to the biologically driven mechanisms that crops use to adapt and survive under environmental pressures. These strategies manifest as physiological and molecular responses to biotic stresses, such as pests and pathogens, and abiotic factors, including drought, temperature, and soil conditions (Dresselhaus & Hückelhoven, 2018). These strategies may also include processes that biologically enhance stress tolerance and resilience. These processes can activate internal defense pathways and utilize beneficial biological interactions within agroecosystems (González Guzmán et al., 2022; Xie et al., 2023). Agroforestry is a system that combines the cultivation of food crops with other crops or livestock (Guodaar et al., 2021). Greenhouses allow farmers to control temperature, humidity, light, and ventilation, resulting in an optimal environment for the growth of growing plants (Usta & Gök, 2024).

Viable innovations for water management include smart irrigation, rainwater harvesting technologies, water-saving technologies, micro-irrigation, and managed aquifer recharge. Managed aquifer recharge is a process used to augment groundwater resources by intentionally infiltrating water into aquifers through various methods (Zhao & Boll, 2022). Innovations in soil management include proper use of organic fertilizers and precision farming. Precision farming is related to more accurate analysis of soil conditions using technology such as internet of things (IoT).

Innovations in integrated pest control that can be implemented include the use of natural predators and parasitoids, crop rotation, pest-repellent plants, biopesticides, and pest control with pheromone

technology. Pheromones are chemical compounds released by one individual and received by another individual of the same species, which then affects the behavior or physiology of the recipient. Pheromones serve as an important chemical communication tool in many animal species (Fleischer & Krieger, 2018; Gryboś et al., 2025).

The systematic literature review has also identified alternatives in the latest technologies for dealing with the impacts of climate change on the agricultural sector. Table 9 shows the results of the alternatives in climate change adaptation technologies that were not included in the discussion of innovations above. Technologies that can be used to address the impacts of climate change in the agricultural sector include IoT, artificial intelligence (AI), and communication and information technology. The use of information and communication technology can take the form of developing applications that provide farmers with weather and climate forecasting information, such as rainfall, wind direction and speed, air temperature, and humidity, with an accuracy of up to 1 kilometer. This allows farmers to reduce crop failures and subsequent losses due to climate variability and increase farmers' resilience to the impacts of climate change. In addition to irrigation, the IoT can be used to monitor soil conditions and accurately detect pests. AI can be used for various things in climate change adaptation, such as predicting weather more accurately and developing new crop varieties.

Table 9 Technologies for Adaptation to Climate Change

Technology	Innovation
Information and Communication Technology	The use of application-based technology that provides farmers with information about weather and climate predictions such as rainfall, wind direction and speed, air temperature, and air humidity with an accuracy of up to 1 kilometer, allowing farmers to reduce crop failures and subsequent losses due to climate variability and increase farmers' resilience to the impacts of climate change.
Internet of Things	• IoT sensors can be installed in fields to monitor soil conditions. • IoT sensors can detect the presence of pests and symptoms of plant diseases early on
Artificial intelligence	• Use of AI to predict weather more accurately • Use of AI-equipped sensors, drones, and satellites to monitor crop health and soil conditions in real time • Use of AI to help manage irrigation more efficiently • Use of AI to develop new varieties of crops that are more resistant to extreme climate conditions

Source: Processed by the authors

Based on the results of the systematic literature review, interviews with informants from the West Nusa Tenggara Agriculture Agency, and other relevant secondary data, an analysis was conducted using the lexicographic ordering method to obtain recommended policy priorities. Key innovations and technologies recommended for prioritization in climate change adaptation include several key areas. First, the use of application-based technology can support farmers by providing timely and localized information about weather and climate forecasts, including rainfall, wind direction and speed, air temperature, and humidity, with an accuracy of up to 1 kilometer. Second, the development and facilitation of high-yielding and climate-resilient crop varieties is essential. These varieties should possess specific characteristics such as resistance to drought and flooding, adaptability to temperature fluctuations, tolerance to pests and diseases, as well as attributes like high productivity, short growing periods, and strong market value. Third, the large-scale adoption of smart irrigation systems is crucial. This includes sensor-based irrigation and the integration of IoT devices for efficient water management, as well as the use of automated irrigation systems driven by real-time weather data. Finally, the implementation of integrated pest management strategies remains a vital component to sustainably address pest challenges while minimizing environmental impacts.

CONCLUSION

The results highlight effective climate change management in West Nusa Tenggara necessitates budgetary allocations by both the central and local governments for not only mitigation but also adaptation measures. Based on ARIMA (12,1,1) forecasts using trends from previous harvest period, rice production in West Nusa Tenggara is expected to decline from 2025 to 2028. It also indicates that monthly paddy production from 2021 to 2024 shows a negative performance trend. The results provide sufficient evidence to the research hypothesis (H1), confirming that budget policies allocating funds exclusively to mitigation, without corresponding adaptation measures, are associated with a measurable decline in agricultural production in climate-sensitive regions.

Field data on the impact of climate change from the West Nusa Tenggara Agricultural Plant Protection Center support the test results using the ARIMA model. Data from the Agricultural Plant Protection Center shows that a significant amount of agricultural land in West Nusa Tenggara is affected by drought and plant pests.

The results of the evaluation using the ARIMA model, together with numerous cases of drought and reported plant pests, indicate that the government must address the impact of climate change on the agricultural sector by allocating an adequate budget for both innovation and climate change adaptation technologies. Moreover, the government should proactively facilitate the adoption of these innovations and technologies among farmers.

The results of the systematic literature review indicate that the most effective response to climate change impacts on the agricultural sector is to combine innovation and adaptive technologies in crop management, farming systems, water management, soil management, and integrated pest management. Based on the results of the lexicographic ordering method, to address the impacts of climate change in West Nusa Tenggara, the government should prioritize budget allocation for the development of application-based technology that provides farmers with information related to weather and climate forecasts with accuracy of up to 1 kilometer, the development of superior varieties of crops and resilience to climate change, the development of smart irrigation, and integrated pest management. This study introduces the integration of ARIMA forecasting with policy evaluation, offering a novel methodology for assessing regional climate change policies. The findings are expected to inform and strengthen the government's efforts to mitigate the impacts of climate change on the agricultural sector, enabling more effective and targeted budget allocation.

The limitation of this study is that it only forecasts rice production, while other food crops such as corn and soybeans are not included due to data limitations. Forecasting relevant food crops may provide a more comprehensive understanding of the impacts of climate change on agriculture. Provided sufficient data are available; future studies should incorporate projections for relevant food crops and explore alternative forecasting models, including deep learning methods.

ACKNOWLEDGEMENT

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