การประเมินความเสี่ยงจากสภาพภูมิอากาศสำหรับพื้นที่เพาะปลูกข้าวและความพร้อมในการจัดการของหน่วยงานภาครัฐ: กรณีศึกษาเกาะลมบก ประเทศอินโดนีเซีย

น.ส.ดอสมายา แอนเดรียอานี

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาศิลปศาสตรมหาบัณฑิต
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ASSESSMENT OF CLIMATE CHANGE-RELATED HAZARDS ON PADDY FIELDS AND PREPAREDNESS OF LOCAL GOVERNMENTS: A CASE OF LOMBOK ISLAND, INDONESIA

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A Thesis Submitted in Partial Fulfillment of the Requirements
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หัวข้อวิทยานิพนธ์ การประเมินความเสี่ยงจากสภาพภูมิอากาศสำหรับพื้นที่เพาะปลูกข้าวและความพร้อมในการจัดการของหน่วยงานภาครัฐ: กรณีศึกษาเกาะลมบก ประเทศอินโดนีเซีย

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ดอสมายา แอนเดรียอานี :
การประเมินความเสี่ยงจากสภาพภูมิอากาศสำหรับพื้นที่เพาะปลูกข้าวและความพร้อมในการจัดการของหน่วยงานภาครัฐ: กรณีศึกษาเกาะลมบก ประเทศอินโดนีเซีย. (ASSESSMENT OF CLIMATE CHANGE-RELATED HAZARDS ON PADDY FIELDS AND PREPAREDNESS OF LOCAL GOVERNMENTS: A CASE OF LOMBOK ISLAND, INDONESIA) อ.ที่ปรึกษาหลัก : สุทธิรัตน์ กิตติพงษ์วิเศษ

การเปลี่ยนแปลงสภาพภูมิอากาศนับเป็นประเด็นสำคัญที่ถูกอภิปรายว่าเป็นปัจจัยขับเคลื่อนต่อการเกิดอุบัติการณ์ภัยธรรมชาติ โดยการเปลี่ยนแปลงสภาพภูมิอากาศส่งผลกระทบต่อทุกมิติของชีวิตมนุษย์ โดยเฉพาะอย่างยิ่งในด้านความมั่นคงด้านอาหาร ทั้งนี้ พื้นที่เพาะปลูกข้าวนับเป็นพื้นที่ที่ถูกคุกคามมากที่สุดเนื่องจากการเปลี่ยนแปลงของปริมาณน้ำฝนและอุณหภูมิอันเนื่องมาจากการเปลี่ยนแปลงสภาพภูมิอากาศ บทบาทของรัฐบาลจึงมีความสำคัญในการลดความสูญเสียที่เกิดจากภัยธรรมชาติ โดยเฉพาะการยกระดับความสามารถในการปรับตัวของชุมชนท้องถิ่นต่อภัยธรรมชาติ วัตถุประสงค์ของการศึกษานี้คือการประเมินผลกระทบของภัยพิบัติจากการเปลี่ยนแปลงสภาพภูมิอากาศในพื้นที่เพาะปลูกข้าว และประเมินความพร้อมของรัฐบาลระดับท้องถิ่นในการรับมือกับการเปลี่ยนแปลงสภาพภูมิอากาศและอันตรายต่างๆ ที่เกี่ยวข้อง โดยคัดเลือก เกาะลมบก ของประเทศอินโดนีเซีย ซึ่งเป็นพื้นที่เกาะเล็กๆ และมีความเสี่ยงต่อการเปลี่ยนแปลงสภาพภูมิอากาศ ระเบียบวิธิวิจัยของการศึกษาครั้งนี้ ได้แก่ การประยุกต์ใช้กระบวนการลำดับชั้นเชิงวิเคราะห์ (Analytical Hierarchy Process: AHP) ร่วมกับระบบข้อมูลทางภูมิศาสตร์ (GIS) ในการประเมินความเสี่ยงที่เกิดจากการเปลี่ยนแปลงสภาพภูมิอากาศในพื้นที่เพาะปลูกข้าวทั้งจากผลกระทบจากอุทกภัย ภัยแล้ง และดินถล่ม ขณะเดียวกัน การศึกษานี้อาศัยการสัมภาษณ์ผู้เชี่ยวชาญ (n=15) เพื่อประเมินความพร้อมของรัฐบาลท้องถิ่นในการจัดการกับการเปลี่ยนแปลงสภาพภูมิอากาศ อาศัยการสัมภาษณ์ในประเด็นที่เกี่ยวข้องกับสถานการณ์ด้านการเพาะปลูก การจัดการภัยพิบัติ และการจัดการน้ำ โดยผลการวิจัยพบว่าพื้นที่ส่วนใหญ่ประมาณร้อยละ 88.18 ของเกาะลมบกมีความเสี่ยงด้านสภาพภูมิอากาศระดับปานกลาง และพื้นที่เพาะปลูกข้าวเกือบทั้งหมดร้อยละ 96.56 มีความเสี่ยงด้านสภาพภูมิอากาศระดับปานกลางเช่นกัน ผลการสัมภาษณ์พบว่าความพร้อมของรัฐบาลท้องถิ่นในการจัดการกับภัยอันตรายที่เกิดจากการเปลี่ยนแปลงสภาพภูมิอากาศมีอย่างจำกัด โดยเฉพาะประเด็นด้านงบประมาณ และทรัพยากรบุคคล โดยผลการศึกษานี้จะเป็นประโยชน์สำหรับหน่วยงานท้องถิ่นในการดำเนินกิจกรรมการปรับตัวต่อการเปลี่ยนแปลงสภาพภูมิอากาศต่างๆ และเป็นกลยุทธ์ในการคาดการณ์ผลกระทบของการเปลี่ยนแปลงสภาพภูมิอากาศในพื้นที่เพาะปลูกข้าวของเกาะลมบก ประเทศอินโดนีเซียต่อไป.

สาขาวิชา	สิ่งแวดล้อม การพัฒนา และความยั่งยืน	ลายมือชื่อนิสิต ....
ปีการศึกษา	2565	ลายมือชื่อ อ.ที่ปรึกษาหลัก ....

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KEYWORD: Climate Change, Multi-hazard, GIS, กระบวนการลำดับชั้นเชิงวิเคราะห์ (Analytical Hierarchy Process; AHP)

Dosmaya Andriani : ASSESSMENT OF CLIMATE CHANGE-RELATED HAZARDS ON PADDY FIELDS AND PREPAREDNESS OF LOCAL GOVERNMENTS: A CASE OF LOMBOK ISLAND, INDONESIA . Advisor: Suthirat Kittipongvises

The issue of climate change is being risen discussed as a driving factor for natural disaster incidences. Paddy fields become the most threatened because the changes in rainfall and temperature due to climate change harm rice production. In this context, the role of government is essential in reducing losses caused by natural disasters, particularly in escalating the adaptive capacity of local communities to natural disasters. The aims of this study were to evaluate the impact of climate change disasters on paddy fields and examine the local government's readiness to cope with climate change and related multi-hazards. Lombok Island, as one of Indonesia's National rice barns, was selected because this small island is vulnerable to climate change. The analytical hierarchy process (AHP) supported by a Geographical Information System (GIS) was utilized in assessing hazards induced by climate change on paddy fields, including flood, drought, and landslide. Expert interviews (n=15) were conducted to assess the preparedness of local government in dealing with climate change. The key questions have been prepared schematically based on: paddy and farmers' situations, disaster management, and water management. The findings reveal that approximately 88.18% of areas in Lombok Island are at the medium multi-hazard level. The final map of the multi-hazard was overlaid with the paddy field maps in the study area and showed that 96.56% of paddy fields are located within areas of medium risk. Ultimately, the interview result indicated that the preparedness of local government in dealing with hazards induced by climate change is still limited due to budget and human resources.

Field of Study:	Environment, Development and Sustainability	Student's Signature ....
Academic Year:	2022	Advisor's Signature ....

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ดอสมายา แอนเดรียอานี

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CHAPTER I

INTRODUCTION

1.1 Background of Study

Climate change is a big issue today because it increases the frequency of extreme weather events and impacts natural hazards potential (Nam et al., 2015). The Intergovernmental Panel on Climate Change (IPCC) liberated a report on the temperature increase effect of 1.5 degrees Celsius, which includes more extreme weather conditions, increased drought and flood, rising sea levels, damage to the coastal ecosystem, loss of vital species and plants, health problem, and global economic problems (IPCC, 2018). FAO reported that Asia was adversely affected by climate change from 2008 to 2018, resulting in crop and livestock production losses of 49 billion, where Southeast Asia and South Asia suffered the most significant losses (FAO, 2015).

Weather significantly affects the rainfall intensity, escalating the risk of flooding. The rising temperature due to climate change accelerates the evapotranspiration process, involving the increase in rainfall relative to the average annual rainfall and contributing to the runoff (Shrestha & Lohpaisankrit, 2017). At the same time, some parts of the world have experienced drought due to less rainfall frequency, which jeopardises food security and negatively impacts the economy (Erdem et al., 2021). Drought due to climate change is also enhancing along with the increased population and air demand while air availability is increasingly limited (Nam et al., 2015). Simultaneously, climate change affects slope stability, contributing to landslide events. Precipitation and temperature control slope stability at different temporal and geographic scales (Gariano & Guzzetti, 2016).

The impact of climate change is now being felt in every aspect of human life, especially in food security. Climate change impacts agriculture, such as land degradation, erosion, less production, and deforestation (Ogunleye et al., 2021). Globally, the agricultural sector suffered a loss of 82% due to drought between 2008–2018. At the same time, floods are the second threat that harms the agricultural sector, with a loss of 19% (FAO, 2015). Southeast Asia is predicted to experience the adverse effects of climate change. Indonesia, the Philippines, Vietnam, and Thailand are expected to experience an average sea level rise of 70 cm and a temperature increase of 4.8 0C by

2100. Climate change threatens these countries because most of their economic activities depend on agriculture (Busnita et al., 2017).

Rice production is closely related to households and national food security, poverty alleviation, and political stability in agro-based countries (Chan, 2015). It is a staple food and primary source of income for more than half of the world’s population, especially in Asia. Rice production is significant because it affects many lives. Rainfall and temperature have a considerable influence on rice growth. These two factors can affect rice production, making rice vulnerable to climate change (Khairulbahri, 2021).

Indonesia is an agricultural country. The agricultural sector is vital for Indonesia because it plays an essential role in national economic growth, labour absorption, and foreign exchange. The number of farmers in Indonesia is approximately 33 million people, or reaches 12% of the population of Indonesia (BPS-Statistics Indonesia, 2018). Agricultural indicator data reported that agriculture contributed 12.72% to Gross Domestic Product (GDP) in 2019 and is the second largest contributor to all sectors. The Indonesian government has issued Presidential Regulation No. 59 of 2017 concerning the implementation of achieving national development goals and integrating the indicators in the SDGs with the Medium-Term National Development Plan (RPJMN). The performance of the SDGs presents a considerable challenge in Indonesia, especially in dealing with target no. 2, Zero Hunger.

Meanwhile, Indonesia is a country that is very vulnerable to natural disasters and climate change. Sea-level rise threatens small islands in Indonesia and puts more pressure on the natural resources (Butler et al., 2016). The agricultural sector is the most affected by climate change in Indonesia. During the last three years, rainfall change, drought cycles, and flooding due to the Australian monsoon and ENSO phenomenon have resulted in lower agricultural production. This affects not only food security but also the low income of people who still depend on agriculture. Temperature changes harm rice production and affect rice price fluctuation in Indonesia (Tanti Novianti, 2017).

Lombok Island is one of the islands in West Nusa Tenggara (WNT) Province, one of the National rice barns capable of producing 774.000 tons of rice in 2019. The total area of rice fields on Lombok Island is 110.000 hectares, with 700,792 people working as farmers (One Data Nusa Tenggara Barat, 2020). On the other hand, as a small island, Lombok Island is vulnerable to climate change (Sapta et al., 2015). Lombok island is threatened with drowning or experiencing flooding due to the sea-level rise impact of global warming, which can have profound effects, especially on the social and economic conditions of the community (Barros et al., 2014). The WNT statistics reported that during the period 2017 - 2021, Lombok Island went through 128 hazards consisting of floods, landslides, and drought, which flooding was the most frequent disaster occurrence. In addition, East Lombok experienced the most disaster occurrences compared to 4 other regencies, of which 45 incidents. 2021 is the year of the most disastrous events in Lombok, with 40 disasters dominated by floods (One Data Nusa Tenggara Barat, 2021).

The impact of climate change has also disrupted the growth of food crops in WNT. The province encounters an increase in the frequency of extreme weather events and a larger volume of rainfall despite the shorter rainy season (Ichsan & Waru, 2019). At the same time, Diversity and dynamics in Lombok Climate are influenced by the El-Nino phenomenon that impacts crop failure. This phenomenon caused severe hunger in Southern Lombok in 1954 and 1996. Long drought in WNT due to the El-Nino phenomenon in 1997/1998 also caused 8.400 Ha paddy fields to encounter water stress and 1400 Ha of them to experience crop failure (Yasin et al., 2004).

This study develops a new perspective on land assessment and the impact of climate change, especially on paddy fields. This study assesses climate change disasters consisting of floods, droughts, and landslides on paddy fields. Spatial assessment of the impact of disasters on paddy fields is urgently needed along with accelerating climate change to assist local governments in making decisions to maintain food security and prevent damage to production.

1.2 Research Gaps

Natural disasters are severe disturbances that threaten the community and cause economic, social, and environmental losses. The danger of disaster will be greater if it occurs in vulnerable communities (McBean & Ajibade, 2009). News of disasters and their threats increasingly surfaced in the mass media. Nearly all countries report the number of casualties and billions of dollars of losses from disasters. The issue of climate change is rising being discussed as a driving factor for the incidence of natural disasters. The sea-level rise phenomenon is also increasingly emerging along with the global warming problem. Natural disaster frequency has increased in the last 20 years, with 2019 being the second warmest year in the history of the hottest ten years (FAO, 2015).

Lombok is a small island in Indonesia with a total area of 4738.7 km^2 (BPS-Statistics Indonesia, 2021)). The island is predicted to be more vulnerable to climate change, disrupting the ecosystem. Sapta et al. (2015), in his research stated that there were ecosystem changes in Lombok Island impact of climate change. Global warming causes damage to the mangrove forest ecosystem, decreases in land cover, loss of endemic species, deficit and reduced water quality. This happens due to changes in rainfall, temperature, and climate type. Suroso stated that Lombok coastal area will encounter severe climate change impact, especially around Mataram City, which is included in the extreme zone (Suroso et al., 2009). Besides, the adaptive capacity of coastal communities in dealing with climate change is still low, so the vulnerable communities are higher (Ichsan & Waru, 2019).

As a part of WNT province, 94% of WNT people believe that climate has occurred despite differences of opinion regarding the factor causing it. Those who work in higher-level organisations believe that human activities cause climate change; meanwhile, those in lower-level organisations assure that climate change is a natural phenomenon (Bohensky et al., 2016). Furthermore, Climate factors and their changes significantly affect agriculture (Li et al., 2014). Kairulbahri, in 2021 claimed that climate change has made WNT province only able to meet local rice demand and cannot provide for other regions (Khairulbahri, 2021).

However, based on the research database, a study on climate change disasters' impact on rice fields on Lombok Island has been relatively limited. Studies related to multi-hazard are also scarce and only deal with one disaster. Due to Lombok Island being one of the rice barns in Indonesia, there is an urgent need to map disasters to maintain food security in Indonesia, especially in Lombok itself. Mapping the impact of multi-hazard induced by climate change and evaluating the local government readiness on Lombok Island can assist the government in implementing effective adaptation strategies, especially for farmers whose rice fields are vulnerable to disasters.

1.3 Research Objectives

Overall, the study aims to evaluate the impact of climate change disasters on paddy fields using the GIS method and examine the local government's readiness to cope with climate change. The results of this study are expected to be the basis of the data that is important for formulating sustainable paddy field strategies, adaptation strategies to multi-hazards caused by climate change and helping the decision-maker detect the impact degree of multi-hazard induced by climate change on paddy field in Lombok Island.

1. To detect the areas of multi-hazards caused by climate change.
2. To examine the effect of multi-hazards caused by climate change on paddy fields
3. To evaluate the local government preparedness to cope with multi-hazards caused by climate change.

1.4 Research Questions

This research will analyse the impact of multi-hazard induced by climate change, including floods, drought, and landslides on paddy fields on Lombok Island. To determine the result, the study will examine the following problems:

1. Where are areas of multi-hazards induced by climate change in Lombok Island, Indonesia?
2. What impact of multi-hazards induced by climate change on rice fields in Lombok Island?
3. How is the preparedness of local governments in dealing with multi-hazards induced by climate change?

1.5 Scope of Study

Lombok Island is a part of West Nusa Tenggara Province divided into four regencies and one City: North Lombok Regency, West Lombok Regency, Central Lombok Regency, East Lombok Regency, and Mataram City. The total area of Lombok Island is 4699.83 Km2, which is the largest Regency in East Lombok. Lombok Island has two seasons, rainy and dry. It is closely related to the geographic existence of the island in the equator area. The rainy and dry seasons vary depending on natural phenomena like the ENSO (BPS-Statistics Indonesia, 2021). Lombok is one of the small islands in Indonesia that is vulnerable to various natural disasters like drought and floods. In Addition, this island has a row of mountains that cause a high landslide incidence (Safril & Ulfiana, 2019).

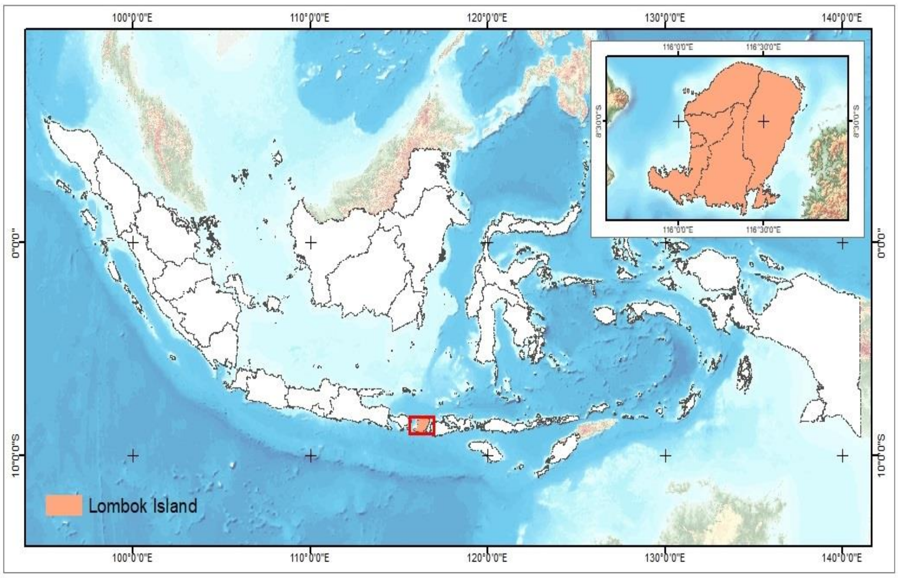

Figure 1 The Location of Lombok Island

1.6 Expected Outcomes

Climate change is an environmental and social challenge that threatens several vital economic sectors, especially those that rely heavily on natural resources like agriculture (Kalele et al., 2021). It is essential to take actions to tackle climate change and its impact. West Nusa Tenggara recently became the pioneer province that developed the Regional Action Plan for Climate Change Adaptation (RAD-API) by inaugurating Governor Regulation no. 54 of 2019. This regulation aims to provide direction for local governments to carry out various climate change adaptation activities as a strategy to anticipate the impacts of climate change in the period 2019 to 2023 (The Republic of Indonesia, 2019). The expected benefits of this study are to provide the highest potential exposure of paddy fields to multi-hazard induced by climate change spatially. This research is also an effort to disseminate information regarding the multi-hazard exposure on paddy fields to accelerate the process of delivering information to local government. Lastly, this study can provide the up-to-date and accurate assessment of multi-hazard induced by climate change impact on paddy field for decision-makers to determine the most urgent and integrated mitigation measures for reducing disaster risk.

CHAPTER II

LITERATURE REVIEWS

2.1 Climate Change

Climate change is one of the serious environmental issues the world faces today. Looking at its history, it started to be on the public agenda in the mid-to-late 1980s. This issue began with the French mathematician and doctor Jean Fourier, in 1824, who depicted the impact of greenhouse gas on the climate debate. Also, Arrhenius, a Swedish scientist, first calculated global warming through human CO_2 emissions half a century later. After that, climate variations are considered a scientific issue, so the discussion mainly occurs in the scientific forum of climatologists. In the 19th century, this matter became more intense by the involvement of stakeholders and the inclusion of community perspectives. The scientific meeting regarding climate change has a broader range of participants, not only climate scientists but also researchers on energy, water resources, and land use. Further, there is a shifting global perspective related to climate change in the new millennium. Many public authorities are coming into managing the climate change problem (Rahman, 2013).

Climate change is a condition change in world climate patterns that result in erratic weather phenomena. Climate change occurs due to changes in climate variables, especially air temperature and rainfall, which happen continuously over a long time. Global climate change is also caused by intensified greenhouse gas (GHG) emissions due to various human activities that increase the earth's temperature (United Nations). Generally, people know that climate change is caused by the increasing carbon dioxide (CO_2) concentration in the atmosphere (Kinose et al., 2020). Climate change will affect many things, such as rising air temperature, changing rainfall patterns, increasing intensity of extreme climate events (climate anomalies) like El-Nino and La-Nina, and rising sea levels. The El Nino-Southern Oscillation phenomenon is a natural global climate system that fluctuated due to the interaction of the ocean with the equatorial atmosphere in the Pacific Ocean, in which El-Nino and La-Nina are phases of this phenomenon. El Nino causes the equatorial surface temperature of the Pacific and Eastern Oceans to be abnormally warm, while La Nina causes abnormally cold sea temperature. These phenomena are often associated with drought and floods events in Southeast Asia, India, Australia, Southeast Africa, Amazonia, and Northeast Brazil (IPCC, 2012).

Regional climate variations are determined by rainfall cycles and location, where the difference in rainfall between wet and dry areas and between rainy and dry seasons will increase. The highlands and part of middle latitudes are also likely to experience an increase in the frequency and intensity of rainfall. Globally. The temperature increase will be more significant inland than over the ocean, wind speed will be maximum, and rainfall rated from tropical cyclones will increase. Global average temperature change is projected from 0.3 °C to 0.7 °C for the period 2016 - 2035. In recent years, the sea surface temperature has warmed, the global average sea level has risen, and glaciers and ice sheets have disappeared.

Climate change has become a top issue in the international forum. The issue is not only considered as an environmental matter but also an economic matter. Climate change is also seen as a problem requiring cooperative action to limit the risk of future damage and an opportunity for strategic leadership. Clean technology has been declared as a strategic goal in many countries (Jotzo, 2012). Many developing countries are experiencing severe challenges due to climate change, especially those with large populations, dependence on non-renewable resources, limited resources and low adaptive capacity to deal with the threats. Alongside, coastal areas are the most vulnerable to climate change risks, particularly sea-level rise. About 10% of the world's population lives in coastal areas, and 29% lives in flood-prone areas with varying inundation levels. This risk is capable of causing significant socio-economic impacts, loss of property, livelihoods, economic activities, tourism, and transportation function (Marzouk et al., 2021).

2.2 Concept of Vulnerability and Resilience

Vulnerability is the tendency to be adversely affected, which affects the capacity of a person or community to anticipate, cope with, resist and recover from the adverse effects of a physical event. This is obtained from various historical, economic, political, social, cultural, natural resources and environmental conditions. For instance, heat waves have different impacts depending on the population and 'where' they occur. People, livelihood, and assets tend to experience vulnerability when affected by disasters (IPCC, 2012). Resilience focuses on the idea of anticipating and improving essential basic structures and functions. In classical theory, pre-existing damage determines vulnerability, not future stresses. The vulnerability of individuals and social groups is determined by their capacity to respond to a problem (Gibb, 2018). IPCC defines vulnerability as the degree to which a system cannot cope with the adverse effects of climate change, including climate variability and extremes (IPCC, 2007). The vulnerability has developed at the local, regional, national and international levels that synergistically affect communities (Gibb, 2018).

This concept is one of the main determining factors of disaster risk and impact when the risk is realised (IPCC, 2012). The experts explicitly acknowledge the relationship between vulnerability with disaster in the twentieth century. The standard definition of vulnerability is the characteristic of a person or a group in anticipating, overcoming and revering from the impact of natural hazard. Currently, the use of vulnerability concept is not only in hazard and disaster risk but has also been integrated into other fields, such as food security, economic, political, human ecology, development, poverty, poverty, climate change, global environmental change, and socio-ecological vulnerability (Gibb, 2018). For instance, the vulnerability in the economic concept focuses not only on the idea of danger but also on the possibility of remaining in poverty, both accounting for severe risks and powerlessness in fighting against their deprivation (Naudé et al., 2009).

Social, political, economic and structural-historical processes drive geographic vulnerability. Interrelated root causes are embedded in ideologies of socio-economic systems, and certain unsafe conditions produce vulnerability, resulting in disaster when combined with natural hazards. Societal inequalities such as class, gender, race, ethnicity, caste, religion, age, health, and marginality determine who is vulnerable and whether a hazard becomes a disaster. Households with easy access to capital, tools and equipment are the quickest to recover in a disaster. In contrast, the poorest are the most vulnerable because they have little choice but to place themselves in an unsafe environment (Proag, 2014). The social system also results in unequal risk exposure and increases certain groups' vulnerability. At the same time, the disaster does not erase the social differences, yet increasingly civilised social oppression and exploitation. Hence, vulnerability strategies must be based on the principles of equality and justice (Gibb, 2018).

The concept of resilience is when a system can return or recover to its original conditions or reduce both magnitude and duration of hazard as efficiently as possible (Proag, 2014). The idea of this concept is the capacity to adapt to stress. Resilience is the ability of a system and its parts to anticipate, absorb and accommodate or recover from the impact of a potentially hazardous event in a timely and efficient manner. This concept has been widely adapted to various subjects, not only in disaster risk management (Gibb, 2018). In addition, resilience can be defined as a reduced vulnerability to disaster risk. It can cope with stress or adversity and has a relatively better outcome despite experiencing risk. Exposure to stress can escalate resistance or denote a reinforcing effect against subsequent stress (Rutter, 2012).

Resilience takes two forms: hard resilience and soft resilience. Hard resilience is the direct strength of the structure when it is placed under stress. The structure or institution is able to arrange special reinforcement measures in an effort to reduce the possibility of damage. Meanwhile, soft resilience is the ability of a system to recover from the impact of a disruptive event without undergoing a fundamental change in its function. This resilience depends on the adaptive capacity system as a whole. Besides, there are three possible responses to disaster threats. First, resistance and maintenance, where a system will do its best to avoid change. Second, margin change acknowledges a problem and is not a sustainable system. Last, openness and adaptability to adopt new basic assumptions and institutional structure (Proag, 2014).

2.3 Climate Change Adaptation

Climate change adaptation aims to address various potentials in the frequency, intensity, and duration of weather and climate events that affect the adverse risk to humans. Nevertheless, disaster risk management strategy and practice depend highly on vulnerability and exposure factors (IPCC, 2012). Adaptation is an effort to reduce risk vulnerability through strategy and actions that adjust practices, processes, and capital in response to climate change threats. This concept is specific and adapts to the local conditions such as socio-economic conditions, traditional agriculture practices, and political influences (Vogel & Meyer, 2018). Climate change requires adaptation to reduce its impact. Some concepts of adaptation strategies are usually carried out to lessen the effects of climate change:

- Expanding the temporal and spatial scale of plans, policies and management. Planning needs to be carried out at various integrated scales and involves various local and national stakeholders. The planning at least looks at the next 20 or 50 years.
- Looking at history, politics and economics to support environmental justice. This is because the poor tend to be more vulnerable to environmental damage. For instance, the poor tend to live near

industrial areas with high pollution due to lower land prices. Nevertheless, they do not have any capacity to resist the presence of these industries and develop their livelihood.

- Collaborating across sectors and various types of organisations in an effort to develop adaptation strategies and combine strengths to address the impacts of climate change.
- Resistance, Resilience and Transition. Resistance-based adaptation strategies need to be carried out in the face of environmental changes by maintaining the existing system. An example is building a sea wall to prevent erosion and storm surges. Meanwhile, resilience strategy is used to form a powerful system to return to its original conditions despite disturbances. Besides, any managed strategy needs to transition to new situations. However, this will be controversial, especially in a social context, because it will create inconvenience and not benefit the community.
- Taking an adaptive management approach to manage and monitor the system based on the management that has been designed. Adaptive management has four basic steps: assessing the potential impacts of climate change, planning management action and addressing potential consequences, a monitoring system for climate change and system response, and evaluating the effectiveness of management actions based on monitoring results and re-designing adaptive management in response to the evaluation results.
- Protecting and restoring biodiversity from species biodiversity, environmental, and genetic biodiversity because diverse systems are more resilient to climate change. In addition, Increasing the resistance of the species and reducing the impact of other actors that reduce the resistance of the entire species—for instance, reducing pollutants, restoring vegetation and protecting habitats.
- Facilitating the dispersal or colonisation of some species that cannot cope with climate change can be called managed relocation and assisted migration. This aims to promote the movement of species in response to climate change outside their native areas.
- Implementing water management, protected areas and restoration strategies to respond to the negative impacts of climate change.
- Addressing changes in terrestrial systems by establishing strategies involving protected land, conservation palling, improving landscape connectivity, and creating site- or species-specific strategies.

- Protecting and restoring natural buffers in coastal areas such as barrier islands, mangroves and coral reefs.
- Considering social conditions in climate change mitigation and adaptation planning. This is because the risk and vulnerability of climate change are not evenly distributed by location due to differences in social, political, cultural, and economic conditions. Besides, integrating mitigation and adaptation strategies does not overlap at local, regional, and international scales. Mitigation and adaptation strategies that do not consider equity, human welfare, and health prove to be ineffective when implemented (Lawler et al., 2013).

2.4 Climate-related Natural Hazards

Natural disasters are rising in frequency and intensity. There has even been a five-fold increase in disasters, peaking in 2000 - 2010. Climate change drives an increase in the frequency and severity of those disasters. The number of people affected by disaster is enhancing as well as the cost of losses incurred. Overall, floods are the most frequent disaster affecting many people's lives (Djalante & Thomalla, 2012). Several social groups become vulnerable to disaster hazards, including elderly age, those with congenital diseases, and those of low economic status. Floods, landslides, drought, heatwaves and forest fires have contributed to massive damage to human settlements. Coastal settlements are the most at-risk area to sea-level rise and coastal storms. The urban poor in informal settlements also experiences a high-risk impact, with almost 1 million people living in it. Vulnerability is high because the houses they live in are of poor quality. The concentration of economic assets and many vulnerable populations create the possibility of an enormous impact (IPCC, 2012).

By definition, natural disasters are natural phenomena that can cause loss of life, injury, health impacts and other damage, driving economic, social, and environmental disruption. Meanwhile, disaster is a severe disturbance to the community because its impact exceeds their ability to cope (UNISDR, 2009). Climate change occurs directly or indirectly due to human activity that changes the composition of the global atmosphere. Climate change enhances the frequency of climate-related natural disasters such as floods, extreme weather, landslides, forest fires and drought.

Climate-related disasters currently dominate most of the world's disasters. In addition, natural disasters can occur in combination with two or more disasters. For instance, coastal flooding can happen due to sea-level rise and rains after fires can cause flooding due to loss of vegetation and soil infiltration capacity, which also encourages erosion and landslides. Furthermore, natural disasters can cause cascading effects with dependence on one or more component systems: flooding can spread over a large area, triggering toxic release in chemical facilities and creating secondary hazards to residents (Tavares da Costa & Krausmann, 2021). This research will discuss three climate-related disasters: flood, drought, and landslides.

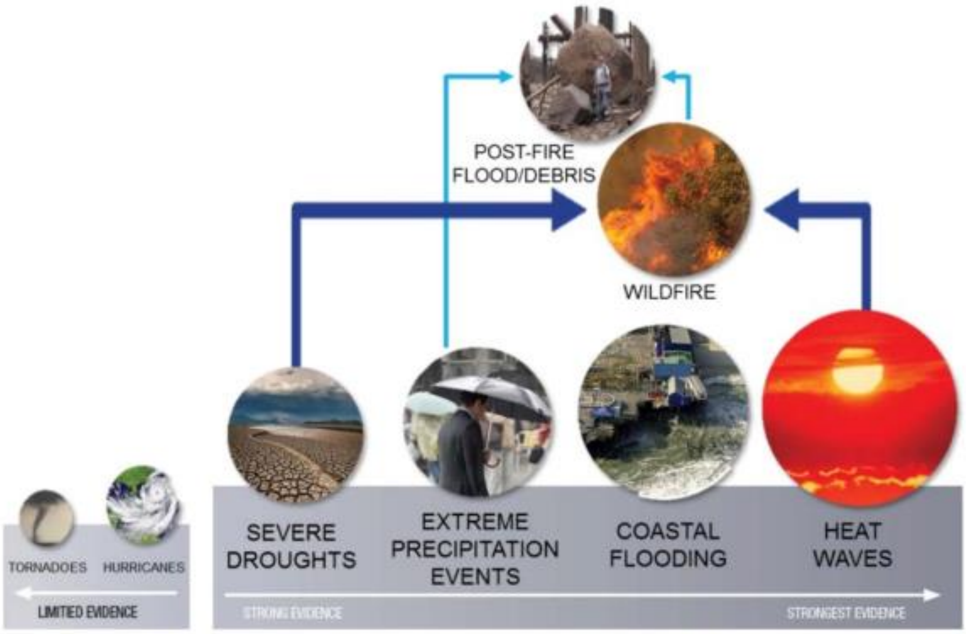

Figure 2 Supporting evidence of the impact of climate change on natural hazards

Source: Tavares da Costa and Krausmann (2021)

2.4.1 Floods

Climate change is predicted to change the earth's hydrological cycle and cause an increase in the frequency of extreme rainfall over the world, especially in middle and high latitudes. An enhancement in rainfall is even predicted to occur in areas that tend to be dry. The extreme rainfall event certainly causes the risk of flooding (Dankers & Feyen, 2008). A Flood is the overflow event from body water that is usually not submerged. Several types of floods are river floods, flash floods, urban floods, fluvial floods, sewer floods, coastal floods and glacial lake overflow floods. The main factor that affects flooding is rainfall, like intensity, duration, amount, phase, time, and phase. River water level, soil characteristics, urbanisation, and dams are other factors that flood events (IPCC, 2012). Generally, rainfall pattern, slope, drainage, elevation and land use are the most common factors used in determining flood risk assessments (Kittipongvises et al., 2020).

The increase in rainfall variability over the last few years indicate an increase in flooding incidences. In East and West Europe, climate change is projected to cause 100-year floods to be doubled in one period or shift to 50 years (Dankers & Feyen, 2008). In the UK, 1.200 households were affected by flooding. This country also experienced a gaining flood risk in autumn due to the increased rainfall. South America is reported to have experienced a rising frequency of flooding in several watershed areas. The research in Asia denoted an increasing trend of flooding in the Yangtze River region over the last 40 years. Besides, extreme flooding in the Mekong River increased during the second half of the 20^{th} century. Floods can cause death, injury, disease outbreaks and malnutrition due to crop failure. Severe flooding in Dhaka, Bangladesh, in 1998 caused an increase in disease during and after the floods. Floods also cause a shift in the malaria epidemic geography by changing in breeding grounds of mosquito vectors (IPCC, 2012).

2.4.2 Drought

Drought is a decrease in the natural balance due to less rainfall that affects land and water resources (Erdem et al., 2021). Drought can occur as a result of a long-term rainfall deficit. This condition is exacerbated by high temperature, relatively low humidity, high water demand and poor water management (Tavares da Costa & Krausmann, 2021). The frequency of droughts in recent years has increased due to climate change. However, there is no universal specific definition regarding drought. Drought depends on each climate characteristic and its impact on a particular sector which varies on a spatial and temporal scale (Nam et al., 2015). This disaster can cause water shortage, form desertification (cracked soil that does not support plant growth), soil moisture reduction, forest fire support conditions, erosion, siltation, and water pollution. Drought delivers losses with huge impacts, even if slowly (Tavares da Costa & Krausmann, 2021).

This disaster in the future will get worse along with population growth and the escalating water demand (Nam et al., 2015). Detecting regional and local scale drought is necessary to prevent adverse economic, social, and environmental impacts. Climate is the main factor that determines climate change. Temperature is one of the climate parameters in measuring drought incidence. On the other hand, the change of land cover affects the soil's surface temperature, and the type of land drives the drought level of an area (Erdem et al., 2021). Drought is divided into meteorological drought, hydrological drought, and agricultural drought. Meteorological drought is a condition where the annual rainfall of an area is less than usual for a long time (months, seasons or years). Hydrological drought is a drought associated with the effect of a lack of rainfall in the water supply. Meanwhile, agricultural drought affects food production due to a groundwater shortage (Shah et al., 2015).

Methods of measuring drought have been used as an effort to predict and monitor drought. Several methods are used, such as Standard Precipitation Index (SPI), De martonne and Erinc, assessing ground surface temperature and remote sensing technology. Several remote sensing indices most used to detect drought are the Palmer Drought Index (PDSI), Crop Moisture Index (CMI) and Surface Water Supply Index (SWSI) (Erdem et al., 2021). After all, SPI, PDSI and Standardize Precipitation Evapotranspiration Index (SPEI) have been designated as representative indexes of drought analysis because these indexes can provide both spatial and temporal characteristics. Hence, the government commonly uses these indexes to monitor the drought hazard (Nam et al., 2015).

2.4.3 Landslides

Climate change supports future landslides through greater frequency and intensity of rainfall. Precipitation drives the movement of rock or soil down the slope due to progressive strain and collapse (Crozier, 2010). Heatwaves and high rainfall are believed to affect the slope instability that causes landslides in several areas (IPCC, 2012). Landslides involve a combination of different types of motion like flowing, sliding, rolling, falling and spreading. This hazard plays an essential role in the landscape evolution and poses a major serious threat to affected people. Precipitation, snowmelt, temperature changes, earthquake shocks, volcanic activity, and various human activities trigger slope instability and cause landslides.

Precipitation and temperature are vital factors controlling slope stability at different temporal and geographical scales. Temperature changes will affect bedrock stability through the fall of ice and rock. Due to the formation or opening of fracture, changes in rainfall will encourage landslides, mud and rock flows (Gariano & Guzzetti, 2016). Soil infiltration capacity is also a factor in the occurrence of landslides. Infiltration capacity can regulate rainfall input into the soil, where if the rainfall intensity exceeds the infiltration capacity, it will cause overland on the slope, triggering landslides. Landslides distribution will not be evenly distributed in each area due to differences in infiltration capacity (Crozier, 2010). Landslide significantly affects settlement in tropical mountainous regions because informal settlements are often located on unstable soil. This hazard occurs mainly in an area experiencing deforestation and prolonged heavy rains (IPCC, 2012).

2.5 Climate Change Impact on Agriculture

Climate change renders an increase in water scarcity and affects the water salinity surface due to sea-level rise. FAO reported that economic losses and damage caused by climate hazards such as floods and droughts in 48 developing countries affect the agricultural sector as much as 25% (FAO, 2015). Climate significantly affects plant growth processes such as temperature, rainfall, solar radiation, soil moisture, carbon dioxide concentration, and microbial processes (Vogel & Meyer, 2018). Climate change can reduce rice production and threaten people already suffering from food shortages. The worst impact will be felt by developing countries in Asia, which have many rainfed rice fields through reduced rainfall and increased temperature. On the other hand, increasing temperature will be predicted to positively impact agriculture at higher latitudes (Kinose et al., 2020).

Climate risk has direct and indirect impacts on agriculture. Direct impact occurs due to changes in temperature levels and rainfall distribution. Meanwhile, indirect effects happen to agriculture production through disease vectors, pests, and pollinators. Climate change negatively impacts households, especially those who work as farmers (FAO, 2015). The number of people who depend on agriculture in developing countries is very high, being one of the most vulnerable groups (Vogel & Meyer, 2018). Production costs or prices affect people's income level and stability.

Further, exposure to climate risks can destabilise food availability at the national level through market disruptions, impact supply and storage systems, and increase agricultural commodity prices. This matter encourages a macroeconomic effect for countries that rely on agriculture as the primary contributor to GDP and hinders agricultural development by interfering with investment (FAO, 2015). Climate change is also affecting nutritional needs. About 768 billion people will experience malnutrition, and the risk of extreme hunger is predicted to be shared by about 1300 billion people by 2080. In the poorest countries where the population is mainly dependent on agriculture, low adaptive capacity at the agricultural and national levels will suffer the worst impact (Syaukat, 2011).

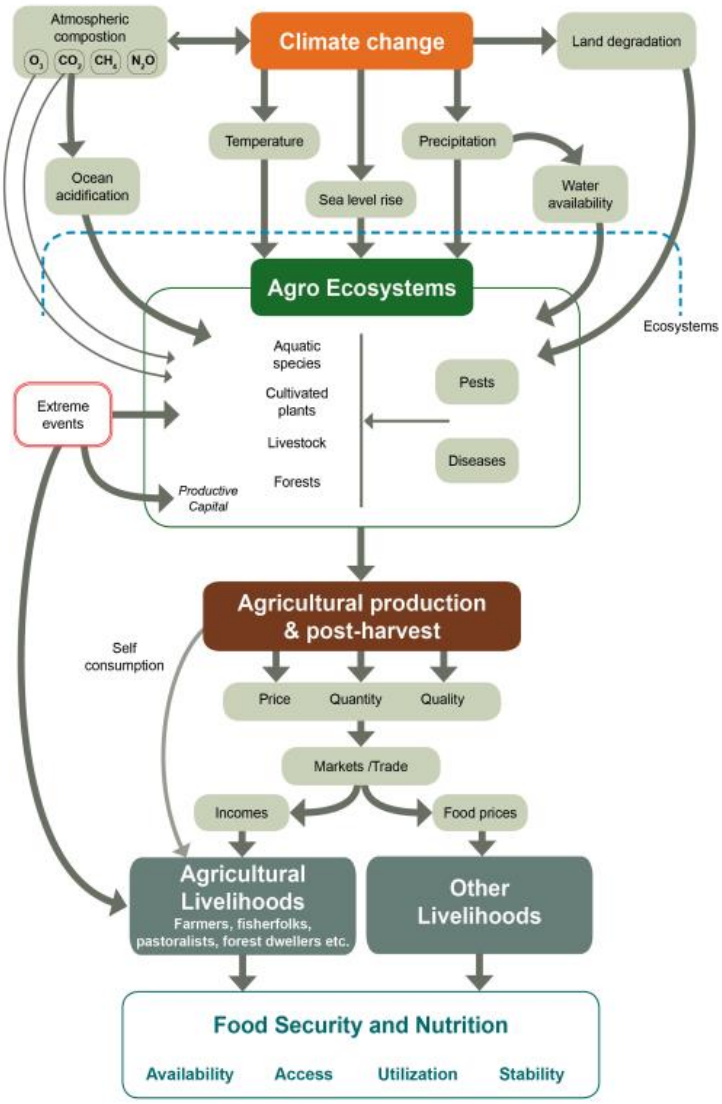

Figure 3 Climate change impact scheme on food security and nutrition

Source: FAO (2015)

Some developing countries are very vulnerable to climate change, especially in achieving food security, because of their status in international trade and are exacerbated by the poor development of domestic and regional markets. The world's population is projected to reach 0.7 billion people by 2050, so food production must increase by 70% to meet future demand. Besides, the human diet has changed due to the rising income, especially in developing countries, so global caloric consumption is projected to increase (Vogel & Meyer, 2018).

Climate change will affect food ability by impacting a series of dynamic food chain interactions such as production, storage, procurement distribution, exchange, preparation, and consumption. Currently, extreme weather events, drought, sea-level rise and increased frequency of rainfall have impacted agriculture, such as:

- Changes in land suitability for various crops
- The emergence of various vectors of pests and disease
- Loss of biodiversity and ecosystem function naturally
- Loss of fertile land because of the increase of drought and groundwater salinity.
- Many low-income countries rely heavily on local production, unable to meet the food need of their people.
- Impact on agricultural production will affect the livelihood and access to food, particularly for affected farmers.

Agricultural adaptation plans and strategies need to be integrated into sustainable development to reduce risk at local and national levels to achieve food security. There are two types of agricultural adaptation, first is autonomous, where farmers measure rainfall patterns to determine the correct planting date. Second, adaptation measures to facilitate the transformation of certain plants by substituting new plants, deliberately selecting plants, and substituting scarce resources. The second method needs to include four main components: integrating climate change mitigation and adaptation strategies within the economic, social and development framework, collaborating in implementing adaptation and strategies measures, strengthening knowledge at both local and national level, and developing a multi-level strategic framework and comprehensive roadmap (Syaukat, 2011).

2.6 Agricultural System to deal with Climate Change

Creating a resilient agricultural system is indispensable in the face of climate change. The adaptation strategy used must implement specific and local system measures so that each farmer can adopt them. FAO (2015) has pointed out ways to achieve a resilient agricultural system, such as:

- Improving water use efficiency. Climate risk significantly changes the rainfall pattern, affecting water availability. Therefore, strategies are needed in overcoming water scarcity to maintain productivity by storing water, improving technology and access to irrigation, increasing groundwater retention in agronomic practices.
- Adaptation strategy to crops in protecting the risk of crop failure. Adapted crop varieties, which can live optimally in a different environment and/or have greater tolerance, can be done. Adaptive changes in crop management can increase production yields by an average of 7-15%, although the results are highly dependent on the environment and plant species.
- Restore a healthy and resilient forest ecosystem. Healthy ecosystems are more resistant to the adverse effects of climate change. Restoring degraded forest ecosystems is a critical strategy in increasing resilience. Measures that can be taken are integrated pest management, forest fire and disease control, low-impact logging technology in production forests, and forestry law enforcement.
- Enhancing disparity in the production system. Diversity in the production system can protect the production from climate change risks. Combining several different types of crops varieties and the use of multiline plants is the best way in climate change strategies.
- Adaptation actions at the landscape level are urgently needed to increase community capacity in dealing with climate change issues. Management using a landscape approach must consider the physical and biological features of an area and the institutions that influence it. It is excellent to carry out watershed management, fire and erosion control, coastal area management, and disease control.
- Investment in Agriculture and farmers can bolster adaptation and alleviate poverty because the agriculture GDP growth from investment is three times more effective than growth in other sectors. Farmers' investment is also necessary through the mutualised systems to assess risk, vulnerability, and adaptation action. Providing station weather observations, weather forecasts, climate projections, yield response models, environmental monitoring tools, and vulnerability assessments can determine how local climatic conditions will change in the future and how they will impact production. It can also establish an early warning system for adaptation options.

- Climate change adaptation policy is urgently needed to support the strategies developed, particularly in supporting small-scale food producers in adapting to climate change, managing pests and disease, securing land tenure and equitable access to land, facilitating investment. The role of government is also essential in bridging the economic and political gap between the small farmers and their families, agricultural actors and other actors in the food chain. Regulation can develop markets and create better linkage between farmers and domestic, national, and regional markets to support climate change adaptation. In addition, Regulation can also reduce financial risks, which is a significant investment target for smallholders and family farmers. It helps lower transaction prices, facilitating access to financial services and long-term investment.
- Upgrading the contribution of markets and trade to the stability of food security because global markets and trade can stabilise the food price and provide alternative food options for areas negatively impacted by climate change.

2.7 Climate Change in Indonesia

Indonesia is the largest archipelago country globally, located in the tropics and at the junction between two oceans and two continents, making it has a tropical climate with moderate temperature and humidity (Syaukat, 2011). The country has enormous natural resources, yet exploitation of the environment continues rapidly. Conversion of the forest to plantation and mining is vast for creating profit and meeting demand. The country is one of the populous nations and the largest emitters of greenhouse gases globally (Jotzo, 2012). Its emissions come from deforestation, burning peatlands, and fossil fuels combustion. Deforestation generated 58 million tonnes of carbon dioxide emission per year; forest loss delivered 529 million tonnes of carbon dioxide during 1990 - 2021 and 466 million tonnes of carbon dioxide for peat fires between 2000 - 2006 (Alisjahbana & Busch, 2017). The Ministry of Environment and Forestry of Indonesia reported that Indonesia produced 1.637.156 Gg CO_2e in 2018, which increased by 450.928 Gg CO_2e compared to the emission level in 2000. Indonesia also experienced the worst forest and land fires in 2015, burning more than 2.6 million ha of forest and land. Sumatra and Kalimantan were the islands that experienced the largest forest fire (World Bank Group, 2021). This incident attracted international attention because it disrupts public health and impacts neighbouring countries like Singapore and Malaysia.

In 2009, the Government of Indonesia committed a voluntary emission reduction target of 26% on its efforts and up to 41% with international support, against the business as usual (Romieu et al.) scenario by 2020. Indonesia submitted its emission reduction target to the UNFCCC in 2011 and issued Presidential Decree No. 61 of 2011 on the National Action Plan for Reducing Greenhouse Gas Emission (RAN-GRK). Indonesia also submitted an NDC report to the UNFCCC in 2016 for an emission unconditional reduction target of 29% and conditional reduction up to 41% of the business-as-usual scenario by 2030. As part of the Government's efforts to provide guarantees to the public for a quality environment and to follow up on this agreement, the Government released regulation no. 16 of 2016 concerning Ratification of the Paris Agreement to the United Nations Framework Convention on Climate Change (The Ministry of Environment and Forestry, 2016).

On the other hand, Indonesia is greatly vulnerable to hazards induced by climate change, such as sea-level rise that harms coastal zones and agriculture, floods due to the escalation of rainfall patterns, and the spread of disease caused by the changing of temperature that affects human health (Jotzo, 2012). The intensity of the hazard increases due to climate change. ND-Gain Country Index, which calculates a country’s vulnerability to climate change and readiness to enhance resilience, reported that Indonesia was ranked 103 in 2019 (ND-GAIN, 2019). In addition, Indonesia is ranked the top 5th among 191 countries in terms of natural hazard risk by the 2021 Inform Risk Index, where flooding is the most vulnerable disaster (Inter-Agency Standing Committee and the European Commission, 2021). Bali, Java, Sumatra and Papua islands, economically productive areas in Indonesia, are very susceptible to climate change (Measey, 2010). The ENSO phenomenon significantly affects Indonesia's climate, where dry conditions occur due to El-Nino events while wet conditions occur due to La-Nina events. Asian Development Bank (World Bank Group) predicts that there will be an increase in temperature from 26.5 ^{0}C to 29 - 30 ^{0}C in 2100 due to climate change. The annual rainfall is projected to go up by 7%. Based on climate model projections, Indonesia is one of the vulnerable countries to extreme heatwaves. El-Nino events will rise in frequency and intensity so that the country will face severe meteorological drought in 2090. The continuous gain in drought will intensify forest fire events and poor air quality (World Bank Group, 2021).

Climate change will make Indonesia experience rainfall about 2 - 3 % higher each year. High-intensity rain will persist and result in a shorter rainy season, increasing the risk of flooding (Measey, 2010). Every year, the number of people affected by floods is estimated at 1.5 million people, with damage reaching 1.4 billion over the last 25 years. Climate change is predicted to increase the annual population affected by 400.000 people and urban damage by 6.1 billion in the 2030s. The risk of coastal flooding is also expected to increase by 19 - 37%. This country is threatened with a sea-level rise of 10 cm in 2030 and 21 cm in 2060. This will give a significant loss where Indonesia is ranked 5th in the world that inhabits the coastal zone. Coastal areas will experience permanent inundation, land subsidence, and erosion. Also, it will affect settlement, rice fields, and ponds because surface and groundwater are threatened with potential salinisation. Vulnerability to natural disasters is exacerbated by the dense population in hazard-prone areas and extreme dependence on natural resources. ADB predicts that climate change losses will cost 2.5 - 7 % of Indonesia's GDP in 2100. Poor people will bear the brunt of the loss (World Bank Group, 2021).

As a tropical country, the recent minimum and maximum temperatures are approaching the rice temperature threshold, threatening rice production. An increase in temperature during the growing season in this country is predicted to reduce rice production per capita in the future (Hasegawa (Hasegawa & Matsuoka, 2013) & Matsuoka, 2015). In Indonesia itself, the geographical position and social capacity of the community in anticipating climate change determine the main factor that causes variation in the decline of agricultural production. Geographical position determines the magnitudes of El Nino's influence on rainfall frequency, while social capacity determines the amount of mitigation effort carried out by farmers in reducing production losses (Syaukat, 2011). An El Nino event increases the risk of lowering rice production by a 30-day delay in rainfall in the rainy season from 9 - 18% to 30 - 40% (World Bank Group, 2021). Looking to 1968 - 2020, the El-Nino event caused food production losses of up to 3.06% (Syaukat, 2011).

Research indicated that Climate change would disrupt rice productivity in Indonesia over the next 25 years because it encourages an increase in air temperature, which stimulates a reduction in photosynthesis and an increase in respiration. Agricultural production is predicted to decrease by 12.1% in 2039 - 2042 (Kinose et al., 2020). Weather and climate are critical factors in agricultural production despite technological advances in enhancing irrigation capacity and systems (Syaukat, 2011). The impact of climate change in Indonesia is getting worse with many poor people in Indonesia who are not educated about climate change. Many farmers are confused by the changing seasons, causing crop irregularity (Measey, 2010). Meanwhile, agriculture contributes

13.4% of Indonesia's GDP and absorbs one-third of total employment (Alisjahbana & Busch, 2017). Also, Indonesia is ranked third in the highest rice-producing and sixth in per capita rice consumption (Kinose et al., 2020).

The effect of climate change in Indonesia is not only on the environment but also on its people and development, especially the economic sector. Climate change has shaken Indonesia, growing over the past two decades. The intensity of the multi-hazard induced by climate change will pose an economic development threat (Measey, 2010). For instance, as an archipelago country, many people depend on agriculture and fisheries (Alisjahbana & Busch, 2017), which are vulnerable to climate change. Many people will lose their jobs and fall into poverty. At the same time, food costs will grow if production fails due to climate change. An increase in food prices will increase extreme poverty in Indonesia by more than 25%. Per capita income per province in 2050 is predicted to experience a loss of around 1 - 5%. Health problems will dominate urban areas, coastal areas experience the sea-level rise, and the rural regions will experience agricultural losses. In addition, climate change affects the environment and biodiversity by threatening coral reef and turtle populations in Indonesia through warming sea surface temperature, rising sea levels and increasing extreme weather conditions. The drastic impact will also be felt by orangutans who rely on forests for survival. However, warming temperature and changes in rainfall affect the phenology of trees and fruits and encourage forest fires (World Bank Group, 2021).

Research in West Nusa Tenggara province on the variability of future seasonal rainfall indicates a water deficit resulting in a water shortage for the growing period of the two rice plants. Saltwater intrusion and lowering groundwater levels will also reduce rice production (World Bank Group, 2021). Lombok is vulnerable to climate change and faces a growing frequency of climate hazards. This island has many potential climate hazards such as rising sea levels, storm surges, ENSO phenomenon, and high waves. Coastal areas are vulnerable to sea-level rise and high tide waves. At the same time, water scarcity is one of the severe problems that Lombok will face in the future, where vulnerable areas are centred in the middle of Lombok and Mataram City. Lombok is predicted to undergo a decline in agricultural production (Laskmi (Laskmi et al., 2022).

2.8 Previous Studies

Khairulbahri conducted a study on the impact of climate change on rice yield, rice production, and harvested areas in West Nusa Tenggara using the combined quantitative method between statistical models and the system dynamics modelling. The statistical model estimated the relationship between climate, production factors, and rice yield. Meanwhile, the SD modelling assessed the impacts of climate change on harvested areas and rice production. This study found that rice yield is predicted to encounter the worst effects of climate change, followed by rice production and harvested areas. Due to climate change, WNT can only meet local rice needs and cannot share it with neighbouring provinces (Khairulbahri, 2021).

In 2010, Lorz et al. assessed three significant natural hazards: windthrow, drought, and forest fire using GIS Technology. Forest areas in Central and Southeast Europe were chosen because they are one of the affected climate change ecosystems, especially natural disaster threats. This research aims to carry out an assessment and map the possibility of natural disasters. Also, they intend to analyse the spatial distribution and make recommendations for future-oriented forest landscape management. They found that the Ceko Republic has a high probability of undergoing windthrow. Most East Germany, North Serbia, half of Austria, and the Ceko Republic have a high probability of experiencing drought because these regions already encountered a water deficit from 1961 to 1990. Besides, most countries have a low probability of forest fires, except Serbia. This country has forests covering 17% of its total area, and 57% of forest areas fall into the high probability zone. Based on the study, the researchers recommend transforming homogeneous forests into multi-structure forests to conserve water, maintain ecology stability in the long term, and expand an effective monitoring system to manage and prevent forest fire (Lorz et al., 2010).

Meanwhile, Merem et al. conducted research in 2019 on a regional assessment of the climate change hazard consisting of sea-level rise, floods, and coastal erosion in Southern Nigeria by using GIS Technology and descriptive statistics with an emphasis on trends, factors, impacts and efforts. This research aims to improve coastal environment management strategies as most of the urban community and economic activities in Southern Nigeria are located along the lowland’s coastline. Also, to support policymakers in designing methods for identifying regional climate strategy indexes and frameworks for effective coastal zone planning. The analysis elucidated that extreme climate events threaten the country with a relatively high risk of drowning due to sea-level rise. Damage to coastal areas because erosion also increased due to the fall of supporting vegetation like mature forests and mangroves. In addition, the exposure to flood risk increases along with the surge of population growth in coastal areas. Hence, budget allocation, policy instruments related to mitigation, sophisticated early warning systems, and support for regional climate agreements are urgently needed to reduce exposure to climate change threats (Merem et al., 2019).

Climate change is causing heavy losses in Europe and is predicted to have a more significant impact over the next few decades. Hence, Forzieri et al., in 2016, held a climate hazard assessment with a focus on modelling seven critical climate disasters in Europe, such as heat and cold waves, river and coastal floods, drought, forest fire and windstorms. This research aims to identify the potential areas of highest exposure to various climate hazards. This research is expected to lead to better adaptation efforts and land planning throughout Europe. Based on the study, Europe is predicted to face the enhancement of climate disaster, especially in the Southwest region, with the primary disaster being heatwaves, droughts and forest fires. Coastline areas and floodplains of densely populated and economically important areas in South and West Europe face the emergence of hotspots. Exposure is projected to increase along with extreme events due to a marked change in frequency (Forzieri et al., 2016).

Natural disasters are increasing in many urban areas. Thus, a multi-hazard assessment is needed to reduce vulnerability in urban areas and make recommendations for prevention and preparedness. Tosic et al. carried out research in Banja Luka city using the GIS approach and cartography that aims to determine the geographical distribution of major natural hazards, including seismic hazards, landslides, rock slides, floods, flash floods, and erosion. Research indicated that 41.33 Km2 of Banja Luka municipality was vulnerable to natural hazards, representing 74.11% of its total area. The high vulnerability was mainly due to seismic hazards, flash floods and erosion. According to the research, it is essential to make a natural hazard risk cadastre in Banja Luka city for urban spatial planning, thereby enabling an acceptable level of risk at all levels and all planning phases (Tosic et al., 2013).

Many locations are vulnerable to natural disasters that can coincide or manifest in a series of tiered events. For this reason, three disasters, including landslide, flood, and earthquakes, were considered for the integrated hazards assessment in Dharan, Nepal. Aksha et al. employed the statistical method and Analytic Hierarchy Process (AHP), focusing on geospatial and socio-economic data. Researchers applied a social vulnerability index (SoVI) to establish a vulnerability map and then mixed it with multi-hazard maps to generate a risk map. A spatial approach was used to model multi-hazard risks effectively and help identify an optimal location to hazard mitigation. The result indicated that the eastern Dharan along Seuti River and the southwest Daran on the left bank of the Sardu River are at high risk of various hazards. Meanwhile, Central Dharan and the hills in the western part of the city are categorised as low-risk areas. Almost all densely populated areas of Dharan are classified as moderate, moderate to high risk, or high. Social vulnerability analysis revealed that central Dharan is less vulnerable than other cities. The western part of areas studied is categorised as low risk, although a relatively poorer built environment characterises the area. This research is useful in urban land-use planning, allocation of scarce resources and informed risk for policy planning at the local level (Aksha et al., 2020).

Climate change impact has raised major concerns for future food supply. Accordingly, Venkatappa in 2021 assessed the impact of drought and flood on agricultural land and production in Southeast Asia. Southeast Asia was chosen because paddy is the main crop for countries like Myanmar, Cambodia, Laos, Indonesia and Thailand. Thus, Southeast Asia is very vulnerable to climate change. Researchers applied Google Earth Engine to assess disasters and their impact on agricultural land and crop production over the 40 years from 1980 to 2019. Palmer Drought Severity Index (PDSI) was also used as a basis for determining the level of drought and flood, crop damage level, and crop failure in the Monsoon Climate Region (MCR) and the Equatorial Climate Region (ECR) of Southeast Asia. The research indicated that there had been an increase in the incidence of mild drought to severe over the last 40 years in all MCR countries. At the same time, the incidence of mild to severe floods had occurred in almost all ECR countries. Rainfed crops were severely affected by drought in the MCR areas and floods in ECR areas. About 9.42 million hectares and 3.72 million hectares of agricultural land were damaged due to drought and flood, with a total loss of 20.64 million tons of crop production between 2015 and 2019 (Venkatappa et al., 2021).

Pourghasemi et al. carried out a multi-hazard probability mapping for three disasters, including landslide, flood, and earthquake, to manage the hazard susceptibility areas in Lorestan Province, Iran. This research used a new ensemble model called SWARA-ANDIS-GWO approach to evaluate and compare the prediction accuracy for each hazard. Disaster susceptibility areas were identified and divided into two data sets: 70% of these locations were chosen randomly to create susceptibility maps, and the remaining 30% were used to assess the model's accuracy. Eleven factors related to terrain and land use were chosen to build drought and flood maps, such as elevation, aspect of slope, design curvature, degree of slope, distance to the river, curvature profile, distance to fault, lithology distance from the road, rainfall and land use. Earthquake maps were prepared based on the probabilistic seismic hazard analyse (PSHA). SWARA-ANFIS-GWO was established for landslide and flood cases, while multi-hazard maps were developed by synthesising three natural hazard maps. The result showed that 43% of Lorestan Province was included in the multi-hazard zone category, and only 17.14% of the total area was not exposed to any hazards (Pourghasemi et al., 2019).

Rangel-Buitrago et al. undertook research to specify coastal hazard as the first step to climate change adaptation using GIS technology in Cartagena City, the Caribbean coast of Colombia. This coastal area experienced hazard related climate change threats in the latest year, especially extreme waves. Researchers used a semi-quantitative method and GIS technology, which used imposition, vulnerability and hazard indexes. The results pointed out that several areas are highly affected by erosion, inundation and flooding. 62% of the Cartagena Region is classified mostly as a medium class in the Coastal Forcing (CSI) index, 30% as a high class in the Susceptibility (CSI) index, and 60% as middle class in the Hazard index (Rangel-Buitrago et al., 2020).

CHAPTER III

RESEARCH METHODOLOGY

3.1 Research Location

Lombok Island is one of the West Nusa Tenggara Province islands and is located east of Bali Island. Geographically, this island is located at 116.351° E dan 8.565°S. Administratively, Lombok Island is divided into four administrative areas and one city: Mataram City, West Lombok Regency, Central Lombok Regency, East Lombok Regency and North Lombok Regency. East Lombok is the largest regency, while Mataram City is the narrowest. The total population on the island in 2020 was 3.758.631 people, with details of 1,873,416 males and 1,885,216 females. The population continues to grow every year, with an increase of 589.939 people compared to 2010. North Lombok has the highest annual population growth rate of 2.08% from 2010 to 2020 (BPS-Statistics Indonesia, 2021). North Lombok and East Lombok Regency had the highest percentages of people in 2017 (West Nusa Tenggara Province, 2019).

The average annual rainfall is 1875 mm, with an average number of rainy days of 140 days per year and an average sunshine duration of 73% per year. The annual average air temperature is 26.80 °C, with an average yearly minimum temperature of 23.30 °C and an annual average maximum temperature of 32 °C (BPS-Statistics Indonesia, 2021). Lombok island is influenced by seasonal climate due to its location at the equator and flanked by two continents and two oceans. The location of this island also causes the influence of east trade winds coming from the Pacific Ocean. The rainy season usually lasts from November to April, peaking in January or February. The timing of the start and end of rainfall varies greatly, with the rainfall onset sometimes shifting or retreating up to a month or two months. The Southern Region receives less rain than the rest of the island (Yasin & Ma'shum, 2006).

The topography of this island starts from flat areas to hills and mountains. The highest elevation is on Mount Rinjani, reaching 3,726 metres above sea level. Lombok island is also surrounded by beaches, primarily white sand beaches, making Lombok one of the favourite tourist destinations. The broadest slope classification ranges from 2 - 15%, covering 198,616 Ha (9.85%) (West Nusa Tenggara Province, 2019). In addition, each region in Lombok Island has a fairly wide and fertile agricultural land, especially in East Lombok, West Lombok and North

Lombok. This is why most people work as farmers, with the primary commodities being rice, corn, soybeans and tobacco (BPS-Statistics Indonesia, 2021). The failure of rice harvest is mainly related to the global climate variation caused by the ENSO phenomenon (Yasin & Ma'shum, 2006).

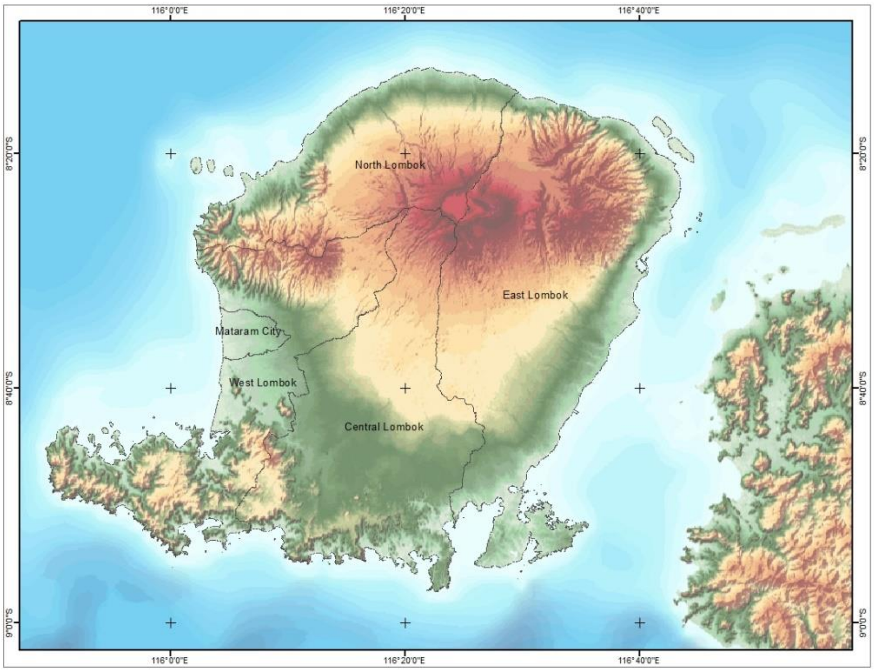

Figure 4 Lombok Island

3.2 Research Design

The study utilized the mixed methods between quantitative and qualitative methods, explicitly focusing on GIS Technology. AHP analysis and questionnaire surveys were employed to generate multi-hazards maps on Lombok Island. The questionnaire was distributed to experts regarding climate change disasters and agriculture to determine the weight of parameters to support AHP analysis. Different questionnaires were spread out to local government regarding climate change disasters and agriculture in Lombok Island to answer their readiness in dealing with climate change. The scope of this study was limited to assessing the impact of multi-hazard induced by climate change in Lombok Island. The methodology was divided into five stages, as below:

1. Identifying the parameters that affect the phenomenon of flooding, drought and landslides. Parameters are selected based on the intense literature regarding each disaster. Then, each parameter is mapped using GIS Technology.

2. Performing the calculation of the Flood hazard, drought hazard and landslide hazard. The flood and drought hazard maps are constructed using AHP-GIS methods. Meanwhile, the landslide hazard map uses the available map from the relevant ministry.
3. Utilising AHP analysis to create a multi-hazard map.
4. Analysing the susceptibility of paddy fields to multi-hazards maps using the overlay method in the GIS environment.
5. Spreading the questionnaire to relevant stakeholders to answer the latest research question regarding the readiness of stakeholders in dealing with hazards caused by climate change.

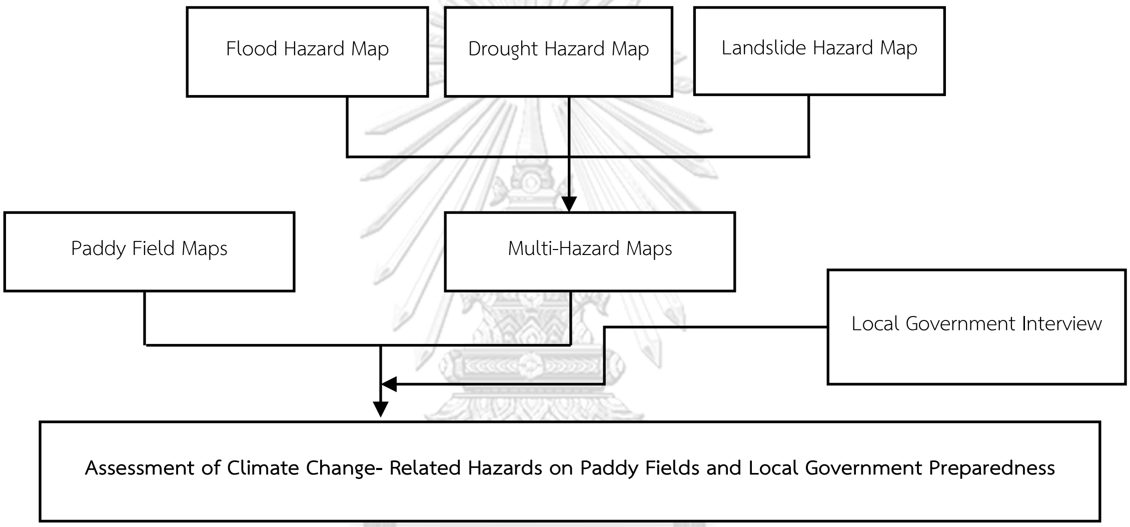

Figure 5 Workflow Diagram of The Research

3.3 Data Collection and Processing

Hazards induced by climate change can damage the environment and the economy, so their evaluation and monitoring is a global priority. Climate hazards spatial assessment is needed along with the acceleration of climate change to assist stakeholders to make decisions in preventing the damage caused (Venkatappa et al., 2021). A spatial approach in disaster risk assessment can provide important information regarding the disaster source areas, possible impact zones, geography of vulnerable populations and the location of infrastructure in hazardous areas (Aksha et al., 2020). GIS technology is able to employ spatial components to manipulate multidimensional phenomena from natural disasters (Seejata et al., 2018). This study will apply the GIS approach to analyse multi-hazard hazards induced by climate change.

GIS technology is commonly used in geohazard research (Tosic et al., 2013). The use of GIS technology is simple to define areas with the status of vulnerability in each region. GIS can manage the different information, analyse and process the information together. It opens new possibilities for the simulation of a complex system. GIS provides the technology to the researcher to analyse the data in new ways, predicting natural behaviour, explaining events, and planning strategies (Maracchi et al., 2000). Using GIS can store large amounts of data, georeferenced, retrieve data, perform analysis, and efficiently determine its location with user-defined specifications (Blanco et al., 2018).

Meanwhile, the Analytical Hierarchy Process (AHP) method will be applied to analyse flood map, drought maps and multi-hazard maps. AHP is most helpful when it comes to complex issues with high stakes. The AHP is a method for organising and analysing complex decisions using maths and psychology. Thomas L. Saaty developed this method in the 1970s and has refined it since then. AHP provides a rational framework for a needed decision by quantifying its criteria and alternative options and relating those elements to the overall goal. AHP converts these evaluations into numbers, which can be compared to all possible criteria. This quantifying capability distinguishes the AHP from other decision-making techniques (Passage Technology). AHP enables a better, easier and more efficient framework to identify selection criteria, calculate weights and analyse them (Ouma & Tateishi, 2014). This method has several stages:

(1) Defining the problem (Hammami et al., 2019) and identifying the level of participation of each parameter (Radwan et al., 2018). Each factor is organised into independent elements and represented in a hierarchical diagram (Ouma & Tateishi, 2014).

(2) Preparing a pairwise comparison matrix. At this stage, each factor is assigned an arithmetic value from 1 to 9 (Table 1). The weights indicate the relative significance of the relevant factors after the pairwise comparison matrix is constructed (Seejata et al., 2018). A value of 1 indicates that both factors are equally significant, and a value of 9 indicates that the row factor is much more significant than the column factor (Hammami et al., 2019).

Table 1. Level of Preference Weight for AHP Analysis

Level of Importance/ Preference Weight	Definition	Explanation
1	Equally Preferred	Two activities contribute equally to the objective
3	Moderately	Experience and judgment slightly favor one activity over another
5	Strong Importance	Experience and judgment strongly or essentially favor one activity over another
7	Noticeable Dominance	An activity is strongly favored over another and its dominance demonstrated in practice
9	Extreme Importance	The evidence favoring one activity over another of the highest degree possible of affirmation
2,4,6,8	Intermediate Values	Used to represent compromise between the preferences listed above

Source: Ouma and Tateishi (2014)

The significance and specificity of the study were obtained by using the hierarchical analysis method and interviewing experts. The experts were asked to complete the matrices of the paired comparisons of each level using questionnaires (Pourghasemi et al., 2019). The flood susceptibility maps and multi-hazard maps are generated from the total weight multiplied by the rate of each factor (Eqs. (1)).

$$H = \sum_{i=1}^{n} w_i X_i \quad (1)$$

where H is the flood hazard index, n is the number of factors, Wi is the weight of each individual factor i, and Xi is the rank of each individual factor i (Kittipongvises et al., 2020).

(3) Conducting a consistency test to prevent incidental judgments in the pairwise comparison matrix. The result of the Eigenvector matrix created by the AHP method needs to be evaluated for consistency. The value of the eigenvector is the weight of each element. This step is to synthesise options in prioritising elements at the lowest hierarchical level until achieving goals. The Consistency Ratio (CR) is calculated using deviation ratio value (Eqs. (2)) (Kittipongvises et al., 2020). This allows the user to conclude whether the evaluation is sufficiently consistent (Ouma & Tateishi, 2014). If CR ≤ 0.1 or CR ≤ 10%, the matrix is considered relatively consistent, but the assessment requires revision if the value exceeds 10% (Nsangou et al., 2022).

$$CR = \frac{CI}{RI} \quad (2)$$

where CI is the Deviation Ratio and RI is Index Random (Eqs. (3)).

$$CI = \frac{(\lambda \max - 1)}{n-1} \quad (3)$$

λ_{max} is the maximum eigenvalue dan n is matrix size.

Each parameter of hazards caused by climate change consisting of a flood, drought, and landslide will be mapped in the GIS environment. Then, AHP analysis will be applied to obtain the weight of physical and socio-economic factors in the hazard map. Also, it is to determine the appropriate weight in specifying which disasters will most affect rice fields. Hazard maps and multi-hazard map will be generated using a weighted overlay after the AHP analysis is performed.

3.3.1 Floods Hazard

Floods are one of the most frequent natural disasters and cause a lot of damage (Nsangou et al., 2022). Hence, flood hazard maps become an essential tool in identifying and understanding the level of flood susceptibility (Seejata et al., 2018). GIS application in flood assessment can also serve as basis data for making flood mitigation strategies in order to reduce local flood risk (Kittipongvises et al., 2020). The depiction of flood susceptibility based on geo-environmental factors effectively implements flood mitigation strategies in an area (Nsangou et al., 2022). Generally, morphological and hydro-meteorological factors are commonly used by researchers in constructing flood hazard maps (Kittipongvises et al., 2020). Six parameters have been identified in this study as factors that support the flood phenomenon.

Table 2. Data used with their sources for Flood Hazard Mapping

Data	Data Sources
Annual Average Rainfall from 1981 to 2018	Indonesian Agency for Meteorology, Climatology, and Geophysics (BMKG)
Slope	The Geospatial Information Agency (BIG)
Elevation	The Geospatial Information Agency (BIG)
Drainage Density	The Geospatial Information Agency (BIG)
Distance from the River	The Geospatial Information Agency (BIG)
Land use	The Ministry of Agrarian Affairs and Spatial Planning/National Land Agency (ATR/BPN)

The amount of rainfall that falls in the area is not the same at every point in the area. Consequently, the area with the most significant rainfall is considered vulnerable to flooding (Nsangou et al., 2022). Topography has a significant influence on flood risk. Elevation significantly influences flood propagation in the study area and controls the movement of water direction and flood depth. Also, areas with low slopes are at higher risk because they are more susceptible to flooding. This factor plays a vital role in determining the amount of surface runoff and infiltration (Hammami et al., 2019). The elevation and slope maps are obtained from the Digital Elevation Model of Indonesia, which has a spatial resolution of 0.27-arcsecond. The elevation index and slope percentage will be estimated with the spatial tool in ArcGIS software.

Drainage density will be created using line density analysis in ArcGIS software. The density level is essential to flood control measures (Hammami et al., 2019). Drainage density indicates the soil and geotechnical properties of an area, which the higher the drainage density, the more susceptible the catchment area to erosion (Ouma & Tateishi, 2014). The distance from the river denotes the risk of flooding due to proximity to the channel (Nsangou et al., 2022). The buffer analysis will be used in determining the distance level. Meanwhile, the land use map is essential to identify vulnerable areas to flooding as they affect the infiltration rate. The city areas generally increase runoff while forests support water infiltration (Hammami et al., 2019).

To carry out a comprehensive flood hazard assessment, it is necessary to assign the weight of each parameter to all other parameters. Hence, flood hazard maps will be generated using the AHP-GIS method, which is often used in mapping flood hazard assessment in the world (Kittipongvises et al., 2020) and has adequate accuracy (Radwan et al., 2018). The AHP-GIS method will be applied to manipulate six parameters to produce a flood hazard map. This method can consider several parameters sequentially to obtain precise results (Nsangou et al., 2022). Parameters used are weighted based on the importance of each parameter in influencing flood events, which is determined by the assessment of experts (Kittipongvises et al., 2020).

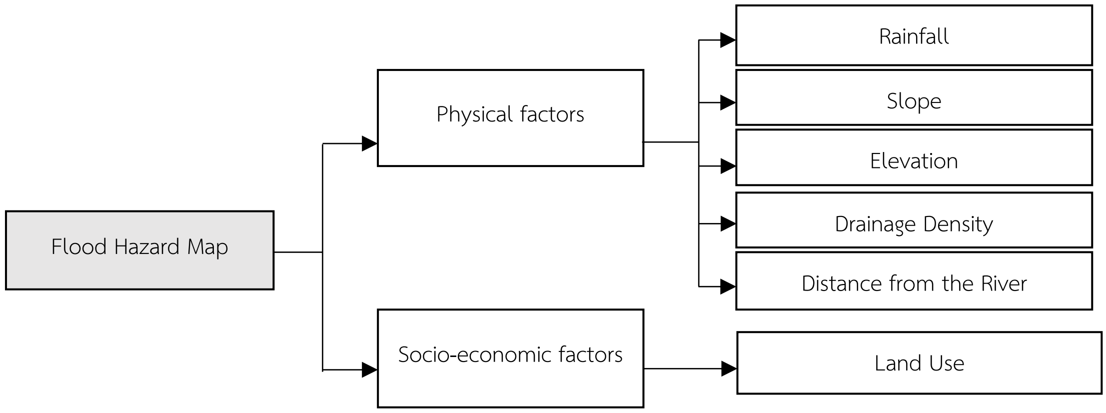

Figure 6 Three-level hierarchical structure of flood map parameters

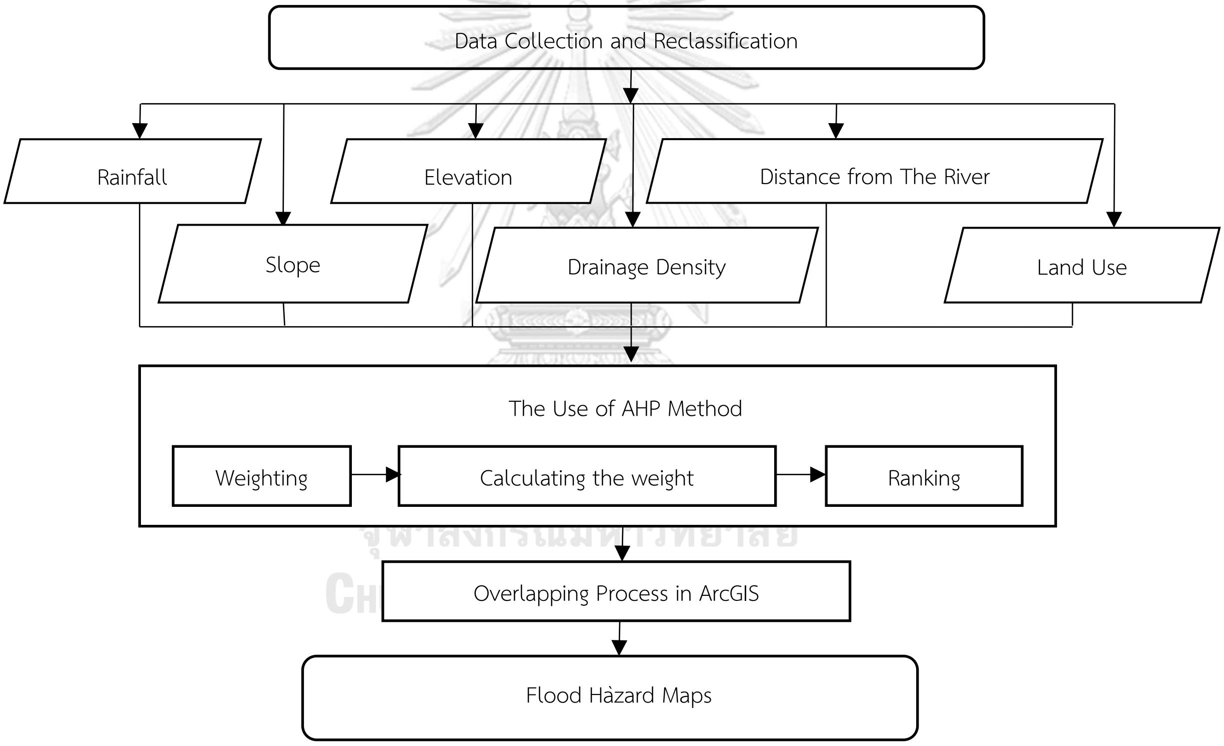

Figure 7 Methods followed in generating Flood Hazard Maps

3.3.2 Drought Hazard

Drought is a complex phenomenon that involves natural and human factors, causing vulnerability (Asrari et al., 2012). Some researchers define drought as a period of arid weather that causes water shortage and crop damage. Lack of water is the main feature of this disaster (Shah et al., 2015). Drought provides many disadvantages such as loss of crops, reduced urban water supply, land degradation and desertification, forest fires and social alarms.

Basically, this disaster is considered a climatic phenomenon, an abnormal decrease in rainfall (Asrari et al., 2012). This research will examine the meteorological drought disaster and as a base to build a multi-hazard map.

Researchers around the world have developed many methodologies for assessing and classifying drought. Drought indices based on climatic and hydrologic variables are the most common. These various methods and indices can give different results regarding the impact and severity of drought in the same area (Sobral et al., 2019). GIS has become a trend that is used to map various natural hazards. This technology helps forecast natural risk and make decisions to monitor and evaluate the hazards. In addition, decision-making multi-criteria analysis like AHP analysis can eliminate bias in weighting assigned to factors that contribute to drought (Zagade & Umrikar, 2020). Hence, this study will develop a multi-parameter model to undertake spatial analysis of drought by implementing the AHP-GIS method. Parameters are carefully selected through a literature survey so that they can represent decision-making and contribute to the ultimate goal. Some of the parameters that affect vulnerabilities and their data sources are below.

Table 3. Data used with their sources for Drought Hazard Mapping

Data	Data Sources
Annual Average Rainfall	Indonesian Agency for Meteorology, Climatology, and Geophysics (BMKG)
Slope	The Geospatial Information Agency (BIG)
Drainage Density	The Geospatial Information Agency (BIG)
Land-use	The Ministry of Agrarian Affairs and Spatial Planning/National Land Agency (ATR/BPN)
Land surface temperature	Google Earth Engine - Modis Imagery 1991 - 2020
Geomorphology	The Geospatial Information Agency (BIG)

Drought occurs mainly due to lack of rainfall (Palchaudhuri & Biswas, 2016). Average annual rainfall is used to understand the characteristics of drought and its intensity in Lombok Island from 1981 to 2018. The slope determines the runoff-recharge ratio and water availability (Zagade & Umrikar, 2020). Slope data is generated using a Digital Elevation Model (Erdem et al.), which can be downloaded from the Geospatial Information Agency website. Water bodies significantly influence drought, reducing drought susceptibility for areas close to water sources due to subsurface flow and irrigation sources (Hoque et al., 2020). River data is extracted from DEM data and Drainage density is created by applying line density analysis in GIS.

Land use is a crucial factor in regulating the hydrology of each watershed. This parameter is the basis for mapping the severity of drought because land use that produces a lot of runoff triggers this disaster (Zagade & Umrikar, 2020). High temperatures increase evapotranspiration and trigger drought, which causes crop failure and reduces agricultural production (Palchaudhuri & Biswas, 2016). Land surface temperature (LST) is exported from Google Earth Engine after processing using Modis imagery for the MOD11A2 V6 product, which provides an average of 8-day per pixel of LST with a spatial resolution of 1 km x 1 km in a 1200 x 1200 km grid from 1991 to 2020. Lastly, geomorphology influences drought hazards through the water availability and surface runoff. Area with sloping to flat geomorphology have moderate surface runoff areas, so it is assumed to have surface water availability more than hilly areas (Zagade & Umrikar, 2020).

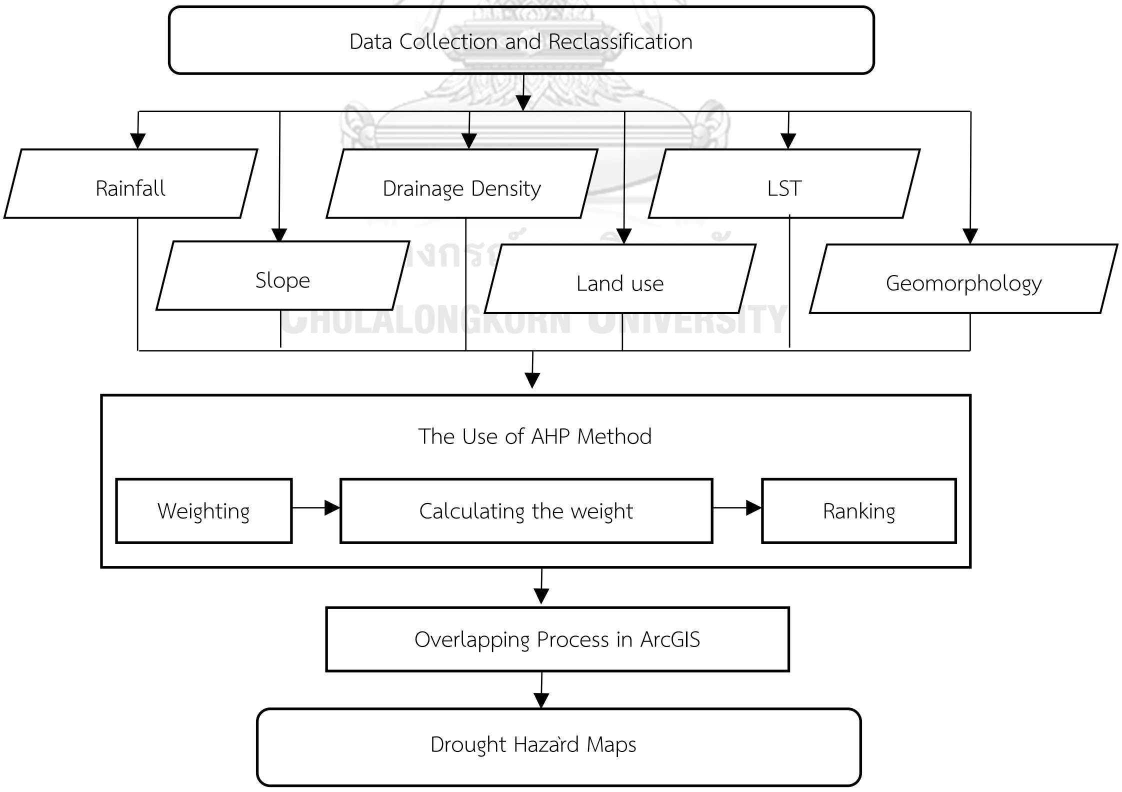

Figure 8 Methods followed in generating Drought Hazard Map

3.3.3 Landslide Hazard

Landslide has been developed worldwide with different intensities and scales. This hazard occurs due to natural factors such as earthquakes, extreme rainfall and human activity like the road or built-up land construction on a hillside prone to landslides. Landslides affect the natural environment and human life (Myronidis et al., 2015). Globally, landslides occur due to geo-environmental combinations. The factors that influence these hazards are bedrock geology, geomorphology, soil, land use, and hydrology condition (Kumar & Anbalagan, 2016). Landslide vulnerability mapping is essential in planning and mitigating landslide hazard because it is able to denote the possibility of landslides in certain areas (Panchal & Shrivastava, 2022). A study of vulnerability to natural disasters in an area facilitates the implementation of infrastructure development planning (Kumar & Anbalagan, 2016).

Various approaches have been developed for mapping landslide susceptibility. However, this study will use the AHP-GIS analysis to synthesise factor or class weight transparently. This method is able to engage all information related to landslides, evaluate all of this information, and detect inconsistencies in the decision-making process by using the consistency index value (Kayastha et al., 2013). It also provides flexible and straightforward decision making that can be accommodated in the GIS domain (Kumar & Anbalagan, 2016). Regarding that method, this study will utilise several parameters to determine the landslide hazard as below.

Table 4. Data used with their sources for Landslide Hazard Mapping

Data	Data Sources
Rainfall	Indonesian Agency for Meteorology, Climatology, and Geophysics (BMKG)
Slope	The Geospatial Information Agency (BIG)
Geology	The Ministry of Energy and Mineral Resources (ESDM)
Topographic Wetness Index (TWI)	The Geospatial Information Agency (BIG)
Land Use	The Ministry of Agrarian Affairs and Spatial Planning/National Land Agency (ATR/BPN)
Distance from Road	The Geospatial Information Agency (BIG)

Rainfall is one of the main factors in generating landslide. Heavy rainfall can produce flooding, which encourages the occurrence of landslides. The water produced by precipitation seeps in and increases soil saturation level, leading to landslide potential (Moradi et al., 2012). This study will employ annual average rainfall data from 1989 to 2018 from BMKG. Another factor that causes landslides is the slope due to its capability to affect the frictional force and control the water flow. The steeper the slope in an area, the greater the chance of landslide (Panchal & Shrivastava, 2022). National Digital Elevation Model (DEMNAS) downloaded from the Geospatial Information Agency website will produce slope data.

In addition, Geology plays a role in slope stability because it is related to the weathering properties of the soil. Land use in general also affects the slope material's strength against sliding and controlling water content. Plant roots can strengthen slope, and land use that absorbs groundwater reduces landslide potential (Moradi et al., 2012). Topographic Wetness Index (TWI) effectively understands soil moisture conditions and is associated with flow accumulation in specific terrain. TWI factors consider the catchment water area and slope, which can be calculated using the formula below.

$$\mathrm{TWI} = \ln \frac{CA}{\tan slp}$$

Where CA is catchment area, and *slp* is slope angle. TWI will be calculated using ArcGIS software (Kumar & Anbalagan, 2016). CA indicates a tendency to receive water, while the slope angle denotes a tendency to drain water. Meanwhile, the road is able to change the topographic properties and reduce the shear strength of the slope foot. Roads also affect slope water infiltration and evoke extra pressure due to traffic load (Moradi et al., 2012). The distance from the road will be generated using the buffer technic in ArcGIS software.

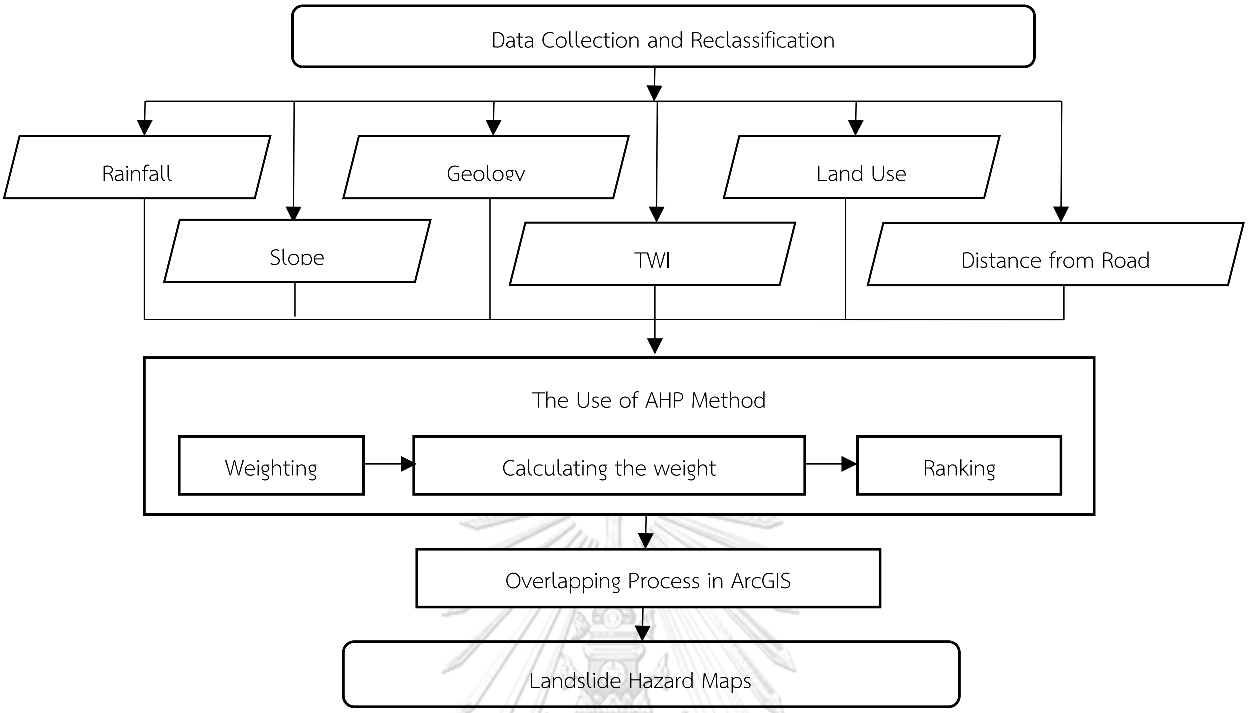

Figure 9 Methods followed in generating Landslide Hazard Map

3.3.4 Multi-hazard Maps Assessment

The multi-hazard is a good approach in observing several hazards in one location, even though each hazard can be monitored separately and integrally (Tosic et al., 2013). Many areas are vulnerable to various natural hazards, which can coincide or in stages, thus requiring consideration of combined hazard risks (Aksha et al., 2020). Besides, it is necessary to analyse the most significant natural hazard assessment in the selected area because disasters occur suddenly (Tosic et al., 2013).

Three disasters caused by climate change were utilised for the final preparation of the multi-hazard assessment, including flood, drought and landslide. First, each hazard is mapped individually based on the conditioning factors and method chosen. Next, the three maps were overlaid to generate a unified multi-hazard map. However, in order to integrate the various variables in spatial decision-making and determine their relative importance, it is necessary to weigh and rank the individual hazard. The AHP method was used as a basis for integrating and determining the importance of each hazard. After selecting the relevant weight, an integrated hazard map was established using GIS technology. The result of the multi-hazard map was classified into three classes: High, Medium, and Low.

Then, spatial analysis tool in GIS technique was performed based on an overlapping analysis of the multi-hazard map and generated with the Lombok rice field map to spatially assess the multi-hazard impacts caused by climate change on paddy fields. Paddy field map was obtained from The Ministry of Agrarian Affairs and Spatial Planning/National Land Agency in 2018. The map was classified into four classes: High impact, medium impact, Low Impact, and No impact.

3.3.5 AHP-Pairwise Comparison: Interview Method

In this study, the AHP method was used in 2 phases. The first phase is used to prepare the flood hazard mapping. The second phase is the preparation of the multi-hazard mapping. Interviews were conducted with several expert respondents (n=8) to provide an assessment based on a relevance value of 1-9. Relevant experts will assess how to influence each factor is in causing flooding and how much impact each hazard caused by climate change will have on rice fields. This assessment score will calculate each criterion in the pairwise matrix comparison to produce the appropriate weighting factor.

Table 5. Pairwise comparison matrix for each parameter

No.	Parameters	A	B	C
1	A			
2	B			
3	C			

Table 6. Questionnaire scoring the relative significance of the relevant factors for experts in determining Flood Hazard Map

Question: Please select a number to answer, as per the relevance									
1	How much more strongly does "Alternative A" contribute to, dominate or influence the Flood hazard than "Alternative B"?								
	1	2	3	4	5	6	7	8	9

2	How much more strongly does "Alternative A" contribute to, dominate or influence the Flood hazard than "Alternative C"?								
	1	2	3	4	5	6	7	8	9

Table 7. Questionnaire scoring the relative significance of the relevant factors for experts in determining Drought Hazard Map

Question: Please select a number to answer, as per the relevance									
1	How much more strongly does "Alternative A" contribute to, dominate or influence the drought disaster than "Alternative B"?								
	1	2	3	4	5	6	7	8	9
2	How much more strongly does "Alternative A" contribute to, dominate or influence the Flood disaster than "Alternative C"?								
	1	2	3	4	5	6	7	8	9

Table 8. Questionnaire scoring the relative significance of the relevant factors for experts in determining Multi Hazard Map

Question: Please select a number to answer, as per the relevance									
1	How much more strongly does "Hazard A" contribute to, dominate or influence the paddy field than "Hazard B"?								
	1	2	3	4	5	6	7	8	9
2	How much more strongly does "Hazard A" contribute to, dominate or influence the paddy field than "Hazard C"?								
	1	2	3	4	5	6	7	8	9

Table 9. List of relevant experts to assess each parameter for AHP analysis

No.	Experts
1.	Lecturer related to disaster mitigation
2.	Lecturer related to agriculture study

3.	Regional Planning & Development Agency of WNT Province
4.	Regional Agency for Disaster Management of WNT Province
5.	Department of Agriculture and Plantation of WNT Province

3.3.6 Local Government Preparedness Interview

Lastly, the interview method is needed to assess the preparedness of stakeholders in dealing with climate change. This method used semi-structured interviews where the respondents have to answer predetermined open-ended questions. The key questions have been prepared schematically and explored so that the interviews will become more systematic, comprehensive, and focus on the desired objectives. The key questions for each institution arrange based on 4 groups: paddy and farmers situation, paddy field situation, disaster management, and water management.

Table 10. The List of Institutions and The Key Questions of Interview

1. Paddy Field and Farmer's Situation

List of Institutions	No.	Questions
1) Department of Agriculture and Plantation of WNT Province 2) Department of Agriculture, Maritime Affairs and Fisheries of Mataram City 3) Department of Agriculture and Livestock of West Lombok Regency 4) Department of Agriculture and Livestock of Central Lombok Regency 5) Department of Agriculture, Plantation, Forestry, Maritime Affairs and Fisheries of North Lombok Regency 6) Department of Agriculture and Livestock	1	Do farmers know that climate change is happening?
	2	Are farmers in Lombok Island (or each regency) already aware of the dangers of climate change disasters?
	3	How are farmers aware of climate change events? (For instance, change in the rainy or dry season, increase in temperature)
	4	Has there been any climate change adaptation action plan in paddy fields?
	5	Are small and large farmers involved in formulating and implementing adaptation strategies?
	6	Is the disaster preparedness plan in Lombok Island (or each regency) well-informed to farmers?
	7	Have agricultural adaptation extension services been running effectively?
	8	Are agricultural adaptation extension services able to change farmers' perceptions regarding climate change?
	9	What is your institution assistance to farmers in dealing with climate change?

List of Institutions	No.	Questions
of East Lombok Regency	10	Are farmers adequately trained in disaster preparedness plans?
	11	Have farmers ever or actively attended training related to flood disasters?
	12	Have farmers ever or actively attended training related to drought disasters?
	13	Have farmers ever or actively attended training related to landslide disasters?
	14	How many crop losses/failures did Lombok Island (or each regency) experience due to Hazard induces by Climate change?
	15	What are the risks faced by rice farmers during a flood disaster?
	16	What are the risks faced by rice farmers during a drought disaster?
	17	What are the risks faced by rice farmers during a landslide disaster?
	18	Do disasters due to climate change affect farmers' livelihood/sources of income?
	19	Do disasters due to climate change affect farming activities, for example, starting the farming season?
	20	Did the disasters affect the rice supply throughout the island of Lombok Island (or each regency)?
	21	Do farmers know that their paddy fields are vulnerable to climate change disasters?
	22	Are there adequate facilities to prevent the catastrophic impacts of multi-hazard-induced by climate change on farmers? If so, what?
	23	Do farmers have access to affordable credit to increase their ability and flexibility to change farming strategies?
	24	Do all farmers in Lombok Island (or each regency) have easy access to farming facilities provided by government?
	25	Have the farmers seriously used the facility?

2. Paddy Field Situation

List of Institutions	No.	Questions
1) Regional Planning & Development Agency of WNT Province	1	What is the area of the rice fields planned in the spatial plan?
	2	How much Protected Paddy Fields in Lombok Island (or each regency?)

List of Institutions	No.	Questions
2) Regional Planning & Development Agency of WNT Province of Mataram City 3) Regional Planning & Development Agency of WNT Province of West Lombok 4) Regional Planning & Development Agency of WNT Province of Central Lombok 5) Regional Planning & Development Agency of WNT Province of North Lombok 6) Regional Planning & Development Agency of WNT Province of East Lombok	3	What is the area of conversion of paddy fields to other land uses?
	4	Is changing rice fields to other land use in Lombok Island (or each regency) related to climate change?
	5	What disasters (Flood/Drought/Landslide) most damaged rice farming activities?
	6	What does the changed rice field usually become?
	7	How does the government defend rice fields from disasters caused by climate change?
	8	What is your institution's assistance to farmers in dealing with climate change?
	9	During disasters, does the government actively assist affected farmers?
	10	Do disasters due to climate change affect farming activities, for example, starting the farming season?
	11	Are there adequate facilities to prevent the catastrophic impacts of multi-hazard-induced by climate change on farmers? If so, what?
	12	Do all farmers in Lombok have easy access to farming facilities provided by government?

3. **Disaster Management**

List of Institutions	No.	Questions
1) Regional Agency for Disaster Management of WNT Province 2) Regional Agency for Disaster Management of Mataram City 3) Regional Agency for Disaster Management of West Lombok 4) Regional Agency for Disaster Management of Central Lombok 5) Regional Agency for Disaster Management of North Lombok	1	Do your institution know that climate change is happening?
	2	Does your institution know the dangers of climate change?
	3	What are the impacts of climate change on Lombok Island (or each region)?
	4	what are the disasters induced by climate change that occurred in Lombok?
	5	Do farmers know that climate change is happening?
	6	Are farmers in Lombok already aware of the dangers of climate change disasters?
	7	Do you think farmers in Lombok Island know about multi-hazard induced by climate change?
	8	Do you think farmers in Lombok Island feel the increasing trend of flood disasters?

List of Institutions	No.	Questions
6) Regional Agency for Disaster Management of East Lombok	9	Do you think farmers in Lombok Island farmers in Lombok Island feel the increasing trend of drought disasters?
	10	Do you think farmers in Lombok Island farmers in Lombok Island feel the increasing trend of landslide disasters?
	11	What are the impacts of climate change on Lombok Island (or each region) to paddy field?
	12	Has there been any climate change adaptation action/disaster preparedness plan in agriculture?
	13	Are small and large farmers involved in formulating and implementing adaptation strategies?
	14	Is the disaster preparedness plan in Lombok well-informed to farmers?
	15	Are farmers adequately trained in disaster preparedness plans?
	16	Have farmers ever or actively attended training related to flood disasters?
	17	Have farmers ever or actively attended training related to drought disasters?
	18	Have farmers ever or actively attended training related to landslide disasters?
	19	During disasters, does the government actively assist affected farmers?
	20	Where are the locations most vulnerable to flooding affecting rice fields?
	21	Where are the locations most vulnerable to drought affecting rice fields?
	22	Where are the locations most vulnerable to landslides affecting rice fields?
	23	Is there any mapping related to flood hazards in Lombok?
	24	Is there any mapping related to drought hazards in Lombok?
	25	Is there any mapping related to landslide hazards in Lombok?
	26	Is there any mapping related to multi-hazards in Lombok?
	27	If there are already hazards mapping, do farmers know the map?
	28	Do farmers know that their paddy fields are vulnerable to climate change disasters?

4. Water Management

List of Institutions	No.	Questions
1) Department of Public Works and Spatial Planning of WNT Province 2) Department of Public Works and Spatial Planning of Mataram City 3) Department of Public Works and Spatial Planning of West Lombok 4) Department of Public Works and Spatial Planning of Central Lombok 5) Department of Public Works and Spatial Planning of North Lombok 6) Department of Public Works and Spatial Planning of East Lombok	1	Does the volume of water in irrigation sources in Lombok Island (or each region) support rice farming?
	2	What is the impact of climate change on water availability?
	3	Is the water availability able to meet the needs of paddy farming?
	4	How many irrigation sources are in Lombok Island (or each regency)?
	5	How much water resources are needed in paddy fields?
	6	What are the main factors in the water crisis?
	7	Is the number and capacity of irrigation infrastructure for irrigation on paddy fields adequate?
	8	Are irrigation infrastructure and supporting facilities maintained and utilized optimally?
	9	Is there still local wisdom in irrigation water management?
	10	Who manages the irrigation water management system in Lombok? Are Farmers involved?
	11	Is there management of water use and efficient use of irrigation water in order to overcome water shortages?
	12	Are there institutions related to water management?
	13	If so, do farmers play an active role in water management institutions?
	14	During the drought, did your institution actively assist farmers?

CHAPTER IV

RESULT AND DISCUSSIONS

4.1 Flood Hazard Assessment

4.1.1 Factors Affecting Flood Hazard

In this study, a flood hazard map was developed using six parameters, including rainfall, slope, elevation, drainage density, distance from the river and land use. Each spatial data was classified into five classes and given a higher score based on its influence on flood hazards. According to experts, rainfall is an essential factor in controlling flood hazards. The amount of rainfall that falls in an area is not the same as in other areas, so areas with the lowest rainfall have a lower potential for flooding. In contrast, areas with higher rainfall have a higher potential for flooding. 43.8 % or 2,001 Km^2 of the Lombok Island area experience an average annual medium rainfall with rainfall value between 15000 - 2000 mm. Meanwhile, the lowest rainfall covered only 1,23% or 55.34 Km^2 of the total area.

The slope is essential in regulating surface runoff. Furthermore, the infiltration process is influenced by gradients, so that higher gradient will reduce the infiltration process but increase surface runoff. This process makes the areas with a lower gradient more vulnerable to flood because surface runoff becomes more stagnant in that area. Lombok island is dominated by a moderate slope between 5 - 10%, covering 33% of the total study area. Areas with a lower slope between 0 - 2 %, mainly in Lombok Island's south-central region, cover 8% of the total area.

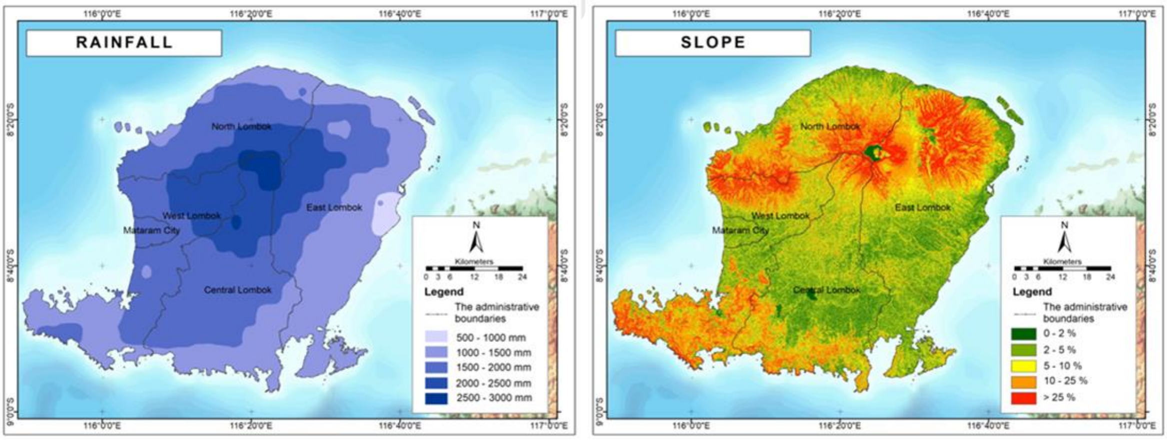

Figure 10 The Rainfall and Slope Maps for Flood Hazard Analysis

Elevation affects flood hazard incidence through surface runoff that tends to move from higher to lower areas. Thus, lower areas with a flat surface experience a higher potential for flooding. The height variation of Lombok Island is 0 to 3635 m. The highest area is in the Northern part of Lombok Island due to the presence of Mount Rinjani. Most of Lombok Island, or a total of 1,424.70 Km^2 of the total area, is at the lower elevation (0 - 100 m), accounting for about 31.18% of the entire study area. Drainage density controls flood hazards because the higher the drainage density, the more potential it is to experience flooding. Lombok Island's area with higher density covers 52.66 Km^2, accounting for about 1.15% of the total area. Most Lombok Island is medium-density, between 0.8 - 1.7 and 1.7 - 3.5, covering about 34% and 33% of the entire study area.

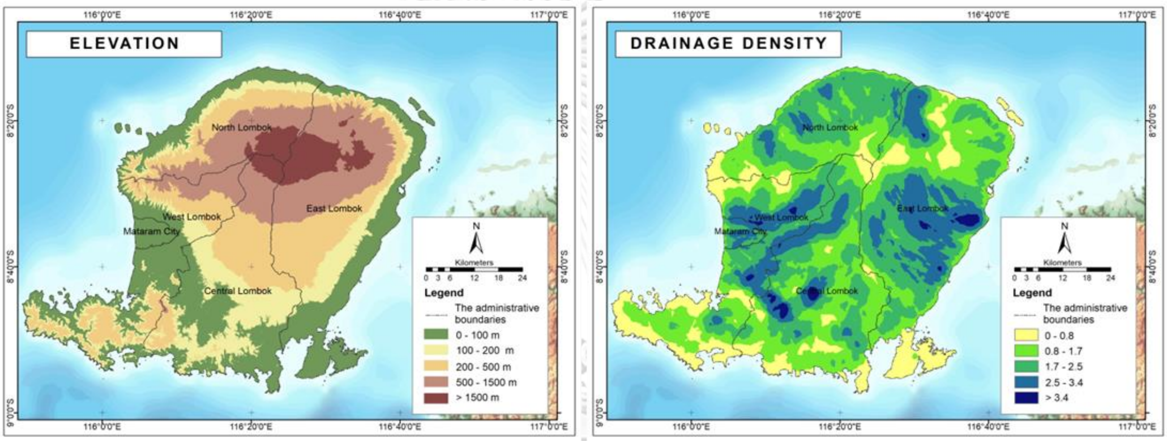

Figure 11 Elevation and Drainage Density Maps for Flood Hazard Analysis

Flood hazard generally occurs in areas around rivers. The further area from the river usually experiences an increase in slope and elevation. Hence, areas further away from the river have a low potential for flood disasters. Distance from the river map is divided into 5 classes, where the class with a high potential for flooding is assigned a classification of 0 - 100 m. Land use is able to identify areas that are vulnerable to flooding because this factor influences the infiltration rate. Land use classification in Lombok Island is divided into 5 classes: agriculture, built area, fallow land, forest, and water. 56.92% of the total area on Lombok Island is agricultural land. The forest area is the second-largest and occupies the northern part of Lombok Island, accounting for about 29% of the total area. Besides, the built area is predicted to be one of the causes of flooding, covering 109.67 Km^2 of the island.

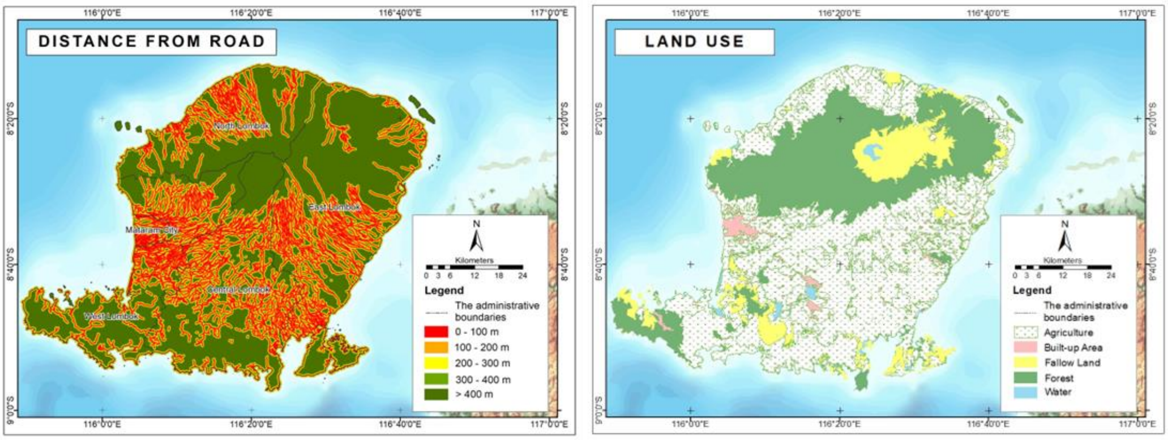

Figure 12 Distance from River and Land use Maps for Flood Hazard Analysis

4.1.2 Flood Hazard Mapping

Weighting process and priority setting are the main goals of AHP analysis. In this study, the decision-making process is determined by eight disaster management experts and agricultural experts who were asked to provide an assessment or weights regarding the significance of the six analysed factors to flood hazards. The pairwise comparison matrices are utilised to specify the weight of each factor. According to the result, rainfall and slope are essential for flood hazards, and elevation is the most negligible significant factor in this hazard. Rainfall is essential in determining flood incidents on Lombok Island because the average annual rainfall varies greatly due to the ENSO phenomenon. Rainfall is a triggering factor for flooding, generally related to the terrain that divides the basin. Natural features and surface changes are decisive in redistributing rainfall to form floods. The water concentration moves from high to low slopes so that floods only appear in areas with lower slopes (Dung et al., 2021). Due to variations in the slopes of this island, the central to the southern region will be more vulnerable to flooding because surface runoff becomes more stagnant in the area.

The results of the flood hazard mapping in this study are a bit different from other research using the AHP method. Munpa et al. (2022) reported that land use and rainfall is the most significant factor affecting the flood hazard in Ayutthaya City, Thailand while the slope is considered a less important factor. In the Mfaoundi watershed, Yaoundé city, South-Cameroon plateau, the AHP method revealed that land cover and elevation are influential factors in the occurrence and distribution of flood hazard due to 62% of its location being a built-up area that tends to encourage runoff and increase flooding (Nsangou et al., 2022). A study by Das (2018) also provides different results where elevation and slope are considered essential factors in identifying flood hazards. This indicates that flooding is a very complex phenomenon because the influencing factors vary between locations due to different conditions and natural phenomena.

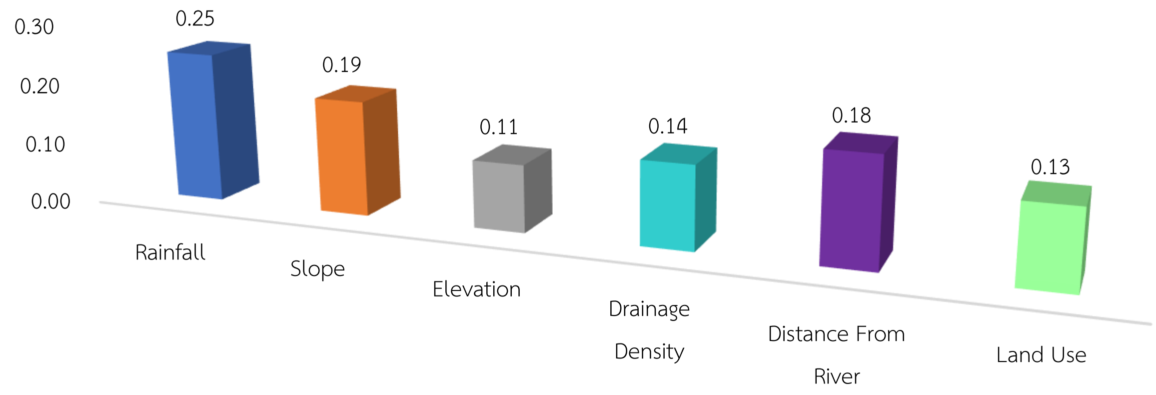

Figure 13 Factor class for Assessing Flood Hazard Using AHP Analysis

The estimated Consistency Index (CI) value is 0.05, and the Consistency Ratio (CR) is 0.04. The CR value is less than 0,1 so that the consistency of the weights is accepted. Flood Hazard is categorised into three classes: High, Medium, and Low. The total area with a high hazard level is 1086.50 Km^2, or covering an area of 24.33%. The high hazard level focuses on the central part and a small part in the northern part of the study area. Besides, Lombok Island is dominated by medium hazard levels, reaching 49.13% of the total area. Central Lombok, West Lombok and East Lombok are the broadest exposure at the highest level of flood hazard. About 393.87 km^2 (36.25%), 275.08 km^2 (25.32%) and 251.05 km^2 (25.32) of their area, respectively, are in the highest category of flood hazard. Simultaneously, East Lombok and Central Lombok dominate the medium-level flood hazard of their area, covering 874.75 km^2 and 579.29 km^2, respectively.

When compared to the area of each regency, Mataram city is the most vulnerable area to flood hazards because 98.47% of the total area is at a high hazard level. The city has relatively high rainfall and is a lowland with an elevation of fewer than 100 m and a slope of less than 5 m. Due to geographical factors, the upstream area exacerbates flood vulnerability in Mataram City. In addition, Mataram City is also a centre of service and trade activities and the most densely populated area on Lombok Island, so most of its territory is a built-up area.

Central Lombok and West Lombok is at the second and third as regency with the highest hazard level, accounting for 30.85% and 16.01% of the total area, respectively.

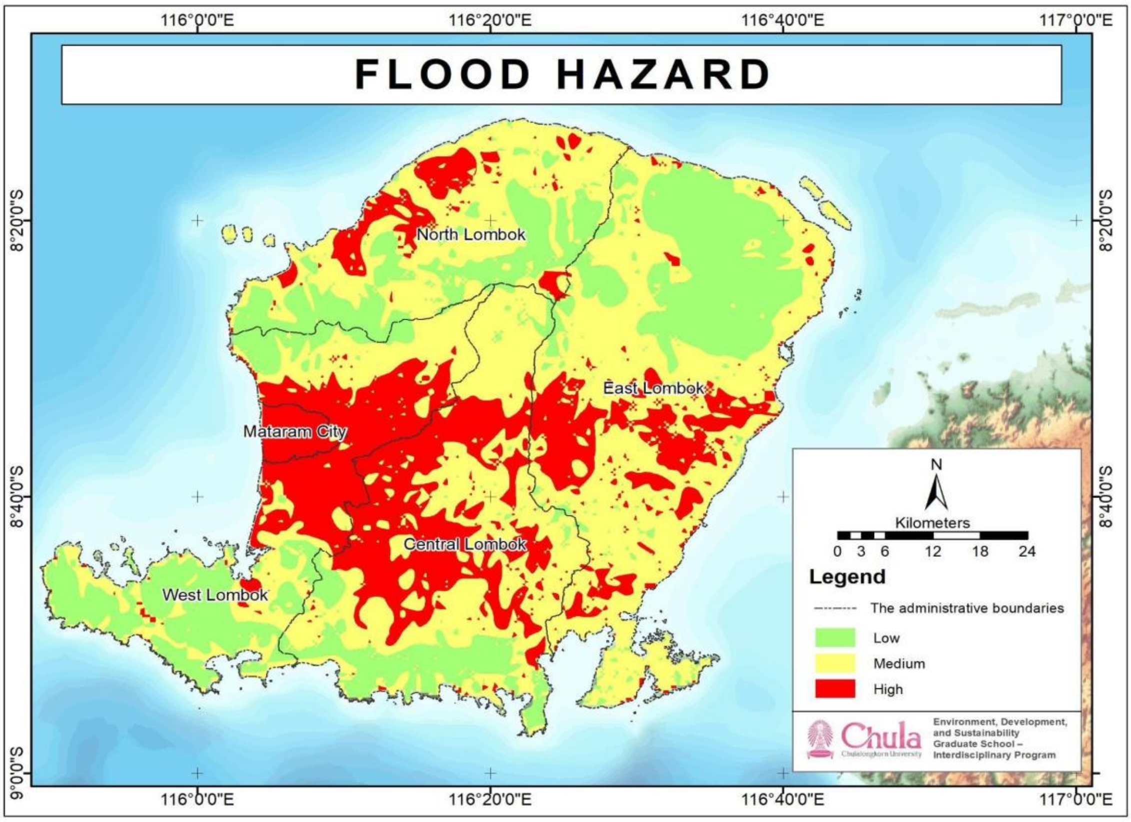

Figure 14 Flood Hazard Map of Lombok Island

Moreover, the broadest medium hazard level is in East Lombok Regency, reaching 55.78% compared to the total area. North Lombok and Central Lombok followed by 54.26% and 50.16%, respectively, of the total area of their respective regions. On the other hand, the result of the flood hazard map generated by the AHP analysis is quite similar to the flood hazard event that occurred from 2017 - 2021. East Lombok experienced the most flood hazard incidents with 30 incidents, followed by West Lombok and Central Lombok with 22 and 17 incidents, respectively, regarding WNT One Data. The increasing rainfall and land-use change in the hilly areas into settlements cause the severity of this hazard in East Lombok. Differences in elevation and slope also significantly affect the downstream area causing flooding due to river overflows and the flood of submission from upstream. At the same time, according to the number of affected victims in the 2017 - 2020 period, East Lombok experienced the most affected victims, as many as 10,467 households, followed by West Lombok, with as many as 7,543 households.

4.2 Drought Hazard Assessment

4.2.1 Factors Affecting Drought Hazard

In developing drought hazard, six factors were utilised, including rainfall, slope drainage density, land use, land surface temperature, and geomorphology. The amount of rainfall and the number of rainy days in an area generally are the critical factors influencing the drought hazard level. The short rainfall duration affects the surface runoff, and the low amount of rainfall allows the possibility of insufficient groundwater supplies (Senapati & Das, 2021). A study by Wijitkosum and Sriburi (2019) in Thailand revealed that rainfall is the most significant factor influencing drought hazards. These findings are supported by (Sivakumar et al., 2021) in India, that reported that drought hazards are highly dependent on rainfall factors, so this factor is given the highest priority in weighting. The dry season in Lombok Island also plays an essential role in impacting soil moisture and water availability. The variation in annual average rainfall is between 500 mm to 3000 mm. The lowest annual-average rainfall covers 56.34 Km^2 or 1.23% of the total area. East Lombok has the lowest annual average rainfall compared to other regions.

Simultaneously, the slope determines infiltration levels in areas. Higher slopes will undergo a shorter rainfall residence time, resulting in lower infiltration rates, and drought is likely to occur. The slope on the island of Lombok is quite diverse, where steep slopes cover the Northern and southern areas while the centre tends to be flat. 40,034.32 Km^2 of the area study lies in slopes of more than 25%, covering 15% of the total area—this area is designated at a high level for drought disaster.

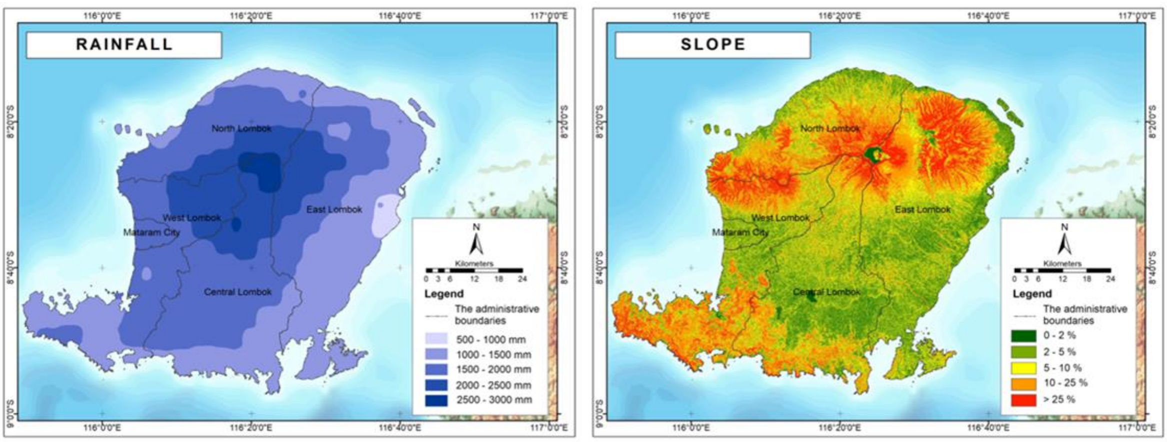

Figure 15 Rainfall and Slope for Drought Hazard Analysis

Drainage density is a sensitive parameter because it depicts the erosion strength of surface runoff, soil, and rock surface resistance and connects landforms along the river (Zagade & Umrikar, 2020). High-density areas are less exposed to drought hazards (Hoque et al., 2020). Hence, the low-density area is predicted to be more vulnerable to this disaster. Approximately 576.82 Km^2 areas in Lombok Island have a density of 0 - 0.8, covering 12.63 of the total area.

Besides, land use influences surface runoff that impacts water deficit. Differences in land use depict differences in the amount of runoff that contributes to the scarcity of water data sources. In this study, land use is formulated into five categories: agriculture, built-up area, fallow land, forest and water. Analysis revealed that agriculture is the primary land use in Lombok Island, reaching 2.600,48 Km^2, and covering 56.92% of the total area. Forest and water have been assigned the lowest rating because it is likely to experience the lowest drought risk.

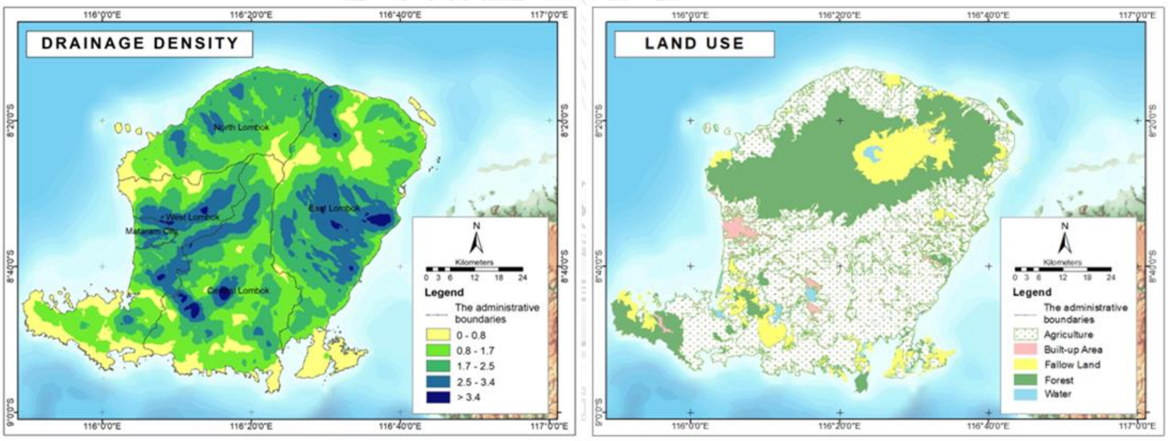

Figure 16 Drainage Density and Land use for Drought Hazard Analysis

Land surface temperature (LST) is commonly used to monitor and investigate drought conditions in an area because this parameter is able to indicate temperature conditions on the earth's surface. This parameter assumes that higher temperatures induce severe drought because it leads to vegetation stress (Kumari et al., 2022). Analysis indicated that 51.25% of Lombok Island's areas are in high temperatures between 29 - 33 ^{0}C, and 4.74 % of areas reach the highest temperature, which is 33 ^{0}C. These indicators indicate that most Lombok Island area is vulnerable to drought. Besides, area study has various geomorphology, starting from flat to mountainous. Most of the research study is dominated by flat geomorphology, covering 51.18% of the total area. Hilly and mountainous areas are scattered in Lombok Island's Southwest and Northern parts.

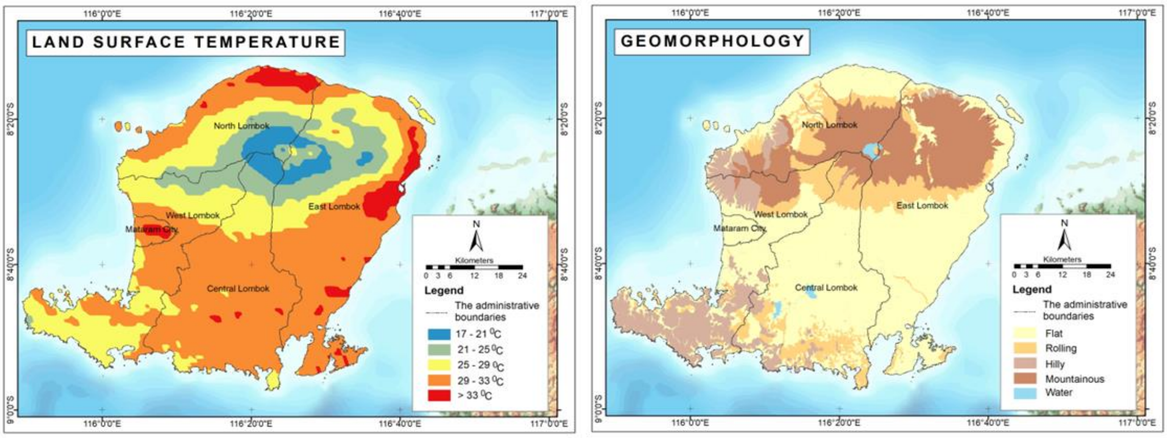

Figure 17 Land Surface Temperature and for Drought Hazard Analysis

4.2.2 Drought Hazard Assessment

Six parameters were calculated to develop a drought hazard map. Each map is weighted due to the different values of each map in determining the drought hazard. The weights were generated after designing the AHP questionnaire, which experts filled out, and a pairwise comparison was made. In this study, the Consistency ratio value is 0.03, so the weight consistency is accepted. With GIS technology, six parameters are analysed, integrated and then multiplied by their respective weights and ratings to produce a drought map. The output map is classified into three classes: High, medium and Low.

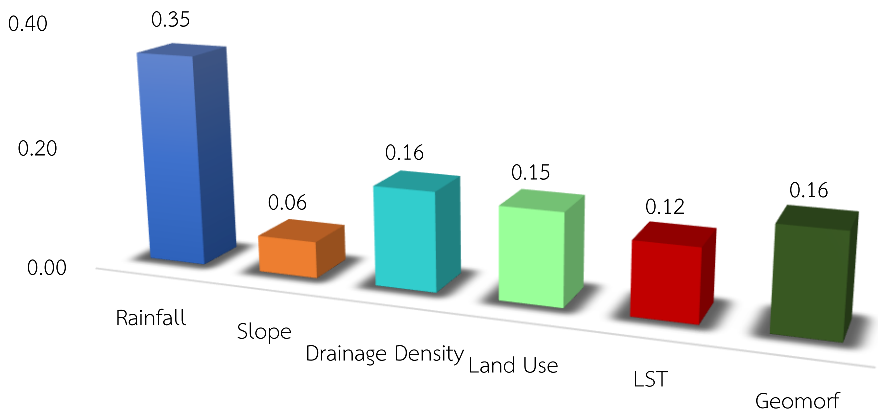

Figure 18 Factor class for Assessing Drought Hazard Using AHP Analysis

According to the results of AHP Analysis, three parameters, including rainfall, drainage density and geomorphology, have the highest weight scores. This indicates that these are the most significant factor affecting drought hazards on Lombok Island. In Contrast, the slope exhibits the lowest AHP weight. Rainfall plays a vital role in the hydrological cycle, where rainfall becomes an input for water sources undergoing various processes such as evaporation. Reduced rainfall will lessen water input, and if this is continuous, the water reserves in the soil will exsiccate and the impacts are a decrease in the number of spring and water discharges (Nandini & Hadi Narendra, 2011). In addition, the southern part of the island is an area that receives less rainfall (Yasin & Ma'shum, 2006), making it more vulnerable to drought.

A study by Wijitkosum and Sriburi (2019) in Thailand revealed that rainfall is the most significant factor influencing drought hazards. These findings are supported by Sivakumar et al. (2021) in India, that reported drought hazards are highly dependent on rainfall factors, so rainfall is given the highest priority in weighting. A Study by Palchaudhuri and Biswas (2016) on drought hazards in Paruliya district, India indicated that rainfall and groundwater are considered important factors in identifying areas susceptible to drought hazards. Another study by Ekrami et al. (2016) in Taft Township, Yazd Province, Iran highlighted that Rainfall and Qanat are influential factors in the occurrence of drought hazards in Iran. It should be noted that rainfall is the crucial factor in drought analysis due to rainfall is repeatedly determined as the most essential factor in the occurrence and distribution of drought hazards.

The drought hazard map denotes approximately 745.34 Km^2 (16.81%) under a high level of drought hazard. These areas have agriculture, fallow land and forest as the main land-use, annual average rainfall less than 1500 mm, less drainage density (< 1.7) and hilly geomorphology covering most southern and Northeast areas. Meanwhile, 61.92% of the study area are classified as a medium level of drought hazard that most of the primary land use is agriculture and built area, flat geomorphology and LST less than 33^0C. At the highest level of drought hazard, East Lombok and West Lombok are the vulnerable regencies due to the large area exposed, about 314.98 Km^2 (42.26 %) and 235.89 Km^2 (31.65%), respectively. Meanwhile, East Lombok holds the widest medium-level drought hazard of 1047.19 Km2.

Looking at each administrative area, West Lombok is the widest regency that experiences a high level of drought hazards of 26.83% of the total area, particularly in the southern region. The main trigger for the broadest exposure to drought is a relatively low average rainfall in a year, low drainage density and many agricultural activities exploit water discharge. East Lombok is the second regency that experiences the widest high level of drought hazard of 20.22% of the total area. Meanwhile, Mataram City and North Lombok are the most expansive areas that encounter drought hazards at medium-level of 82.88 % and 76.56 % of the total area, respectively.

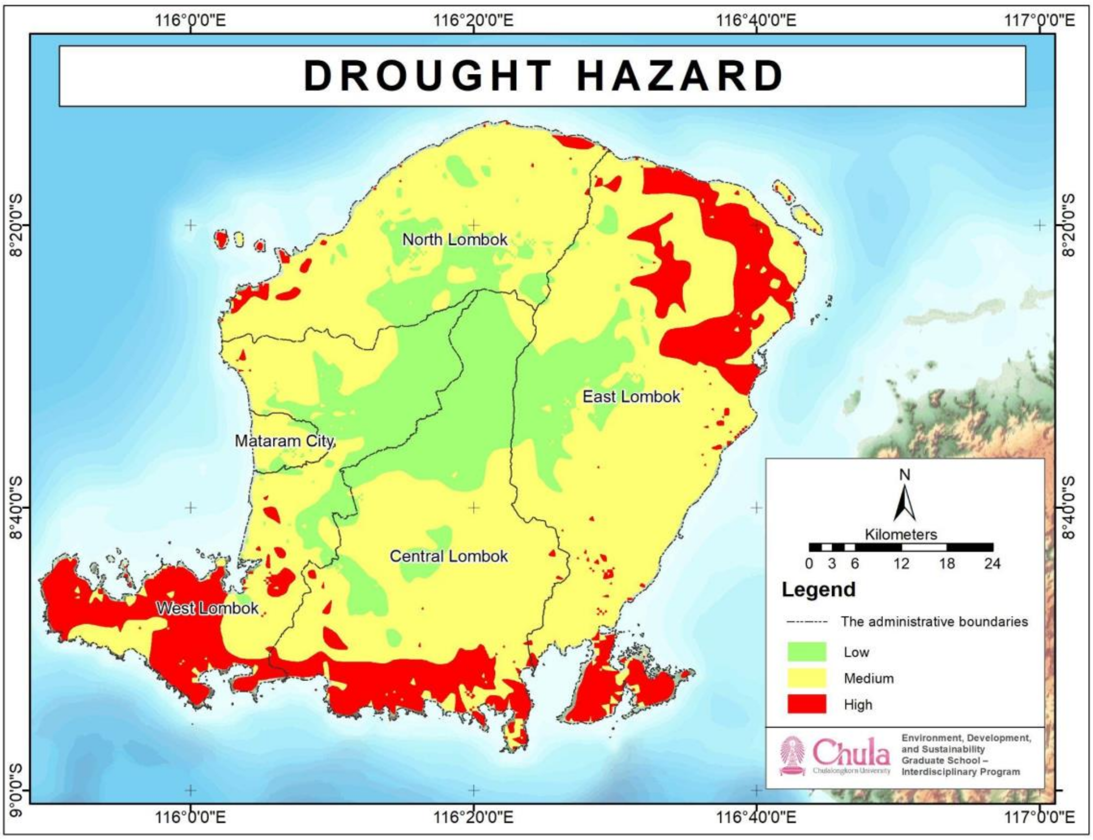

Figure 19 Drought Hazard Maps

Simultaneously, this study represents quite similar results to disaster events data released by One Data West Nusa Tenggara. East Lombok encountered a higher drought hazard in Lombok Island during 2017 - 2021 compared to other regencies, with six incidents. Meanwhile, West Lombok, Central Lombok, and North Lombok followed with five incidents in the same period. Mataram City has reportedly not experienced a drought disaster for the last five years. Along with it, 211.836 households in East Lombok were affected by this disaster, spread over 35 districts. Central Lombok followed as the second number of affected households, which is 109.775 households. Contrary, West Lombok had the least number of affected households, which was around 36.990 households.

4.3 Landslide Hazard Assessment

4.3.1 Factors Affecting Landslide Hazard

Landslide hazard is influenced by various factors. Considering the literature review and available study area data, a landslide hazard map was constructed using six parameters, including rainfall, slope, geology, topographic wetness index (TWI), land use, and distance from the road. Rainfall sways the occurrence of landslide hazards through water that seeps and increases the level of soil saturation, causing landslide potential. Due to the variation of annual average rainfall on Lombok Island, the rainfall map is classified into five classes. Rainfall with the highest classification of 2500 - 3000 mm is in the central part of Lombok Island, a mountainous area.

The occurrence of landslides also depends on the slope, which affects soil stability. The steeper the slope, the greater the chance of landslides. Slope map is classified into five classifications due to their variation. Based on the analysis result, Areas with the highest slope or more than 25% lie in the Northern part and Southwest parts of Lombok Island. The highest slope covers 15.98% of Lombok island's total area, categorised as areas with a high vulnerability to landslide hazards.

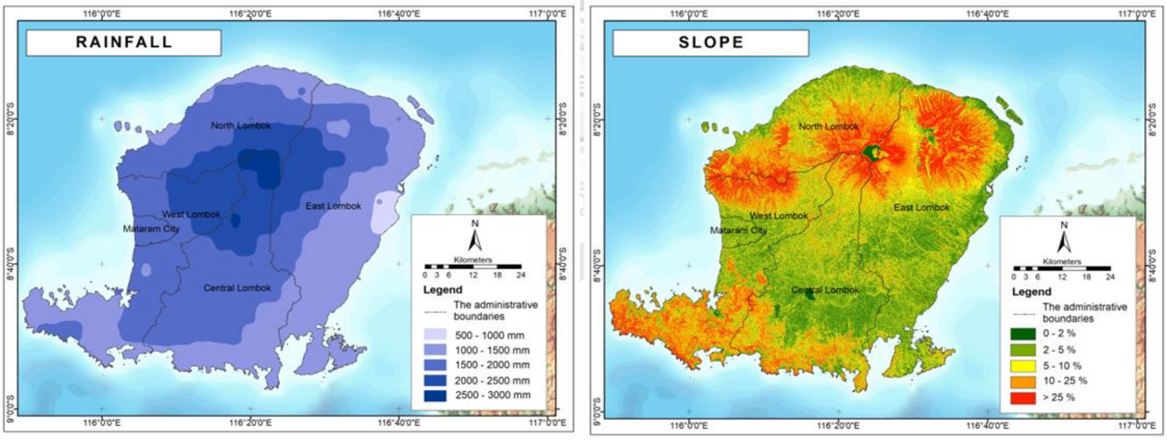

Figure 20 Rainfall and Slope Maps for Landslide Hazard

Research area have diverse geology characteristics. This island is covered by alluvium, young volcanoes, old volcanoes, intrusive rocks, and limestone. The alluvium is predicted to have a very high vulnerability to landslides, covering 9.08% of the total area. Young volcanoes envelop 71.65% of the total area. This geology is also vulnerable to landslides because it is able to be soil if it undergoes a weathering process because the rocks have not yet experienced compaction. Hence, their strength is deficient if they are on steep slopes.

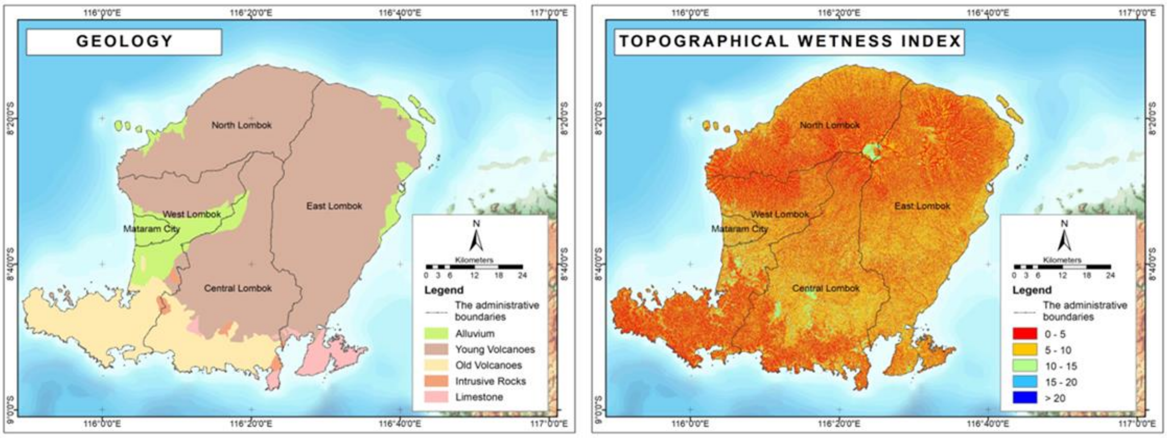

Figure 21 Geology and TWI Maps for Landslide Hazard

Topographic Wetness Index (TWI) are derived from DEM using flow accumulation and slope functions. Using TWI dynamically can describe wet conditions or the inundation possibility. Hence, TWI is considered helpful in determining the location prone to landslides. The highest classification is given to the highest value of TWI or more than 20, covering approximately 0.08% of the total study area. The highest value of TWI was associated with increased water infiltration, which causes an increase in pore water pressure and further reduces soil strength, making it susceptible to slope failure and causing landslides. Most of the research areas are in the TWI range 0f 5 - 10, covering 59.71% of the total area.

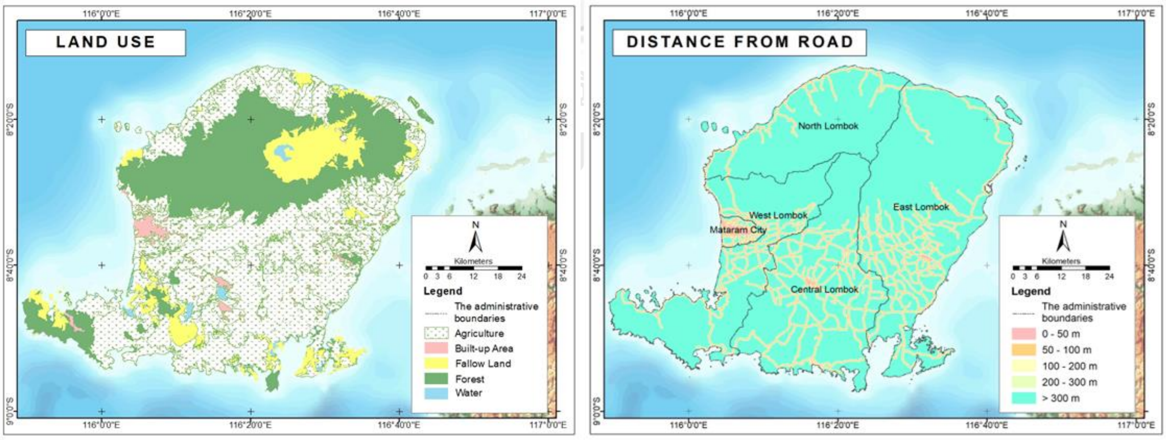

Figure 22 Land use and Distance from Road Maps for Landslide Hazard

Land use is one of the parameters in determining the landslide because it affects slope stability. This study considers five classes of land use: agriculture, built-up area, fallow land, forest, and water. Based on the analysis result, 56.92% of the research study is covered by agriculture. Distance from the road also plays a vital role in a landslide because cutting activities disrupt the natural slope during road construction. In this study, the distance from the road map is divided into five classes, where the closer the distance to the road, the more vulnerable it is to landslides. Areas between 0 - 50 m to the road cover 3.84% of total areas.

4.3.2 Landslide Hazard Mapping

AHP analysis is also implemented to assess landslide hazard maps. AHP was employed to determine factor weight and ranking for each parameter, and the results are checked for consistency. The consistency ratio is 0.03, so the pairwise comparison is considered consistent. The factor weight of each parameter is shown in Fig 4.13. The results denote that the slope holds the highest weight in influencing landslide occurrence, while the distance from the road has the lowest influence. Landslide hazard classification is divided into three classes: High, Medium, and Low.

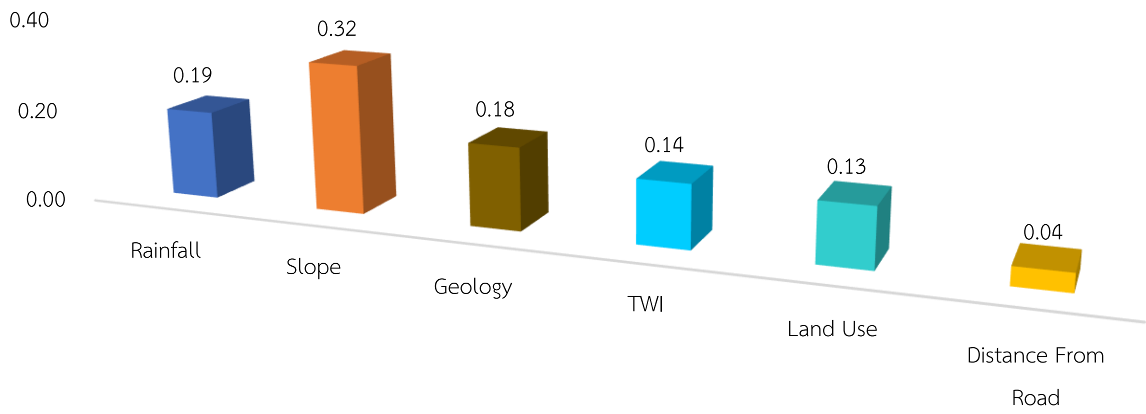

Figure 23 Factor class for Assessing Landslide Hazard Using AHP Analysis

The results of the AHP method pointed out that rainfall plays an essential role in triggering landslides in mountainous areas with high slopes on Lombok Island. Rainfall with high intensity in a short time usually triggers shallow landslides, while the long duration of rainfall triggers deep landslides. The results also mean that steeper slopes in Lombok Island have less friction, and consequently, the produced landslide is more significant. The findings of the landslide hazard mapping in this study are in line with Moradi et al. (2012), who denoted that slope, lithology and geology, and rainfall are the most significant factor affecting landslide hazard in Lombok Hazard. Meanwhile, Kayastha et al. (2013) research in the Tinau watershed, West Nepal, reported that rainfall, land use and distance from the stream are the most influential factor in triggering landslide phenomena. Lombok island is vulnerable to landslides due to its steep mountainous terrain, weathered volcanic sediments and humid tropical climate (Ferrario, 2019). Hence, it should be noted that slope, runoff and geology are considered important factors in identifying areas susceptible to landslide hazards.

The research results indicate that approximately 6.20% of areas in Lombok Island have a high level of landslide hazard. The highest class commonly is in the mountain area, with a slope of more than 10% and an annual average rainfall of more than 2000 mm. However, almost half areas of Lombok Island, approximately 52.13%, are in medium-level hazards. East Lombok is the more vulnerable regency with the broadest exposure at the highest level of landslide hazard, followed by North Lombok and West Lombok. Compared to each area, North Lombok is the widest regency with a high level of landslide hazard, covering 9.89 % of the total area. Followed by East Lombok, covering 8.90 % of the total area. These regencies are mountainous areas that are very vulnerable to landslides. At the same time, Mataram City and West Lombok are the widest regency with a medium level of landslide hazard, covering 89.80% and 73.36 % of the total area, respectively.

Furthermore, the number of disaster events data on Lombok Island during 2017 - 20121 indicates that West Lombok experiences the most landslide incidents with 11 incidents, and East Lombok is in second place with 9 incidents. At the same time, East Lombok and West Lombok have the highest number of households affected during 2017 - 2020, which are 7 households and 6 households, respectively. The analysis of AHP's result provides pretty accurate results in assessing the landslide hazard on Lombok Island.

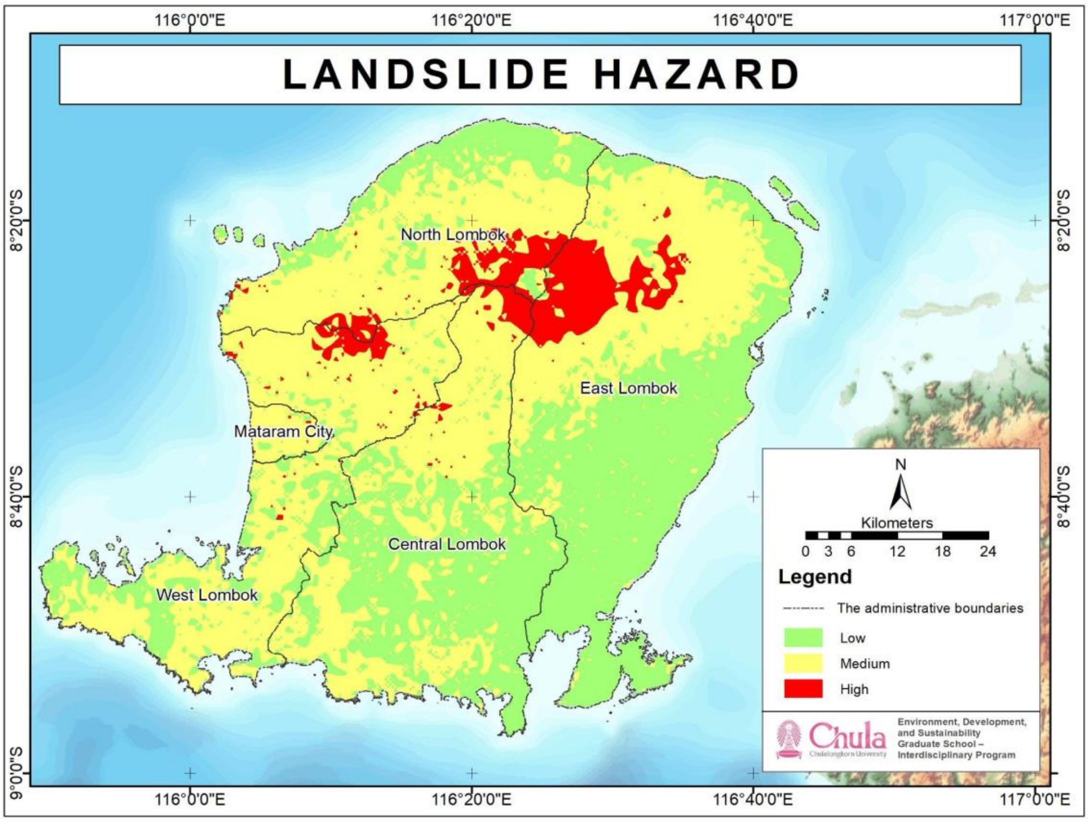

Figure 24 Landslide Hazard Map

4.4 The Impact of Climate Change- Related Hazards on Paddy Fields

4.4.1 Multi-Hazard Assessment

The implementation of AHP analysis was applied to develop three hazard maps: flood, drought, and landslide. This method was also employed to establish a multi-hazard map in a research study. Regarding the results of interviews with disaster management and agricultural experts for AHP method processing, drought is the leading disaster affecting Lombok Island’s paddy fields. Contrary, the landslide is offered the lowest score due to the lowest significance in influencing the paddy field. The multi-hazard output map is categorised into 3 classes according to the different hazard levels: High, Medium, and Low.

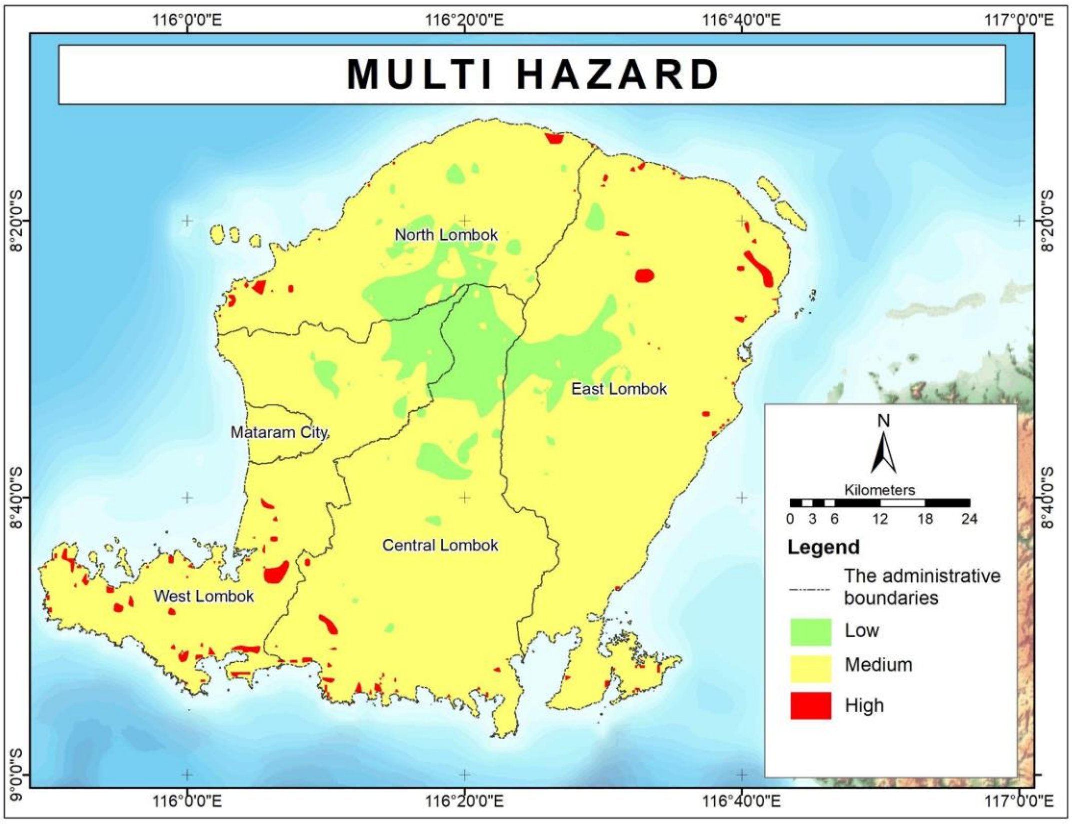

Figure 25 Multi-Hazard Map in Lombok Island

The high level of multi-hazard spread all over Lombok in a small area. It only covers 1.4% of the total area, where West Lombok is the widest. Nevertheless, 88.18% of total areas are in a medium level of multi-hazard induced by climate change, where East Lombok is the widest regency affected, covering 91.48% of the total area. At the same time, Mataram City is also vulnerable to multi-hazard induced by climate change because all of the areas in this regency are at the medium level of multi-hazard. The vulnerability to multi-hazard caused by climate change on Lombok Island is encouraged because most of the land use is agriculture, which requires large water availability. Climate change is also worsening through changing climate patterns.

Figure 26 Areas with High-Level Multi-Hazard in Lombok Island

Figure 27 Areas with medium-level multi-hazard in Lombok Island

4.4.2 Multi-Hazard Impact on Paddy Fields

The area of paddy fields mapped in Lombok Island in 2019 is 1101.61 Km^2. The largest paddy fields are Central Lombok, followed by East Lombok, with 492.20 Km^2 and 401.06 Km^2, respectively. Using the overlay technique, 6.41 Km^2 (0.58%) of paddy fields are at a high level of multi-hazard, and 1063.71 Km^2 (96.56%) of paddy fields are at a medium level of multi-hazard. West Lombok is the most expansive area of paddy fields at a high-level hazard of 2.73 $Km^{2,}$ followed by East Lombok of 2.44 Km^2. Besides, Central Lombok and East Lombok are the most expansive area of paddy fields affected by a medium level of multi-hazard, about 476.28 Km^2 and 390 Km^2, respectively.

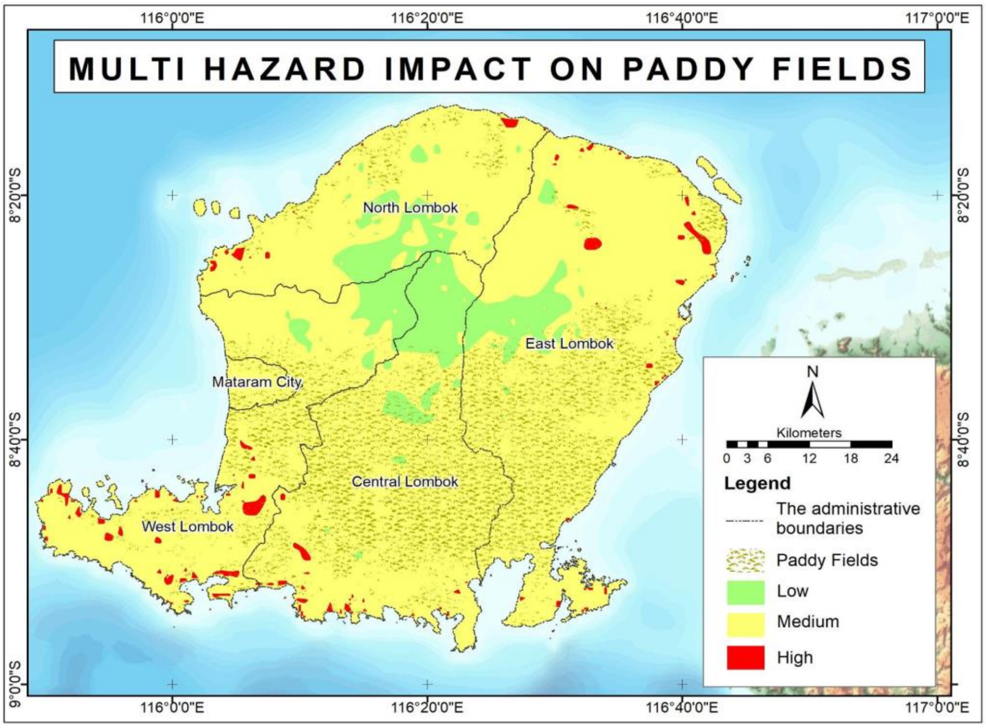

Figure 28 Multi-hazard Impact on Paddy Fields Map

Figure 29 Paddy fields with a high level of Hazard (a) north Lombok (b) Central Lombok

Figure 30 Paddy fields with a medium level of Hazard (a) East Lombok (b) West Lombok

The abundance of agriculture land in Lombok Island makes the agricultural sector as the most significant economic supporter and the main livelihood of the community. Nevertheless, enormous population growth and industrialisation have attracted rural communities to leave agriculture and seek work in other sectors. The development of the tourism sector also contributes to the increase in land use change, where Lombok Island is chosen as one of 10 New Bali Programs. In addition, the effect of climate change on the agricultural sector is getting worse through the increased intensity of floods, droughts and landslides that cause crop failure. Paddy statistics in Lombok Island denote that total paddy production in WNT over the past 11 years has experienced a decline in production and harvested area. There was a significant decline in 2019 due to a prolonged dry season which caused a drought.

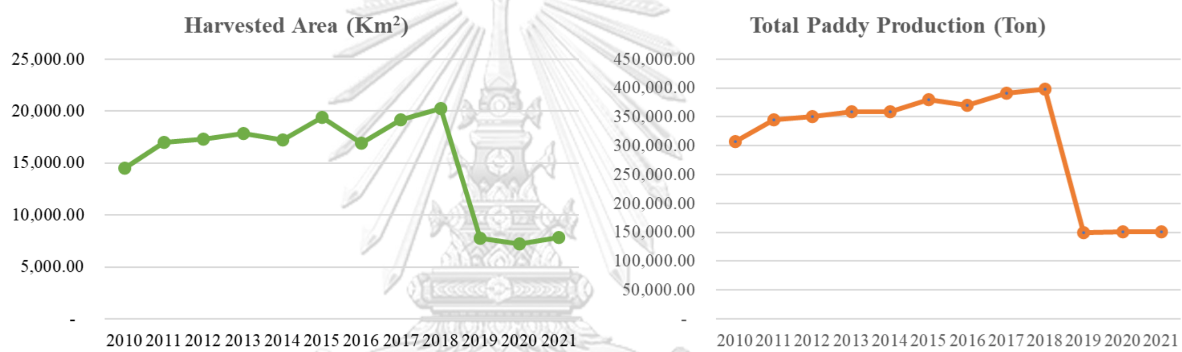

Figure 31 Paddy statistic in Lombok Island during 2010 - 2021

In addition, the ENSO phenomenon also significantly affects extreme weather events, directly impacting rice production growth. The drought due to the El-Nino phenomenon is the main factor affecting severe productivity and food insecurity declines. History in 1997/1998 reported that Lombok Island experienced a paddy production decline of as much as 8400 Ha paddy plants due to severe drought (Yasin et al., 2004). Therefore, to prevent a decline in paddy production due to disaster induced by climate change, the government related to agriculture, agricultural experts and farmers need a deep understanding of the phenomenon of climate change and ENSO. Adaptation efforts in dealing with climate change in the agricultural sector are one of the steps to prevent future rice production failure. This multi-disaster mapping can also help describe rice fields on the island of Lombok, which is at a medium level against the threat of hazards due to climate change. This can assist the Government of Lombok determine adaptation policies and strategies based on local needs and conditions. Climate change is a formidable challenge for the agricultural sector in the present and future because agricultural production must continue to increase to achieve food security, reduce poverty, malnutrition and maintain the livelihoods and welfare of farmers.

4.5 Interview Results

Risks and hazard vulnerability are generally differed in different places due to the different landscapes. Hazard experience, knowledge and risk perception build disaster adaptation for each individual (Guo et al., 2021). Disaster preparedness plays an essential role in disaster management and disaster risk reduction. It can reduce the risk of injury and damage and increase the ability to overcome disturbances associated with hazardous activities (Kusumastuti et al., 2021). Trust in stakeholders, especially local governments, is one of the determinants of disaster preparedness behaviour (Zhang et al., 2017). This research interviewed the representative from Regional Agency for Disaster Management (BPBD), Regional Planning & Development Agency (Bappeda), Department of Agriculture, and Department of Public Works and Spatial Planning (PUPR) to study the Lombok Island government's preparedness in dealing with climate change hazards to paddy fields.

4.5.1 Paddy and Farmers' Situation

Generally, West Nusa Tenggara (WNT) is one of the country's main crop producers, particularly rice. There is a monument called the Bumi Gora, which is a milestone in the pride of WNT, especially Lombok, in developing rice with the Gogo Rancah (Gora) planting system inaugurated in 1988. The construction of this monument is a gratitude form for the success of the farmers, who became one of the largest contributors to rice self-sufficiency in 1984. Every year, this island is able to produce more than 300.000 tons of rice. Nevertheless, about 19% of all paddy fields on this island are paddy rainfed, which is heavily affected by rainfall. Along with it, this island is a small island with a greater vulnerability to climate change. Extreme weather events causing floods and prolonged drought exacerbated by climate change pose a significant threat to rice production.

The interview results stated that floods and drought were the most dominating disasters on Lombok Island. This island is also anticipating the occurrence of tornado whose intensity is starting to occur frequently. The beginning of the year is the largest frequency of flood incidences, while entering July, the government is preparing for the drought hazard due to the decreasing rain intensity. BPBD of WNT respondents claimed that climate change caused a seasonal shift, and the timing of the rain became erratic. Lombok Island, which should have entered the dry season in May, has been experiencing rain for the past few years.

Nevertheless, every regency on this island has a different vulnerability to hazards. West Lombok government declared that the main factor in the occurrence of the disaster in this regency was the weather that caused flooding, drought, landslide and tornado. Meanwhile, the North Lombok government asserted that drought is the biggest threat in their territory. Water scarcity has been the primary obstacle felt by the community, especially in carrying out daily and agricultural activities. Hence, the government announce a drought alert status in July. Southern Lombok, which consists of West Lombok, Central Lombok, and East Lombok, is also very vulnerable to drought, significantly disrupting agricultural activities. It makes central and private agencies work together to supply water. Additionally, West Lombok and Central Lombok sometimes experience multi-disasters due to heavy and prolonged rains that cause floods and landslides.

There are different opinions between the provincial and regency governments regarding farmers' awareness of the hazards induced by climate change. The provincial government stated that farmers should be aware of those hazards because WNT province has been actively providing information and outreach to the public regarding climate information. They also have been providing infographics on how to deal with disasters. This awareness is also based on the farmers' experience, who find it increasingly difficult to predict the weather. Conversely, West Lombok, Central Lombok and East Lombok governments claimed that farmers' awareness is very low. It also could be said that they are unaware of hazards caused by climate change, or they only realized that their areas were often affected by disasters without knowing what climate change was. They feel that the disaster they experience is only an annual phenomenon, so no preparedness action is taken.

On the other hand, there are many land-use changes, especially from agricultural land to industrial areas. Most of the changes occurred in paddy fields on the side of the road. Every year paddy fields on Lombok Island continues to decrease due to various development for housing, shop, and offices. Mataram city is one of the higher areas that experienced land use change, followed by West Lombok and Central Lombok. The main reasons supporting land conversion are the higher economic value of land, the need for land for non-agricultural activities, and the lack of interest of the younger generation in managing agricultural land. Hence, the Lombok government stated that there is no specific correlation to the impact of climate change. Land use changes occur due to economic factors more beneficial to the community.

4.5.2 Disaster Management

Disaster preparedness is a stage in disaster management to be able to anticipate greater loss. In anticipating disaster, knowledge regarding climate change will support better response in the preparedness phase. The interview result indicated that all respondents and their institutions are aware of climate change. It started with the bold initial step to mainstream adaptation into its development plans. The WNT government is the first in Indonesia to consider its vulnerability to climate change impacts by issuing a climate change action plan inaugurated through government regulation No. 54/2019.

A respondent from BPBD of WNT declared that their institution always coordinates with BMKG related to climate data to inform the community regarding climate data for anticipating climate change hazards. Detailed climate-related information was disseminated through social media to the sub-district level and then forwarded by village officials to the community. BPBD also completed potential disaster and hazard risk maps on Lombok Island using maps compiled by BNPB. Mitigation disaster activities are also often socialized to the community in collaboration with NGOs and students. BPBD of Mataram City also stated that the climate change program in their area is very adaptive and mitigative because it is well coordinated between sectors.

In formulating a preparedness strategy, BPBD usually invites village officials whose specific areas have the potential to experience certain disasters. Some programs have been done by the Lombok Island government, such as Desa Tangguh Bencana (Disaster Resilient Village), The Siap Siaga Program (Preparedness Program), Sekolah Awam Bencana (Disaster Early School) and training to the community concerning how to deal with the disaster. One leading program is Desa Tangguh Bencana (Disaster Resilient Village). This is the program carried out by the Lombok government to rural communities through training for having the ability to recognize the threat in their areas and organizing their resources to reduce vulnerability and, at the same time, increase capacity to reduce disaster risk. Some activities in this program include learning and application, such as planting trees, community services, collecting rainwater, strengthening river borders and planting mangroves to withstand flooding due to high tides. There are 100 villages in this program until 2021. The government felt that the community actively participated in this program. Besides, there is also the Siap Siaga Program to improve the capacity of the community in prevention, preparedness, emergency response and recovery from disasters in collaboration with Australia to strengthen the disaster management system. This program is expected to educate the community to grow awareness and understanding of disasters.

The Lombok government has also made several preparedness activities to deal with the three hazards. For instance, they have been restoring the water tunnel and strengthening riverbanks every month for flood hazard preparedness. Mataram government expressed that there is a regulation regarding the binding of agricultural land with spatial planning regulations due to many land conversions. This regulation is also bound by a central government regulation which aims to inhibit the rate of land use change, especially agricultural land, and maintain food security. West Lombok government addressed that they asked the village to build a water storage tank for Rainwater harvesting in order to anticipate drought hazards. They have also collaborated with the central government and private sector to supply water, especially during the dry season. In anticipating landslide hazards, the Central Lombok government said they do reforestation due to many land conversions in upstream areas.

However, disaster preparedness activities carried out by the Lombok government are sometimes still limited by the central government's budget. This limitation causes a small amount of outreach and direct education to the community. West Lombok government claimed that these activities were delayed during the covid-19 pandemic due to budget constraints. In addition, there is a constraint regarding disaster experts in the Lombok government. Some disaster data, such as potential disaster and risk disaster maps, were obtained from the central government. Hence, some Lombok Island regencies do not have detailed data-scale. The complete disaster study was found in the North Lombok regency because of the availability of qualified staff. Conversely, West Lombok and East Lombok have taken advantage of vulnerability maps compiled by disaster risk reduction forums or non-governmental organizations in their areas.

On the other hand, BPBD province and regency/city asserted that there is no specific preparedness strategy for agricultural activities. The target for their program is the community, yet no strategy for farmers specifically. BPBD claimed that the preparedness strategy for agricultural activities is the authority of the Agriculture Department. BPBD will coordinate with all institutions involved in agricultural activities when the disaster occurs. Hence, BPBD will only provide logistical support to affected communities through rescue assistance and logistical assistance (blankets, ready-to-eat food and drinking water). Regardless, to anticipate climate change impact, the Ministry of

Agriculture has launched a rice farming business insurance that is beneficial for farmers to avoid losses due to crop failures due to pests, extreme weather and natural disasters. Farmers only need to pay as much as 20%, and the government bears the rest. The NTB Provincial Agriculture Office has also carried out various preparedness programs for climate change. For example, the Department of Agriculture of West Lombok has established a website and android-based agricultural and disaster preparedness system. This is intended as an effort for early warning by providing information on weather predictions and determining the right and appropriate schedule for the planting period.

4.5.3 Water Management

Paddy cultivation is carried out on two types of land: dry land and wet land. Paddy fields are divided into three types: technically irrigated (always receiving water throughout the year), semi-technical irrigated (lack water in the dry season), and rainfed paddy fields. Regarding the three types of paddy fields, rainfed paddy fields are vulnerable to climate change because the water source depends on rainfall. The problem is that climate change causes the arrival and the end of the rainy season to be uncertain, and less rainfall affects drought hazards.

Figure 32 Irrigation Canals on Lombok Island

Related to climate change preparedness in terms of water needs for agriculture, the Lombok Island government has provided irrigation areas that strongly support agriculture activities. The Irrigation network on this island is vital because the need for paddy cultivation is enormous. Hence, the PUPR Department establishes planting season rules divided into three seasons:

1. Planting season 1 (MT 1) starts from December to March. During this season, farmers generally grow paddy.
2. Planting season 2 (MT 2) starts from April to July. The agricultural activities in this season are divided into 2: paddy and secondary crops, where paddy is only growing in technically irrigated.
3. Planting season 3 (MT3) starts from August to November. During this season, farmers are generally only allowed to grow paddy in certain areas close to irrigation or dams. The secondary crop will be the main crop because the water availability is starting to dry up due to the absence of rain.

The result of paddy production in MT 1 is excellent, yet sometimes it experiences crop failure due to flood hazards. Moreover, Crop failure also happened in MT 2 and MT 3 due to farmers still planting paddy far from irrigation or dams. In order to manage the irrigation system, the government creates an irrigation commission to embody order in the management of irrigation networks that have been built. This is a coordinating institution between representatives of regional governments, representatives of associations of farmers using water at the irrigation area level and representatives of users of irrigation networks in regencies/municipalities. The irrigation commission plays a very important role in controlling and conducting socialization in the community. It is also essential as a forum for coordination and communication in determining cropping patterns and plans, including supporting success in developing and managing irrigation systems. The planting season on the island of Lombok has been agreed upon between the irrigation commission and all parties, especially farmers. Hence, if farmers force to plant paddy in MT 3 and experience crop failure, then the farmers will be declared as violating the regulations and will not be assisted.

Figure 33 Paddy and secondary crops in Planting season 2 (MT 2)

PUPR department is very careful in regulating the implementation of the planting season, especially MT-3. Irrigation systems are also very well managed with hygiene control activities once a month because irrigation canals are very susceptible to sedimentation and the growth of bushes. Every year, there are checks on irrigation institutions, farmers' social, and other aspects. The PUPR department also anticipates hazards induced by climate change through infrastructure development for drought-prone areas and regulates the amount of water discharge in an area. Farmers are also actively involved in irrigation maintenance and floodgate management for smooth irrigation. The limited number of officers in the field will be assisted by the Water User Farmers Association (P3A).

4.6 Preparedness of Local Government

Climate change and its impact have caused many losses on Lombok Island. The increasing incidence of floods, droughts, and irregular rainfall patterns affect the community's livelihood, most of whom are farmers. A past study by Nandini and Hadi Narendra (2011) pointed out that climate change caused a tendency to decrease rainfall in the period 1971 - 1980 and 2000 - 2008, an increase in air temperature, and a decrease in the number of springs by 75% on Lombok Island. At the same time, paddy tends to experience a negative impact from a high maximum temperature of around 35^{0}C (Khairulbahri, 2021), increasing the evaporation process and allowing the shrinking of water reserves in the soil. According to the analysis result, East Lombok experiences the greatest vulnerability to hazards induced by climate change. About 88.18% of its total areas are medium-level multi-hazard. The threat is even more real because Ichsan and Waru (2019), in their research, revealed that the community capacity of East Lombok to deal with the hazard impacts is still low, resulting in a high level of community vulnerability to the impacts of changing climate conditions. Moreover, the AHP method results showed that the southern areas of Lombok Island are vulnerable to drought hazards. It was confirmed by Yasin and Ma'shum (2006) research that denoted that rainfall in the southern areas is generally low ad highly variable. This location experienced a surplus of water for only 3 months, yet a water deficit of 5 or 6 months during 48 years from 1950 - 1998.

Rice is the staple food in Indonesia, so an assessment of multi-hazard impacts can provide useful information for policymakers, especially in prioritizing appropriate interventions. Generally, most areas of Lombok Island are identified as disaster hotspots at a medium level. It causes 96.56% of the paddy fields on Lombok Island to be medium-level of multi-hazard. The widest vulnerability is spread in Central Lombok and East Lombok regencies, even the highest-level multi-hazard for paddy fields is in West Lombok. The high vulnerability is also supported by the interview result, in which West, Central and East Lombok governments stated that farmers in their area have low awareness of climate change disasters, making the preparedness actions very low. The impact hazard led by climate change can certainly hamper the food supply and negatively impact the Lombok community's economic condition. A study by Khairulbahri (2021) projected that the paddy field would experience the worst impact from climate change, followed by rice production and harvested area. Climate change will cause WNT province only to be able to supply rice for the local communities, yet cannot provide it for other areas outside.

The role of government is essential in reducing losses caused by natural disasters, particularly in escalating the adaptive capacity of local communities to natural disasters through appropriate preparedness strategy and provision of adequate infrastructure and resources (Shah et al., 2019). Hence, the Indonesian government has established the National Disaster Management Agency (BNPB) and the Regional Disaster Management Agency (BPBD) at the provincial and regency/city levels. The high potential for disasters in Indonesia makes these institutions very important in disaster management and determining policies, and coordinating the implementation of disaster management activities.

This study found that the awareness of the Lombok government on climate change disaster preparedness is quite large. They clearly know the type of disaster in their administrative area and what action should be taken. Awareness is an essential attribute in a disaster so that every institution can utilize its resources to reduce the disaster's impact (Shah et al., 2019). Coordination between institutions from the provincial to the lowest level is also quite effective, indicated by the flow of information related to the weather and assistance during disaster situations. Social Media is the main source of disseminating information related to climate and disasters from local government to the public. Simultaneously, Infrastructure also plays a vital role in disaster preparedness. Past research in Lombok Island by Yasin and Ma'shum (2006) recommended that a water storage system and planting strategy are needed due to climate change conditions. This is also supported by Saputra et al. (2021), who predicts an increase in the need for irrigation water by 1.61% during 2032 - 2040. Hence, through the PUPR department, the Lombok government has prepared many irrigation channels and planting period regulations to anticipate hazards induced by climate change.

On the other hand, the Lombok government is still experiencing a shortage of expert staff to handle disaster risk reduction. Also, adequate financial resources, that are essential in strengthening institutions' capacity to prepare for, mitigate, and respond to basic needs before, during and after disasters. In disaster preparedness situations, local governments take responsibility for providing training and outreach, yet they are often faced with the problem of not having adequate financial resources. This requires more attention because several disaster preparedness activities in several regencies must be limited due to budget constraints that must be focused on disaster emergency activities. The same study on local preparedness assessment was conducted in Pakistan by Shah et al. (2019) using 5 indicators: 1) awareness and training, 2) human resources, 3) financial resources, 4) infrastructure and equipment, and 5) coordination. His study indicated that most local institutions were poorly prepared in all five indicators. The awareness and training indicators were relatively high, but human and financial resources were quite low.

The agricultural sector makes a significant contribution to Lombok Island’s economic growth. However, the performance of the agricultural sector is faced with various challenges, such as converting agricultural land to non-agriculture while directly reducing the area of land for food production activities, which greatly affects local and national food supply. Agricultural land conversion is extensive in Lombok Island, especially Mataram City and East Lombok Regency. The agricultural land in those areas yearly is decreasing due to residential development and industrial activities. Hence, in order to protect and control land as a whole, the Government, both local and central, is committed to minimizing the chances of conversion of agricultural land through the implementation of the Presidential Regulation on Control of Land Conversion. This aims to maintain the availability of paddy fields to support national food integrity, control the rapidly increasing land conversion, and empower farmers not to convert paddy fields. In this regard, the Government has played a key role in making its territory a disaster-resilient area by playing a role in coordinating and promoting disaster risk reduction in their area and implementing practical disaster risk reduction actions through land use planning. This is because inappropriate land use planning increases the occurrence of disasters and vulnerability (Malalgoda et al., 2013).

A competent and accountable local government is one of the parameters of a disaster-resilient. This is because the local government is the brain and vehicle that directs community activities, manages disasters, and plays a key role in making the disaster resilient. Disaster damage can be avoided through good urban planning, understanding the hazard, taking steps to anticipate disasters and minimizing physical and social losses arising from disasters (Malalgoda et al., 2013). The interview results denoted that most of the government of Lombok can be said to be quite prepared in disaster preparedness, especially in terms of agriculture. Nevertheless, there is a knowledge gap at the institutional level in understanding preparedness in agriculture. Most of the information on strategies to reduce climate change on paddy fields is only known by the relevant sector, The Agricultural Department. This was indicated by key informants from BPBD and Bappeda, who stated that agricultural preparedness activities were not under their authority. As a matter of fact, to achieve resilience, all institutions responsible for disaster management need to plan effective overall disaster mitigation strategies. Also, a holistic approach is needed with the participation of all stakeholders, such as the local government as decision-makers, academics, businesses and community groups (Malalgoda et al., 2013).

CHAPTER V

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Lombok island is considered as one of the rice barns in Indonesia that play an essential role in food security. Nevertheless, this island is vulnerable to hazards induced by climate change due to the small island, and most of the community's livelihood is farmers that depend on climate factors. The maps of three hazards, including flood, drought and landslide, were generated based on each parameter and then overlaid to build multi-hazard maps. The AHP method was utilized to develop the hazards and multi-hazard maps combined with GIS technology. The results highlighted that East Lombok was identified as the widest regency affected medium-level multi-hazard. Simultaneously, Lombok Island's paddy fields are vulnerable to multi-hazard induced by climate change. About 6.41 km^2 (0.58%) of paddy fields are at high-level of multi-hazard, and 1063.71 km^2 (96.56%) are at medium-level of multi-hazard. West Lombok and East Lombok paddy field are the widest areas that encounter the highest level of multi-hazard. Meanwhile, Central Lombok Paddy fields are the widest to be affected by a medium level of multi-hazard, followed by East Lombok.

The multi-hazard analysis applied using AHP-GIS in this study achieved reliable results regarding depicting areas prone to hazards. This is evidenced by the comparison between the analysis result with the number of three hazards occurrence experienced by the East Lombok regency and West Lombok regency in the past. Also, the decline in incidents of total paddy production and harvested areas due to drought hazards in 2019. The results of this study also revealed that the AHP-GIS method provides a powerful tool in multi-hazard mapping, as it is effective in hazard zonation. This method is flexible, based on experts' preferences and knowledge, and offers the best solution to complex problems.

The preparedness of local government in dealing with hazards induced by climate change is influenced by the circumstances of each region. All the representatives from the Lombok government are aware of the climate change phenomenon, yet its preparedness is still limited due to budget and human resources. However, Lombok Island is one of the islands that play an essential role in food security in Indonesia, particularly as a rice barn. Hence, hazards caused by climate change need to be a big concern for the government.

The result of the ND-Gain matrix for Indonesia, where Indonesia is the 103rd most prepared country, seems appropriate with Lombok conditions, which is on its way to responding effectively to climate change but requires greater urgency to act. Hence, it needs an integrated disaster risk strategy plan for all sectors, including technical plans, legal framework, regulation and local public policies. Without well-planned adaptation and disaster risk reduction efforts at this level, farmers are likely to suffer significant losses as a result of the impacts of climate change. This assessment can be utilized as a tool to identify the highest potential exposure of paddy fields to multi-hazard induced by climate change spatially. Mapping the impact of multi-hazard induced by climate change can assist the local government in implementing effective adaptation strategies to anticipate crop failure in the future and carry out integrated urban development planning. Further studies are needed to see the results of the government's readiness for farmers to deal with hazards caused by climate change due to the limitations of this study.

5.2 Recommendations

This study contributed to research on the impact of multi-hazard induced by climate change on paddy fields in three important ways. First, these findings provided multi-hazard maps using the AHP method in Lombok Island, which are essential tools to collect and display the disaster vulnerabilities, that can contribute to proper planning and resource allocation for disaster preparedness. Drought is a major disaster on Lombok Island, which causes rice production failure. This study also showed that East Lombok experiences the greatest vulnerability to hazards induced by climate change at the highest and medium levels. Second, overlaying the paddy field maps indicated that almost all of Lombok Island's paddy fields are at medium-level of multi-hazard. The widest vulnerability is spread in Central Lombok and East Lombok regencies. Third, the local government's preparedness indicated that the Lombok government's awareness of climate change disaster preparedness is quite large. Coordination between institutions is quite effective, and Infrastructure has been prepared well. On the other hand, the Lombok government is still experiencing a shortage of expert staff to handle disaster risk reduction and adequate financial resources that are essential in strengthening institutions' capacity.

Overall, the results of this study have several practical recommendations for future practice, as follows:

1. The study's findings indicated several strategies the Lombok government has prepared to anticipate the impact of hazards induced by climate change. Accordingly, disaster preparedness practices in reducing the impact of disasters must be emphasized to the community. Education on disaster management generally must continue to be improved to enhance hazard knowledge and disaster preparedness behavior. Creating disaster awareness at the individual, community, and organizational levels becomes an effective tool in reducing disaster risk and its impact because people who are sensitive and aware of hazards tend to perceive themselves as more at risk (Osuret et al., 2016). Sufficient knowledge of disaster preparedness and mitigation is one of the factors that drive regional resilience to disasters.
2. Local government is one of the main stakeholders that make the region resilient to disasters by playing a key role in contributing to the local level before, during, and after the disaster (Malalgoda et al., 2013). The government's role is crucial in disaster preparedness through proper planning and institutions as well as the provision of adequate infrastructure and resources (Shah et al., 2019). However, disaster mitigation activities are rarely integrated into regional planning and development, increasing vulnerability. Hence, local governments need to pay more attention to risk-oriented urban planning based on the concept of vulnerability. Also, enforcing appropriate rules, policies, and planning standards in limiting the adverse impacts of disasters and using multi-sectoral and inter-disciplinary approaches that contribute to increasing community resilience. The climate change disaster policy must apply clear operating principles or guidelines to manage its impacts. The policy must also be consistent and equitable for all regions, population groups, and economic sectors and consistent with sustainable development goals (Wilhite & Knutson, 2008).
3. Lombok island government faces several challenges in disaster preparedness, such as a lack of human resources and knowledge about disaster reduction and insufficient finance. In responding to this problem, empowering local governments through capacity building and granting authority in reforming governance is needed to realize disaster-resilient Lombok (Malalgoda et al., 2016). Lack of appropriate technical knowledge and managerial skills are problems facing many countries in disaster management. Therefore, the central government needs to carry out disaster management coaching programs, training,

and courses for local governments on disaster risk management initiatives and the stages that must be handled, including their roles and responsibilities (Seneviratne et al., 2012).

4. Climate change threatens to increase the frequency of future disasters. The increasing incidence of disasters is also exacerbated by the many land use change from productive to unproductive land. Some of the upstream areas on Lombok Island experienced deforestation, so the downstream areas experienced severe flooding. Community participation is an essential element in disaster management as an effort to build a safety culture (Hadiyanto et al., 2018), so it is vital to involve the community in planning, implementing, and evaluating disaster management. Community participation is also one of the best solutions in a disaster adaptation strategy based on the local wisdom of the community (Muddarisna (Muddarisna et al., 2019) et al., 2019). Moreover, an adaptation strategy that considers community income, environmental conservation, and economically optimal mitigation action procedures is the best options for reducing disaster risk. Reforesting abandoned terraces is one of the right solutions to reduce disasters most efficiently and cost-effectively (Galve et al., 2016). This research is supported by Muddarisna et al. (2019), which reported that replanting through planting local agroforestry plants based on local community wisdom is the best solution for implementing local community adaptation strategies. Plants affect soil conditions, infiltration processes, runoff, and soil mass loads so they can be relied on in anticipating disasters. Disaster strategy activities that are suitable for the environment and support community income are sustainable strategies.

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