# Optimizing rice production through climate mitigation: a systematic literature review

*Bayu* Pamungkas[1], *Bayu Dwi Apri* Nugroho[1*], ‘*Atiyah Rauzanah* Malik[2], and *Refita* Mayasari[3]

[1]Faculty of Agricultural Technology, Gadjah Mada University, DI Yogyakarta 55281, Indonesia
[2] Faculty of Social and Political Science, Gadjah Mada University, DI Yogyakarta 55281, Indonesia
[3]Karabük University Baliklarkayasi Mevkii Rektorlük Binası C Blok 78050, Karabük, Turkiye

**Abstract.** This research is based on the research gaps in the climate sector and their impacts on rice productivity. From this question, this research aims to identify the main topics and best scenarios to achieve climate mitigation and optimal productivity. The method used is Systematic Literature Review (SLR), searching and reviewing Scopus journals with the keywords: climate, agriculture, and sumatra. Filtering journals using this method has resulted in 52 indexed journals. The result of this study is the discovery of gaps in climate research, especially the correlation of climate phenomena such as El Nino to rice productivity in several regions such as West Sumatra. This region, classified as the west coast of Sumatra Island, contains a minimum of related research topics. Therefore, researching this topic is highly recommended for climate mitigation and maximum productivity achievement.

## 1 Introduction

Indonesia is a state that relies on the agriculture sector, which plays an important position in the nation's economy. The archipelago is blessed with plentiful resources and a favorable geographic location. Located in the equatorial region, Indonesia has a high level of rainfall, a condition that allows various species of plants to thrive and grow rapidly. As an agricultural country, Indonesians livelihoods depend on farming or the agricultural sector. The country produces a variety of commodities for export, such as cassava, chilies, corn, rice, soybeans, sweet potatoes, and vegetables. In the plantations sector, Indonesia produces cotton, palm oil, sugar, tobacco, and coffee. In other words, agriculture is the backbone of Indonesia's economy and contributes superior products to the export market [1].

The agricultural sector has a crucial dual role, as an economic contributor and a cornerstone of food safety and national resiliency. Climate change has a multidimensional impact on the sector, especially on agricultural production systems such as water availability, ideal cultivation timing, land production and degradation, water, and supporting infrastructural resources. These effects are exacerbated by declining land quality, fertility, and capacity, leading to a decline in food production. This situation is further compounded

* Corresponding author: bayu.tep@ugm.ac.id

by the restricted supply and deteriorating water quality, contributing to a significant decrease in agricultural production. These challenges call for comprehensive mitigation and adaptation strategies to ensure the sustainability of the farming sector in the face of climate change [2].

Complex climatic conditions with various causes including rainfall, moisture, average temperature, wind speed, and climatic phenomena such as El Nino, significantly influence crop yields in Indonesia, especially in the Sumatra region [3]. Sumatra Island, the largest island in Indonesia, is crucial role in the national agricultural sector and contributes considerably to the country's rice production. Rainfall patterns are an important variable in determining rice productivity, and any variation in these variables can substantially impact on crop production. Equally, temperature and moisture levels influence the development and productivity of rice plants. In addition, wind velocity and periodic El Nino conditions add to the complexity of predicting rice yields. These challenges demand efforts to understand and anticipate the impact of climatic variables on agricultural productivity in the Sumatra region [4].

According to research assesing the risk assessment of climate variability and climate change for Indonesian rice farming, timing the beginning of planting is an important strategy in agricultural activities in Indonesia, especially for food crops that are highly sensitive to climate anomalies [5]. The emergence of the Indian Ocean Dipole Mode (IOD) and El Niño-Southern Oscillation (ENSO) phenomena have far-reaching impacts, with the most serious impacts occurring in rice crops. Therefore, it is important to recognize the climatic characterization of a region well. One of the efforts that can be made is to study the effect of these two phenomena on planting time in rice production centers throughout Indonesia, both in areas with monsoon and equatorial rainfall patterns [6].

Facts show that the effects of climate change are already being realized in Indonesia. In the last 50 years, temperature has increase quickly, which is 0.16°C per decade. Sea surface rise, primarily in eastern and central Indonesia, reached 0.2-0.6 cm annually. During 1999-2010, rainfall intensity increased in most Kalimantan, Java, and Papua areas. However, the rainfall trend has decreased in some coastal areas of Sumatra, most of Maluku and Sulawesi [2]. Of these effects, extreme climate events have the greatest impact today.

Based on information from an article discussing "Anthropogenic Drivers of Mangrove Loss and Associated Carbon Emissions in South Sumatra, Indonesia", climate mitigation refers to actions taken to mitigate or avoid greenhouse gas emissions inside the atmosphere, reducing climate change impacts. In the context of the study, climate mitigation efforts are specifically focused on reducing carbon emissions from the land sector through improved sustainable coastal land management practices, mangrove forest conservation efforts, and mangrove area restoration programs to support the achievement of Indonesia's national emissions [7].

Developing more effective rice cultivation strategies through climate mitigation approaches is one way to improve food security and optimize rice cultivation strategies for dealing with climate change challenges. This study, will discuss more effective rice cultivation strategies through climate mitigation approaches and how research can help improve food security and optimize rice cultivation strategies. Although climate mitigation has been a widely studied research topic about optimizing rice production in Indonesia, especially in the Sumatra region, there is still a gap in studies focused on the West Sumatra region. It is important to note that West Sumatra has unique climatic characteristics and environmental conditions, may require different and specific climate mitigation approaches. Therefore, further research focused on this region is needed to optimize rice based on climate mitigation, ensure the sustainability of rice production, and maintain national food security.

## 2 Methodology

This research used the systematic literature review (SLR) method. The SLR method is a research method that aims to compile the results of previous research distributed from published journal articles or related proceedings to be synthesized into new knowledge through a certain scheme based on research objectives [8] . In this SLR research, we used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) approach [9]. PRISMA in SLR research further functions as a protocol for transparent data inclusion and exclusion processes, as visualized in the figure 1 below.

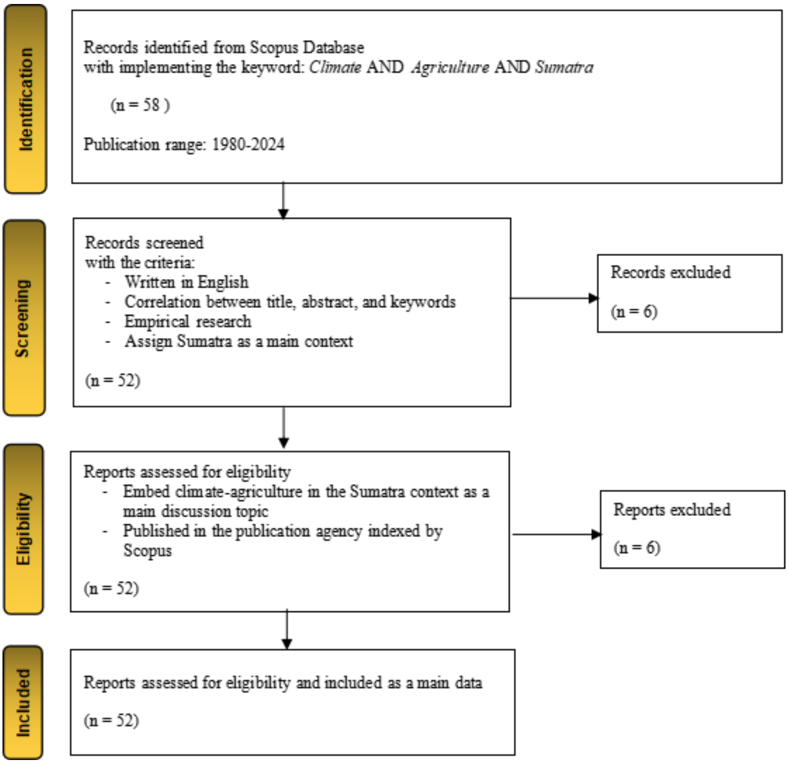


**Fig. 1.** PRISMA Flow Diagram (Modified by Researchers)

In this initial stage, we carried out identification through the Scopus database by applying several keywords: *"Climate" AND "Agriculture" AND "Sumatra".* The result identified 58 documents from various languages, document types, and publication stages from this database. Next is the screening stage. At this stage, we apply criteria in the form of articles that must be in English; there is interconnectivity between the title, article, and keywords; is an empirical study (not a literature study or conceptual study); the context of the study was carried out in Sumatra (Indonesia). As a result, 52 articles that met the screening criteria were included, and six articles that did not reach the requirements were excluded from this stage.

In order to ensure the use of literature data comes from credible and reliable publication sources, we carry out an eligibility test. At this stage, the implementation of articles eligibility was carried out, with criteria (1) study embed climate-agriculture in the Sumatra context as a main discussion topic, (2) research articles were published in the publication agency indexed by Scopus. Scopus is a massive database that contains 90+ million scholarly literature and indexes more than 27.000 journals from various subjects [10] [11]. At this stage, none of the articles were excluded from the eligibility process, and 52 articles were used as main data in this systematic literature study.

# 3 Results

## 3.1 Research clusterization of climate mitigation on rice productivity in the context of Sumatra

The Fig. 2 below illustrates the research clusterization of climate mitigation on rice productivity in the context of Sumatra. A short of each cluster follows. These clusters delineate specific methodologies and interventions aimed at mitigating climate impacts on rice yields, providing a structured framework for understanding regional adaptation strategies and their implication for agricultural sustainability.

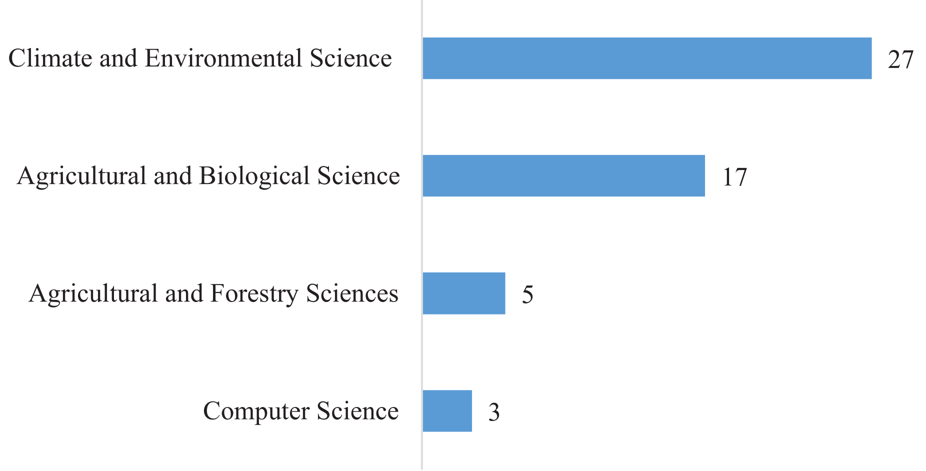


**Fig. 2.** Diagram of Research Topic Distribution

### *3.1.1 Climate and environmental science*

Based on a review of the literature that has been filtered using the Systematic Literature Review (SLR) method in the environmental science sector in the Sumatra Island region, it was found that humans are the main actors and determinants of whether an area is sensitive or not to environmental issues, because humans are more than just doing activities, still also their legal decisions have an impact on the environment [12–16]. Proven research is located in the Duku area, Pesisir Selatan Regency, West Sumatra, which has various land uses, including secondary forest, shrubs, rice fields, and dry land. The soil sampling method was stratified sampling to look at carbon distribution at a depth of 30-60 cm, which showed that intensive land use by humans tends to have lower organic carbon stocks [17-18].

Humans are also one of the causes of the need for studies on biological environmental issues, as evidenced by research on the spread of the bacterium Xanthomonas campestris pv. Oryzae in rice plants is due to the use of pesticides outside of good management and guidance [19]. In addition, humans are also the cause of uncontrolled infrastructure development that reduces agricultural land, disrupts local ecosystems, reduces biodiversity, massively loses carbon in the area of plantation expansion, experiences significant carbon stock losses, and creates and even increases pressure on the availability of natural resources [7, 19-20]. Agricultural activities certainly require ideal land, but if the use of chemical fertilizers is excessive, then the level of soil acidity will not be suitable, the reduction of micro and macronutrients, Fe, and other chemical elements contaminate the soil, and the most fatal result is a decrease in crop productivity[15].

In this subject area, environmental studies caused by population increases and shifts in land use are also in the spotlight, due to population increases or climatic processes such as the environmental identification of Lake Singkarak, West Sumatra, and Lake Toba in North Sumatra, then the distribution of peatlands on the island of Sumatra which must certainly be considered for the sake of sustainability [21– 23]. How to expand agricultural land and land use change (LUC) must, of course, follow the environmental rules that have been agreed upon or out in the law. If this is done without any knowledge of environmental awareness, especially if the area is exposed to El Nino, it will have fatal consequences, such as forest fires in 2015 [24-27].

#### *3.1.2 Agricultural and biological science*

The main topic and discussion in this project area is a variety of research on food security on the island of Sumatra based on the variables used, as well as climate mitigation, to get optimal production in the future. The agricultural system in Indonesia still goes through many traditional processes, starting from land preparation and caring for plants to the marketing process, even social habits that are sometimes not friendly to the ecosystem. Hence, efforts need to be made to realize smart agriculture from upstream to downstream, as well as proper climate data management [1], [33]–[35]. A common practice in developing countries is the deliberate expansion of agricultural areas on the edge of tropical forests. This refers to meeting the needs of the family or for the benefit of the national community, thus disturbing the ecosystem and losing biodiversity [36].

It can be done to maintain stability and food security by predicting rice productivity with various machine learning methods, such as employing hyperparameter tuning methodologies, such as Grid Search CV or Randomized Search CV for each model to optimize its performance. Cross-validation (CV) by k-fold splitting is used to evaluate unbiased models and optimize plant water needs to be integrated with technology [33, 37]. Practical efforts that can be made to maximize rice yield are to pay attention to the ideal planting distance, such as the system [25 cm x 25 cm (J1), 30 cm x 30 cm (J2), 35 cm x 35 cm (J3), and 40 cm x 40 cm (J4)] [38]. Another determining factors are irrigation management, which must be appropriate, regulations, and laws must also be in place to prevent Indonesia from becoming the largest rice importer in the next ten years due to the lack of breakthroughs [33, 39, 40].

Climate mitigation in the Sumatra region can also achieve food security, considering that more than 60% of the population depends on agricultural products, as in several areas in South Sumatra Province that are exposed to climate change [41]. Climate has influenced the growth, development, and final results of agriculture in the South Sumatra region, such as in producing paddy rice, field rice, corn, and soybeans [41, 42]. Climate mitigation is recommended in this case to conserve, pay attention to the suitability of crop water needs and local climate, return to established environmental ethics, and appropriate land use change [43, 44].

#### *3.1.3 Agricultural and forestry science*

Humans have practiced logging for more than 1000 years for various purposes [48]. Agricultural activities near forest areas often violate environmental laws due to haphazard practices. For example, the expansion of farming areas in central Sumatra was carried out without regard to the surrounding biodiversity, disrupting ecological stability, depleting carbon stocks, and contributing emissions due to forest burning [49]. Land conversion on the island of Sumatra by burning forests has occurred in the last few decades. 80% of emissions occurred in 2005-2009 due to land degradation. In 1973-2005, forest cover in Bungo District, Jambi, dropped dramatically from 75% to only 30% [35]. This disrupts the growth of conservation efforts and impact environmental damage [35, 50].

Land degradation or land use change, especially forests, occurs not only due to problematic management but sometimes also due to increased seasonal climate variations. With this phenomenon, climate mitigation is expected with sufficient knowledge to overcome the uncontrolled movement of forest replacement into monoculture agricultural areas [51].

#### *3.1.4 Computer science*

This subject area shows that global climate change can start from human or natural activities, such as forest fires, drought, and carbon dioxide emissions [32]. The use of satellite data and its processing using software is a top priority in measuring the cause and effect of these natural activities, which also impact agriculture [32, 52]. Consideration needs to be given to forest fire management planning, bias correction in rainfall data to improve the accuracy of drought analysis, and satellite data processing to understand CO2 distribution [32, 52, 53].

### 3.2 Research Gaps

Based on a study of 52 articles, the authors found research gaps. First, based on the research location, the studies only focused on the eastern coastal areas of provinces on Sumatra Island, such as North Sumatra, Jambi, and South Sumatra. The research concentrates mainly on the combination of rainfall data, local climate records, and post-fire environmental conditions affecting agriculture.

Secondly, the study is still centered on human environmental violations. Still, it has yet to specifically examine the forms of natural activities that also contribute to the impact on the agricultural environment, so further mitigation is needed.

## 4 Discussion

Through the literature review that has been conducted on the subject area above, research trends in the field of environmental science on the island of Sumatra highlight various aspects, starting from research methods in the field of climate that include global climate index data such as the dipole mode index (DMI) and the Southern Oscillation Index (SOI) on the distribution of emissions and greenhouse effects. Human activity is classified as the beginning of global warming, leading to climate change affecting the entire environment [28, 29]. Then, the impact of environmental changes on the productivity of crops such as robusta coffee, to the effect on livestock, as well as the important role of anthropogenic activities and climate conditions [1, 30–32].

Overall, the subject area in this field advocates climate mitigation by applying agriculture that is friendly to soil, water, and other environments. Not prioritizing personal or national interests that are not following environmental principles. Activities from upstream to downstream should be carried out with an integrated system, integrated hydrological management, a model that emphasizes sustainability and does not become a mass contributor to emissions [45]. Regular monitoring and the support of local and national governments must be carried out so that climate mitigation can be carried out comprehensively [46, 47]. Based on the description agricultural and forestry science, the most discussed aspect is land conversion, especially forest areas, into agricultural land [35, 48, 49]. This is followed by the effects of forest burning and seasonal climate variations [50, 51].

## 5 Conclusions

This systematic literature study examines climate mitigation strategies pursued by various researchers. The distribution of climate mitigation reviewed consists of 52 studies. It is divided into four main study areas: climate and environmental science, agricultural and biological science, agricultural and forestry science, and computer science.

The uniformity of the study's focus on all research results shows the influence of human activities and the lack of natural causes on global warming, thus becoming the main trigger for climate change, which ultimately affects the productivity of rice and other crops. It is highly recommended that further research be explicitly conducted in areas where very little similar research has been conducted. Research that is collaborative with farmer groups, policymakers, and environmentalists and focuses on comprehensive climate mitigation to maintain the stability of food availability in the future.

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