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Vegetation-Based Disaster Mitigation: A Case Study of Breadfruit Development in Maluku as a Means of Food Diversification

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ABSTRACT

This study examines the potential of local food crops in Maluku, namely breadfruit, within the Food Supply Chain (FSC) concept for disaster management as Emergency Food Products (EFP). In several disasters in Maluku, food supplies face significant challenges related to availability and sustainability. It is crucial to find strategies to maintain availability and sustainability while considering local potential. This study uses qualitative methods, including observation and focus group discussions (FGDs), to analyze vegetation-based disaster mitigation by assessing the potential of local food to ensure resilience in the face of risk-based disasters. The results of this study indicate that breadfruit cultivation in Maluku can be a disaster-responsive food source and fulfill the food supply chain concept for disaster management by increasing the distribution of breadfruit planting locations throughout Maluku Province. The findings of this study provide recommendations for incorporating breadfruit as a local food source into stakeholder policies, making vegetation-based mitigation a key strategy throughout the Maluku region.

Keywords: Breadfruit, Food Supply Chain, Emergency Food Products, Natural Disasters, Risk-Based

1. Introduction

1.1 History of Natural Disasters in Maluku

Natural disasters in Indonesia frequently threaten human life, including in Maluku. Disaster mitigation efforts are crucial for protecting and maintaining the livelihoods of the people of Maluku. Community-based interventions that empower local populations to adopt sustainable food practices are explored as a means to ensure long-term impact.

This highlights the importance of collaborative efforts among government, non-governmental organizations, and private sector stakeholders to develop scalable and sustainable solutions (Kunlere, 2025). The study found that no policies directly target improving food security in slow-onset disasters. Existing policies to support food security in slow-onset disasters are embedded within the context of climate change or national target programs (Le et al., 2024).

Breadfruit is an endemic plant of the Maluku Islands. Among the islands in Maluku Province, several are known for their breadfruit production. In Maluku, such as Ambon, Banda, Namlea, Seram, Tual, Saumlaki, and Moa Islands. Breadfruit serves as a substitute for rice, and it is one of the important sources of carbohydrates found in tropical areas. Breadfruit, also known as an Emergency Food Product (EFP), is a processed food product specifically designed to meet human daily energy needs of approximately 2100 kcal. It is consumed in abnormal situations, such as floods, landslides, earthquakes, famine, fires, wars, and other events. Breadfruit cultivation in the Mutiara Pattimura Program, where Agricultural Potential in Maluku has an impact on disaster mitigation in Maluku province (Respatyo, 2024).

History of natural disasters in Maluku, investigating the various types of natural disasters that have occurred in the Maluku region, and their impact on local communities. Natural disasters in Maluku have become a threat, frequently disrupting the lives of local communities. The history of natural disasters in Maluku encompasses events such as earthquakes, tsunamis, and volcanic eruptions that have resulted in extensive damage and loss of life. Several recorded events concerning natural disasters in Maluku occurred on February 17, 1674. According to the records of Georg Eberhard Rumphius, a Dutch scientist who documented the earthquake and tsunami in Ambon, the impact of this event was devastating for its time.

More than 2,000 people were reported dead, and many homes were severely damaged. In his report, a powerful tremor struck the entire island of Ambon and the surrounding islands. Shortly after the earthquake, a tsunami wave hit the coast of Ambon Island. The northern coast of the Hitu Peninsula was the most severely affected, particularly in the Seit area between Negeri Lima and Hila, with water levels reaching heights of 90 to 110 meters. At least 13 villages were affected. These villages were located in the northern part of Leihitu, from Larike in the west to Tial in the east. On Seram Island, the areas affected included Huamual, Tanjung Sial, and Luhu. Other locations also affected were Oma, located in the south of Haruku Island, and Nusa Laut Island (Pranantyo & Cummins, 2020).

The earthquake that struck Ambon on September 26, 2019, had a magnitude of 6.5 on the Richter scale and was the largest officially recorded earthquake in Ambon, the capital of the Maluku Islands, in eastern Indonesia. This earthquake activated a previously undetected fault (Meilano et al., 2021). On January 10, 2023, a strong earthquake struck the Banda Sea, Maluku Province, with a moment magnitude (Mw) of 7.5. This earthquake caused fatalities near the epicenter due to the collapse of buildings not designed to withstand earthquakes. High seismic vulnerability and substandard infrastructure often result in significant losses during earthquake disasters (BNPB, 2023).

Therefore, preventive and adaptive measures must continue to be taken to mitigate the negative impacts of natural disasters and increase the resilience of the Maluku community. The Maluku region is characterized by its numerous island clusters and low accessibility. Therefore, special efforts are needed for island-based disaster risk reduction, which will undoubtedly differ from disaster risk reduction efforts carried out in other regions.

High disaster risk levels are found in the island clusters in RB III Central Seram and IX Southwest Maluku; moderate disaster risk levels are found in the island clusters in RB I Buru Island, IV East Seram, VI Tual-Dobo, and VIII Saumlaki. In contrast, low disaster risk levels are found in the island clusters in RB II West Seram, V Ambon-Haruku-Saparua-Nusa Laut, and VII Southeast Maluku. Mitigation is carried out through spatial planning to achieve sustainable island development. Disaster risk reduction in the Maluku archipelago is achieved through spatial planning, structural/civil engineering management, education, and community empowerment, as demonstrated by Puturuhu and Christianty.

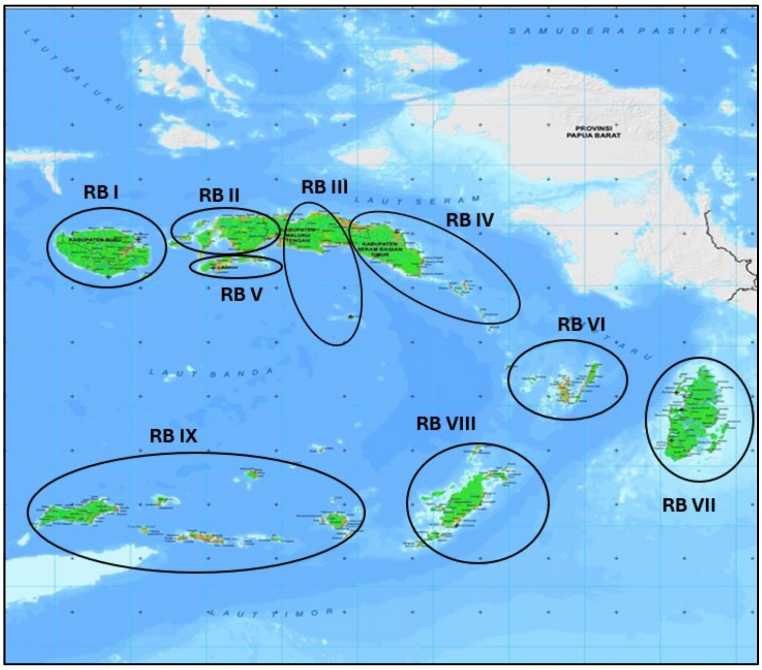

Figure 1. Maluku Risk-Based.
Source: BNPB, 2021

By leveraging the region's local agricultural potential and collaborating with various stakeholders, it is hoped that sustainable solutions can be developed to mitigate the risks associated with natural disasters. Prepositioning assets and supplies before a disaster occurs enables a faster response by reducing the burden on the supply chain associated with humanitarian aid. In both pre- and post-disaster humanitarian logistics, prepositioning assets and supplies in the context of natural disasters is crucial (Sabbaghtorkan et al., 2020).

Explore disaster mitigation programs in Maluku, including those implemented by the government and non-governmental organizations, to reduce the risk of natural disasters in the region. Furthermore, education and outreach to the community must be continually improved to increase awareness of the potential for natural disasters and how to deal with them effectively. With strong collaboration among the government, the community, and various relevant parties, it is hoped that Maluku can become a safer and more resilient region in the face of natural disasters. The Maluku Province capacity assessment refers to 7 (seven) priority disaster risk reduction programs, namely: 1) Strengthening Policies and Institutions, 2) Integrated Risk Assessment and Planning, 3) Development of Information Systems, Training, and Logistics, 4) Thematic Management of Disaster-Prone Areas, 5) Increasing the Effectiveness of Disaster Prevention and Mitigation, 6) Strengthening Disaster Preparedness and Emergency Response, 7) Development of a Disaster Recovery System (BNPB, 2021). Concrete examples of how the seven disaster risk reduction programs priorities are being applied in Maluku include strengthening local governments in disaster risk management, drafting agreements on managing disaster areas across districts, establishing hazard zones and safe zones as the basis for utilization areas for tourism and other cultivation, training communities around disaster-prone areas to recognize natural signs, location planning to avoid areas close to disasters that are used for essential activities, avoiding potential impacts, developing safe buildings, building early warning systems that are easily accessible to the community, and strengthening the practice of Community-Based Disaster Risk Management and Community-Based Early Warning Systems.

Table 1. Risk level for each disaster in Maluku Province.

Number	Disaster
1	Flood Risk: High class covers 9 regencies and 1 city, Medium class covers 1 city
2	Flash Flood Risk: High class covers 6 regencies and 1 city
3	Extreme Weather Risk: High class covers 5 regencies and 1 city, Medium class covers 4 regencies and 1 city

Number	Disaster
4	Extreme Wave and Abrasion Risk: High class covers 2 regencies, Medium class covers 5 regencies and 1 city, Low class covers 2 regencies and 1 city
5	Earthquake Risk: High class covers 4 regencies and 1 city, Medium class covers 5 regencies and 1 city
6	Liquefaction Risk: Medium class covers 8 regencies and 1 city, Low class covers 1 regency and 1 city
7	Forest and Land Fire Risk: High class covers 2 regencies, Medium class covers 7 regencies, and 2 cities
8	Banda Api Volcanic Eruption Risk: High class only in 1 regency
9	Wurlali Volcanic Eruption Risk: High class in only 1 district
10	Drought Risk: High class covers 4 districts and 1 city, Medium class covers 5 districts and 1 city
11	Landslide Risk: High class covers 5 districts, Medium class covers 4 districts, and 2 cities
12	Tsunami Risk: High class covers 6 districts and 2 cities, Medium class covers 3 districts
13	Epidemic and Disease Outbreak Risk; Low class covers 5 districts and 1 city.
14	Technology Failure Risk: Low class covers only 1 district
15	COVID-19 Risk: Low class covers 9 districts and 2 cities

Source:(BNPB, 2021)

Based on the analysis of threat, vulnerability, and capacity parameters, the overall risk level for each disaster in Maluku Province is determined. Table 1, which presents the vulnerability to disasters in Maluku, offers several important insights into the disaster conditions in the region. Maluku faces a range of disaster threats, including both natural and non-natural hazards. This table identifies 15 types of disasters, ranging from hydrometeorological disasters (such as floods and extreme weather) to geological disasters (including earthquakes, liquefaction, and volcanic eruptions), as well as non-natural disasters (such as epidemics and technological failures). This highlights the need for the Maluku government and community to develop a comprehensive disaster management strategy, rather than focusing solely on one type of disaster.

Data shows that most disaster risks categorized as High originate from geological and hydrometeorological hazards. Floods and flash floods pose a serious threat, with high levels of risk spread across many districts and cities. This highlights the need for intensive mitigation efforts, including river normalization, embankment construction, and public education. Earthquakes and tsunamis also pose a high risk in several areas, which is understandable given Maluku's location as a region located at the confluence of tectonic plates. Preparedness for earthquakes and tsunamis is a top priority. The eruptions of the Banda Api and Wurlali volcanoes indicate the presence of two active volcanoes in the Maluku region. Although limited to only one district, the risk of a volcanic eruption has a significant impact and requires a strict monitoring system and a well-developed evacuation plan.

Most districts and cities in Maluku are vulnerable to multiple types of disasters. This indicates that almost all of Maluku requires serious attention in terms of disaster risk reduction. For example, high flood risk covers nine districts and one city. High and moderate extreme weather risks are spread across almost the entire region. High and moderate earthquake risks cover nine districts and two cities. This emphasizes the importance of interregional cooperation in disaster management, as the impact of a single disaster can extend across administrative boundaries.

Cross-sectoral cooperation in disaster mitigation examines collaboration between various parties, including the government, private sector, academics, and communities, in developing a sustainable agricultural system to reduce vulnerability to natural disasters. Cross-sectoral collaboration in disaster mitigation is a crucial step in ensuring the sustainability of the agricultural system in the Maluku region. Collaboration between the government, private sector, academics, and communities is expected to create a resilient agricultural system capable of facing various natural disaster risks. This will enhance food security in Maluku and mitigate the risk of food insecurity resulting from natural disasters. Furthermore, cross-sectoral collaboration can also provide opportunities for local farmers to improve their well-being through a holistic and sustainable approach. Additional policies and investments are necessary to reduce hunger (Rosegrant et al., 2024) significantly.

1.2 Food Insecurity

One of the primary challenges faced by local farmers in Maluku is the impact of climate change, which affects food availability in the region. Furthermore, limited access to modern technology and adequate resources also hinders the implementation of sustainable agricultural practices. To address this, collaboration among the government, farmers, and local communities is necessary to find solutions that can enhance food security and environmental sustainability in Maluku. Providing education as a contribution to maintaining the food supply chain for Maluku communities includes raising awareness of the potential of local, plant-based foods as a sustainable agricultural practice. This gap requires a comprehensive approach to mitigating food insecurity, which goes beyond access and availability to encompass considerations of nutrition, health, and safety (Le et al., 2025).

One step taken is to utilize the potential of local agriculture in Maluku, cultivating breadfruit, as a solution to produce a food substitute for rice. By involving various parties and utilizing local resources, it is hoped that a sustainable agricultural system can be created and the risk of natural disasters can be reduced in Maluku. Food insecurity and malnutrition remain urgent global challenges, disproportionately affecting at-risk populations in low and middle-income countries, including Indonesia, and particularly in Maluku. Addressing food insecurity requires a multifaceted approach that integrates short-term relief measures with long-term sustainable strategies. Exploring comprehensive strategies to mitigate food insecurity and improve global nutrition among vulnerable populations is crucial. Key approaches include enhancing agricultural productivity through climate-resilient farming techniques, improving food distribution systems, and leveraging technology for real-time monitoring and resource allocation. Addressing food scarcity during disasters is crucial, including promoting dietary diversity and nutrition.

Breadfruit is a staple food in several regions and has local cultural relevance in Maluku. Meanwhile, people in the South Pacific ferment excess breadfruit by burying it in the ground. The resulting fermentation produces a long-lasting, nutritious cheese-like paste that can be used to make baked goods. The long history behind this fruit, scientifically known as Artocarpus Altilis, suggests that breadfruit enabled the ancestors of seafarers from the Indonesian archipelago to reach the Pacific Islands and even the South Pacific. It is essential to consider social and cultural factors when introducing breadfruit as an alternative food to ensure its acceptance by local communities.

Therefore, it is hoped that using breadfruit as a substitute for rice can help alleviate pressure on natural resources and improve food security in Maluku. Increased environmental awareness can have a positive impact on the ecosystem and the sustainability of local agricultural practices in the Maluku region. With this awareness, farmers and local communities can pay closer attention to environmentally friendly agricultural practices and maintain food reserves in the event of disasters. Increased environmental awareness can also encourage the adoption of more modern and efficient agricultural technologies, thereby increasing agricultural productivity and food security in the Maluku region. As a follow-up, local governments should implement policies that support local food practices to enhance food security during disasters.

1.3 The Potential of Local Vegetation

Further discussing the potential of cultivating breadfruit and other local crops as an alternative food to reduce dependence on rice and maintain community food security. Increasing local agricultural production, such as cultivating breadfruit and other indigenous crops, can be an effective solution to reduce dependence on rice and maintain community food security in Maluku. By utilizing the abundant local agricultural potential, it is hoped that it can improve the welfare of local farmers and also strengthen the region's food security. Moreover, this effort is also expected to help mitigate the risk of food instability due to natural disasters that frequently affect Maluku. Even though the development program of 1 million premium and quality breadfruit seeds from Maluku, which supports the food security/food diversification program to improve community welfare by raising valuable local commodities, a program of the BUMN MIND-ID, proves the role of breadfruit as a potential food source to face food vulnerability during natural disasters. The breadfruit cultivation program aligns with the Disaster Mitigation program in addressing food availability that is not vulnerable to supply disruptions due to disasters (Respatyo, 2024).

Challenges and opportunities for sustainable food development in Maluku: Analyze the obstacles and opportunities in creating an environmentally friendly agricultural system that supports the long-term survival of the Maluku people. Through an analysis of the obstacles and opportunities in developing sustainable agriculture in Maluku, strategic steps can be identified to create an environmentally friendly agricultural system. Thus, the Maluku people can reduce dependence on food imports and increase local food security. Furthermore, new economic opportunities can also open up for local farmers through the implementation of sustainable and resilient agricultural practices. Some important implications of using local food as an emergency food source include achieving food independence by reducing dependence on imported materials and strengthening local food security. Furthermore, supporting local farmers by increasing demand for local agricultural products provides economic benefits for farmers (Durry et al., 2024).

One of the 7 Priorities for Maluku's Disaster Assessment is the Development of Information Systems, Training, and Logistics. Strengthening Regional Food Security Strategies for Disaster Emergencies requires formulating regional food security strategies based on resource requirements in contingency plans (BNPB, 2021). Breadfruit can be a food alternative during emergencies in Maluku. In a study in Sub-Saharan Africa, they discussed food distribution in response to disasters. In the case of Kenya, which is affected by periodic droughts at the beginning and end of two irregular rainy seasons, these have a significant impact on seasonal food crises. They presented a location model to determine a series of distribution centers where food is distributed directly to beneficiaries in the Garissa region of Kenya. In addition to the results obtained by solving the main food distribution model, they also presented several sensitivity and variance analyses of the basic coverage model of food distribution (Rancourt et al., 2015).

Breadfruit is an excellent substitute for rice because it has superior nutritional value compared to other carbohydrate sources, such as cassava and sweet potatoes, particularly in its phosphorus and energy content, which is comparable to that of rice. Breadfruit is high in carbohydrates and rich in minerals and vitamins. Every 100 g of breadfruit contains carbohydrates (27.12%), fat (1.48%), protein (1.65%), energy (108 calories), and essential amino acids that the human body cannot produce on its own. Breadfruit has a relatively high water content, around 69.3% (D. Histifarina and NR Purnamasari, 2022).

Breadfruit, a food crop substitute for rice, is an essential source of carbohydrates found in tropical regions, such as the Pacific and Southeast Asia, including the Maluku Islands. As a significant source of carbohydrates, breadfruit can be prepared in various ways, including boiling, frying, baking, or grilling. The cooked fruit can be sliced and dried in the sun or in a kiln, allowing for long-term preservation and storage. The prospects for breadfruit as a rice substitute are promising, given Indonesia's annual rice demand of 30 million tons. If 10 percent of Indonesia's rice needs were replaced with breadfruit flour, 3 million tons of breadfruit flour would be needed. This production requires 27.8 million breadfruit plants. Breadfruit trees are typically harvested in January and February, with higher production compared to the second harvest season in August and September. A single tree can produce up to 900 fruits per year.

1.4 Research Purposes

The objective of this study is to synthesize available evidence on the mechanisms linking household and community-level food insecurity in Maluku and to inform food security policies when mitigating disasters. The study also identifies vegetation-based mitigation patterns related to local food emergencies. These insights can inform the design of evidence-based restoration policies, prioritizing the protection and rehabilitation of ecosystems with the highest natural recovery capacity (Sabljić et al., 2025). The study also discusses that improving food and nutrition security also requires changes to food systems beyond the primary agricultural sector, including rural infrastructure, value chains, and public health (Rosegrant et al., 2024).

The Maluku Province capacity assessment refers to seven priority disaster risk reduction programs, including the fifth Priority, Improving the Effectiveness of Disaster Prevention and Mitigation (BNPB, 2021). Improving the effectiveness of disaster prevention and mitigation is achieved through training and education for local farmers to implement sustainable agricultural practices that enhance productivity and food security during disasters, including the development of breadfruit that meets the criteria for disaster mitigation. Through training and education, local communities can learn how to implement sustainable local food crop management practices tailored to their specific local environment, thereby increasing productivity.

Collaboration between local governments, non-governmental organizations, and international institutions to develop environmental protection programs for breadfruit vegetation development can ensure food security in Maluku. The role of modern technology in supporting breadfruit cultivation as a sustainable food innovation in Maluku, for example, is the use of net culture systems for developing breadfruit seedlings. Educating the public about the benefits of environmental protection through the sustainable management of local food crops is crucial for ensuring long-term well-being and food availability, thereby mitigating disasters in Maluku. Although several studies have discussed food diversification and breadfruit cultivation, little attention has been paid to its role as an emergency food product in disaster-prone island regions such as Maluku.

2. Theoretical Framework and Hypothesis Development

2.1 Vegetation-Based Disaster Mitigation.

This theory explains the concept and mechanism of how vegetation can act as a natural barrier to reduce disaster risks, and breadfruit is a plant that prevents abrasion on coastal coral reefs. Vegetation-based disaster mitigation is closely tied to the ecological functions of vegetation, encompassing land protection and water conservation, abrasion and tsunami protection, carbon sequestration and microclimate regulation, as well as ecosystem resilience. Leaf canopies also reduce the direct impact of rainwater on the land surface. The relevance of the concept of vegetation-based disaster mitigation lies in the fact that this research can examine how the integration of vegetation-based mitigation can be encouraged through effective policies, and how community participation and local wisdom can support the success of vegetation planting and maintenance programs.

Communities can utilize coastal vegetation forests as a food source, including traditional fisheries, to provide food and generate income for coastal communities, while also promoting ecotourism (McNally et al., 2011) where the key indicators of this theory are disaster risk reduction through reducing the level of vulnerability, the number of disaster events (frequency), and the number of material losses, or reducing the potential for casualties in areas mitigated by vegetation. Although breadfruit is not a coastal plant, it has the potential to act as protective vegetation in highlands or near rivers to prevent flash floods. As a carbon sink and microclimate regulator, breadfruit vegetation helps mitigate the impact of greenhouse gases, indirectly contributing to the prevention of climate change-related disasters.

2.2 Ecosystem Resilience

Ecosystem resilience theory is a concept that describes an ecosystem's capacity to absorb disturbances, both natural and human-made, while maintaining its essential functions and structure. This concept involves the idea of a stable state, where the ecosystem is ideally in equilibrium without external stress. However, ecosystems inevitably face numerous environmental stressors, making complete stability difficult to achieve. Resilience can be realized through resistance to disturbance or through adaptation, with the degree of resilience varying across ecosystems. The idea of ecological resilience is crucial to understanding the health of social-ecological systems, where human activities interact with the natural environment. This concept emphasizes two aspects: resilience, which is the amount of disturbance a system can absorb before changing its state, and recovery, which is the speed at which the system returns to its original functional state after a disturbance occurs.

This theory is particularly relevant in the context of Social Ecological Systems, where it examines the interrelationships between natural systems (ecosystems) and human systems (society and policy), and applies to studies on food security, shared resource management, and community adaptation to disasters. Large-scale planting of breadfruit can create a resilient ecosystem with high biodiversity, allowing various species to perform similar ecological roles, thereby increasing stability. Studying ecological resilience enables scientists to design effective strategies for restoring and managing ecosystems, ensuring they can withstand future challenges while maintaining their health and function (Folke et al., 2004). A key indicator of this theory is assessing an ecosystem's ability to recover after being disrupted by a disaster. Vegetation diversity, including breadfruit, can increase ecosystem resilience, as is the case in the Maluku Islands.

2.3 Theory of Food Resilience and Food Diversification

The food supply chain (FSC) is considered a critical infrastructure by all governments, and multiple strategies have been proposed to make FSCs more resilient to disruptions. However, major disasters, such as COVID-19, have exposed vulnerabilities in FSCs that were previously invisible (or easily addressed) during normal operations but pose significant challenges in major disaster situations (Béné, 2023). Research gaps have also been identified, and suggested research directions have been presented. One gap identified is the lack of research on humanitarian FSCs. Most articles focus on the resilience of commercial FSCs during disaster events, while research specifically focusing on humanitarian FSCs is lacking. There are several differences between commercial and humanitarian FSCs, necessitating further research on humanitarian FSCs (Perdana et al., 2022).

In the journal Tactical Network Planning for Food Aid Distribution in Kenya, Rancourt applied agent-based simulation to food aid distribution in disaster-affected areas with disaster-related constraints. He also developed three network optimization models, inspired by field research in Kenya, to determine the optimal locations for food distribution centers (DCs) and food aid distribution networks. These three optimization models aimed to minimize total costs, maximize demand coverage, and minimize the number of DCs. This study was grounded in the challenges of food aid distribution that emerged in Kenya, but its findings can also be applied to other developing countries. The goal was to design an effective short-distance food aid distribution network. He presented a location model to determine a series of distribution centers, where food is distributed directly to beneficiaries, for the Garissa region of Kenya (Rancourt et al., 2015).

Distributing food (and other resources) is a challenging task in disaster-stricken areas. It is difficult to cover large areas and manage obstacles within these areas using existing solutions. The use of multi-agent food distribution simplifies and streamlines this task by dividing the area into multiple regions and employing coordination and shortest path algorithms for better performance and faster food delivery. Using multiple agents in a distributed environment provides better performance than using a single agent. Experiments have shown that various parameters play a crucial role in the system's efficiency. With the available statistical data, a knowledge-based system can be designed to aid in critical decision-making related to food distribution issues (Manzoor et al., 2014).

Mechanisms underlying food insecurity following climate-related shocks. Food insecurity is prevalent, affecting 1–2 billion people worldwide in 2021. However, the impacts of food insecurity are unevenly distributed across populations, and climate-related shocks threaten to exacerbate food insecurity and its associated health consequences. This study aims to synthesize existing evidence on the mechanisms linking extreme climate events to household-level food insecurity and highlight research gaps that must be addressed to inform more effective policies for food security and health (Le et al., 2025).

Discussing food security is undoubtedly related to availability, utilization, and access. The discussion on availability describes the availability of food within the food system, which is related to primary production capacity, food reserves and stocks, and production stability. The discussion on utilization encompasses the household's ability to utilize available and accessible food, including components such as food safety, nutritional content, and sociocultural factors. Various sociocultural factors contribute to food insecurity after climate shocks. Consumption patterns influence the types of food consumed and the foods that household members continue to consume when resources are limited (Hadley et al., 2023).

Discussing food security is also important to consider access, which describes a household's ability to obtain food, with the following components: economic access and physical access, according to the UN FAO Pillar model, a component proposed by Savary and colleagues. This section discusses the importance of food resource diversity, especially in disaster-prone areas such as Maluku. The concept of food security encompasses the four main pillars: availability, access, utilization, and stability. These four aspects must be fulfilled to achieve food security in disaster conditions (Peng & Berry, 2018). Based on a survey of papers on food security from the Scopus database, it can be concluded that each country needs to prioritize the six pillars of food security: stability, access, sustainability, utilization, availability, and agency. In Southeast Asia, Indonesia is the country with the most vulnerable food security to the impacts of climate change, indicating that Indonesia has weak food security, where only two of the six pillars of food security have been fully implemented: food availability and food utilization. So, Indonesia still does not have food security that is in accordance with the six principles of global food security (' Azhima et al., 2023).

Food diversification with breadfruit can increase the stability of food availability when disasters paralyze the production of primary commodities such as rice. Food Diversification Theory explains that diversification is a strategy to reduce dependence on a single staple food. In the case of disaster-prone Maluku, having alternative food sources such as breadfruit is crucial. Breadfruit can serve as a food reserve due to its long shelf life and ease of processing. Developing breadfruit as a local food in Maluku not only improves food security but also preserves traditional knowledge and local wisdom in utilizing natural resources. Breadfruit has been registered as a horticultural variety adapted to lowland areas in the Maluku Islands. Breadfruit has been designated a variety based on Decree of the Minister of Agriculture of the Republic of Indonesia Number 22/Kpts/Pv 240/D/I/2023 concerning the Determination of the Registration Mark for Breadfruit Horticultural Plant Varieties (Kementan, 2023).

Natural disasters impact food security because production in affected areas is disrupted, and food security must be a top priority when disasters occur. A study of the Mount Kelud eruption identified the food security status of villages in disaster-prone areas and formulated village development plans to reduce the risk of food insecurity. The case study was Kaumrejo Village, Malang Regency, East Java, one of the villages severely impacted by the Mount Kelud eruption. The food security analysis measured food security. The results showed that Kaumrejo Village achieved food security a year after the disaster. The village's food security status recovered quickly, although local food production was hampered by agricultural land covered by eruption debris. One contributing factor was the high influx of food stocks from other regions (Hidayat et al., 2021).

What about Maluku, which is relatively isolated from other regions due to its archipelago, during the disaster response period? Maluku requires a local food concept that can survive disaster conditions, as a vegetation-based mitigation effort through the cultivation of breadfruit. After the disaster response period ended, villagers struggled to achieve food security because agricultural land needed time to recover. Villagers needed to develop alternative sources for food supplies. By developing breadfruit, land restoration is not necessary because it is resistant to abrasion, and the community will still be able to obtain food from the breadfruit vegetation that has been prepared.

2.4 Sustainable Development Theory and Community Participation

2.4.1 Community-Based Participation. The theory of Community-Based Participation in this study can be defined as the community's willingness to recognize its own potential and problems, and to participate in the process of improving the local community. Participation must be based on a willingness or desire. The theory of Community-Based Participation explains that the success of disaster mitigation and food diversification programs depends heavily on the active involvement of local communities, as they are best equipped to understand the environmental conditions and challenges in their area. The relevance of Community-Based Participation allows for the exploration and integration of local knowledge to produce more contextual and sustainable solutions or recommendations. Sustainable Development links breadfruit development with the three pillars of sustainable development: economic, social, and environmental. Economically, breadfruit can provide new sources of income for the community through the processing and sale of its derivative products.

From a social perspective, the development of local food ingredients such as breadfruit is a program that involves the participation and empowerment of the local community. In environmental conservation efforts, sustainable breadfruit development and cultivation play a crucial role in the Maluku region. The primary indicator is the Contribution of Ideas or Aspirations through community involvement, which involves conveying ideas, suggestions, criticisms, and proposals, as well as active participation in deliberation forums. Community participation is involvement in community activities that promote the development of interpersonal relationships.

Because the structural category encompasses segregated and semi-segregated settings, participation is categorized into three levels: segregated, semi-segregated, and community participation. Finally, while some community activities may progress from presence to participation, this progression is not necessary for each community activity, as individual preferences will help determine the desired level of involvement. Together, these domains — interpersonal relationships and community participation — form the primary components of social inclusion, and they interact (Simplican et al., 2015).

2.4.2 Family Farming. The Decade of Family Farming provides an opportunity to achieve the Sustainable Development Goals (SDGs) in an inclusive, collaborative, and coherent manner. Placing family farming and all family-based production models at the center of interventions will contribute to eradicating hunger and poverty, where natural resources are managed sustainably in line with the core commitments of the 2030 Agenda. Family farming has received global attention since 2014, which was designated as the United Nations International Year of Family Farming (IYFF). Family Farming Programme In the United Nations Decade of Family Farming 2019-2028 Global Action Plan contains 7 pillars, as follows: Pillar 1, Developing a conducive policy environment to strengthen family farming, Pillar 2, Supporting youth and ensuring the sustainability of family farming across generations, Pillar 3, Promoting gender equality in family farming and the leadership role of rural women, Pillar 4, Strengthening family farmers' organizations and capacities to generate knowledge, represent farmers, and provide inclusive services in the urban-rural continuum, Pillar 5, Enhancing socioeconomic inclusion, resilience, and well-being of family farmers, rural households, and communities, Pillar 6, Promoting the sustainability of family farming for climate-resilient food systems, Pillar 7, Strengthening the multidimensionality of family farming to foster social innovations that contribute to regional development and food systems that safeguard biodiversity, the environment, and culture (FAO and IFAD, 2019).

2.5 Policy Analysis and Implementation Theory

This section explores how government policies, both at the central and regional levels, can support or hinder the development of breadfruit as a commodity for mitigation and food diversification. In the case study of Maluku, the geography of the Maluku Islands, which is prone to earthquakes and tsunamis, makes breadfruit development for mitigation highly relevant. This is linked to disaster vulnerability, community dietary habits, and existing policies. Within this framework, there are two main objectives: 1. Disaster mitigation by utilizing the functions of breadfruit vegetation, and 2. Food security by utilizing breadfruit food diversification. Both are mutually supportive and synergistic to improve ecosystem resilience and food security for the Maluku community holistically.

2.6 Research Hypothesis

Based on the theoretical framework discussed, the hypotheses proposed for the study of Breadfruit Vegetation-Based Disaster Mitigation in Maluku relate to the long-term distribution of breadfruit cultivation and the design of the breadfruit distribution network. Therefore, this study formulates the following hypotheses: H_1Breadfruit's potential as an Emergency Food Product (EFP) is believed to be shaped by the recognition and integration of local wisdom within the Maluku community. H_2Breadfruit's sustainability in the Food Supply Chain (FSC) for disaster management is believed to be hindered by the mismatch between current breadfruit planting locations and disaster risk maps, as well as existing informal logistics structures within the community. H_3: Increasing the distribution of breadfruit planting locations, proposed as a policy recommendation, is expected to require cross-sector collaboration to balance breadfruit's function as a vegetation-based mitigation agent and as a means of food diversification. This hypothesis focuses on the role of breadfruit as a mitigation agent. Sustainable breadfruit cultivation and vegetation-based disaster mitigation capacity can be measured through indicators such as reduced disaster impact and increased community resilience in the face of disasters.

3. Methodology

3.1 Conceptual Design

This research begins with the broad problem of natural disasters. It gradually narrows its focus to specific solutions related to local, plant-based food that can be implemented through an effective supply chain as part of mitigation efforts. This diagram serves as a clear roadmap, both for the research process itself (the flowchart on the left) and for a conceptual understanding of the phenomenon under study (the flowchart on the right).

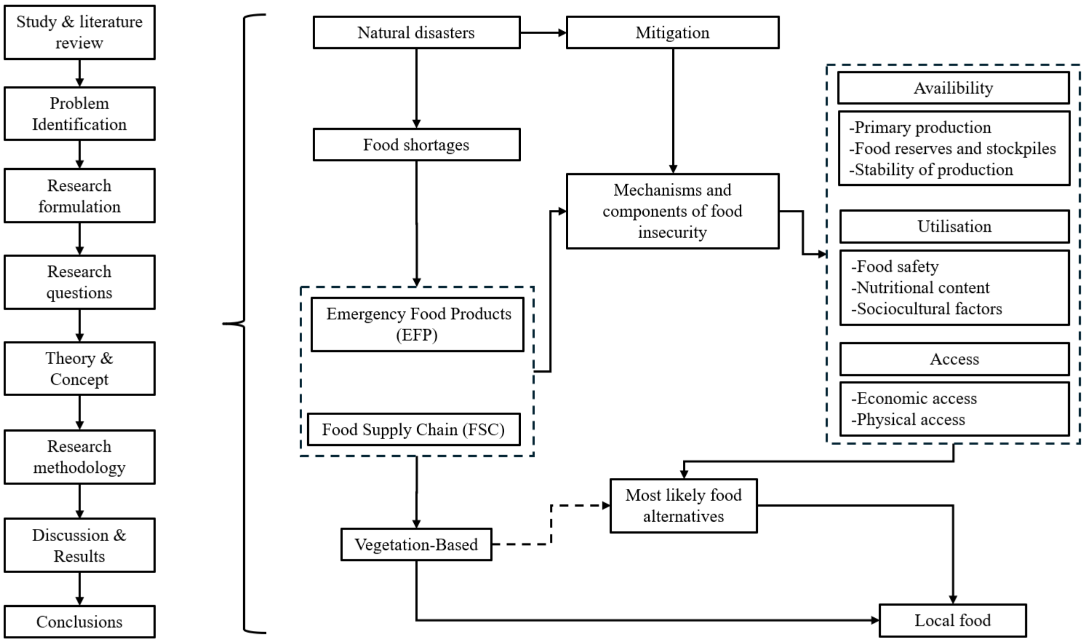

Figure 2. Research Framework

The Research Framework outlines a standard research methodology, from initiation to completion. The Literature Review and Study serve as the initial step in gathering information from relevant literature, such as scientific articles, books, reports, and other secondary data. The goal is to understand current conditions, existing theories, and research gaps. Problem Identification: After reviewing the literature, researchers will identify specific problems that need to be addressed or researched related to food insecurity resulting from natural disasters.

The Research Formulation addresses the identified problems and then formulates them into questions that can be answered through research. Research Questions reveal specific questions that will guide the research. This is the core of what is being sought to be answered. Theory and Concept: This research will identify relevant theories and concepts that support the study, including those related to food insecurity, supply chains, and disaster mitigation. Research Methodology: This stage outlines the research approach, including the method (qualitative/quantitative), data collection methods, and data analysis procedures. Discussion and Results: This stage analyzes the data and presents the results. Researchers discuss their findings and relate them to existing theory. Conclusions: This is the final stage, where conclusions are formulated based on the research, answering the research questions posed at the outset.

3.2 Research Focus

This research focuses on the issue of food shortages that arise from natural disasters. The study begins with the premise that natural disasters are the primary trigger for food shortages. This causal relationship forms the starting point of the problem. Mitigation measures demonstrate a parallel flow, indicating that mitigation efforts are implemented to address the impacts of natural disasters. When food shortages occur, the Mechanisms and Components of Food Insecurity (Mechanisms and Components of Food Insecurity) are discussed. Food shortages caused by natural disasters lead to food insecurity.

This suggests that the proposed solution is emergency food management through an effective supply chain. Emergency Food Products (EFP) is a key variable examined in this study, acting as a bridge between food shortages and proposed solutions. Food insecurity is broken down into three main components, closely aligned with the FAO (Food and Agriculture Organization) definition: Availability refers to the physical availability of food, measured by primary production, food reserves, and production stability. Utilization: How individuals utilize food, related to food safety, nutritional content, and sociocultural factors. Access: An individual's ability to obtain food, both through economic access (purchasing power) and physical access (market availability).

Emergency Food Products (EFP) and Food Supply Chains (FSC) in this study specifically focus on food products during emergencies within the context of the food supply chain.

In the Vegetation-Based study, the results appear to focus on plant-based emergency food, a critical specification. By emphasizing breadfruit as a local plant-based emergency food option, researchers will focus on plant-based food sources as a solution. Identifying the most viable food alternatives from plant-based products will be the focus. This may involve evaluating specific criteria such as availability, durability, nutritional value, and ease of production. The outcome of this study will be the identification of the most viable food alternatives, ultimately leading to the promotion of local food as a solution. This demonstrates that the goal is to build sustainable local food security, which can serve as an EFP and part of disaster mitigation. Designing an innovative mitigation conceptual framework can integrate components that build multidisciplinary solutions, establish functional relationships, and provide a framework for estimating initial emergency food resource needs (Toland et al., 2023).

Overall, this research methodology is very systematic. The goal is to develop and propose sustainable, locally based food solutions to address food insecurity caused by natural disasters endemic to the Maluku region. This research employs a Qualitative Approach, focusing on an in-depth understanding of the social, cultural, and ecological context through case studies in several communities in Maluku that have successfully developed or are in the process of developing breadfruit cultivation. With this method, information can be obtained on how local communities perceive breadfruit, its role in disaster mitigation, and how this cultivation impacts their food security, particularly during disasters.

In-depth interviews were also conducted with community leaders, farmers, and policymakers related to the breadfruit industry, as well as with breadfruit farmers, to gain a deeper understanding of their cultivation practices, challenges, and benefits. Customary/community leaders, to understand cultural values and local wisdom related to breadfruit. Agricultural/forestry experts, to obtain scientific views on the potential of breadfruit. Local governments to examine policies that support or hinder breadfruit development. Participant observation was also conducted by directly engaging in daily community activities related to breadfruit cultivation and utilization. This allowed for direct observation of how breadfruit is processed, sold, and consumed. This method provided authentic and rich data on social practices and interactions.

4. Results and Discussion

4.1 Breadfruit's Potential as an Emergency Food Source

In preparation for natural disasters, the US Geological Survey recommends using this kit in conjunction with a personal disaster kit. It should contain at least 3 to 5 days of food supplies, as well as first aid supplies and emergency lighting. In fact, with the assistance of the American Red Cross, they developed a 24-week calendar for organizing food and emergency supplies. The research findings on the Potential of Breadfruit Vegetation as Disaster Mitigation began with the identification of disaster types in Maluku, which revealed that Maluku frequently experiences natural disasters such as earthquakes, tsunamis, coastal erosion, and strong winds. Physically, breadfruit trees (Artocarpus altilis) are used as a food source in disaster response.

Ecologically, breadfruit vegetation has a strong root system that has been proven effective in binding soil particles, thereby reducing erosion rates, especially in coastal areas and hillsides. Field observations indicate that areas planted with breadfruit exhibit significantly lower erosion rates compared to areas without this crop. The dense trees and their sturdy trunks act as natural windbreaks, reducing wind speed and its impact on surrounding buildings and plants. While not able to completely stop tsunami waves, dense rows of breadfruit trees along the coast have the potential to reduce wave energy and speed, thereby minimizing land damage from abrasion.

Suboptimal breadfruit production will hamper the distribution of breadfruit-based foods in Maluku, which are a mainstay of food security during disasters. Therefore, policy support through the Maluku provincial government programs is essential to address this issue. Breadfruit is one of the leading commodities in Maluku and is nationally recognized. Therefore, the Maluku Provincial Agriculture Office needs to play a role in implementing policies to synergize with relevant stakeholders and expand breadfruit plantation areas in the

Maluku region. Further research is also needed to determine the suitability of land for breadfruit cultivation in Maluku as part of the breadfruit distribution program in Maluku Province.

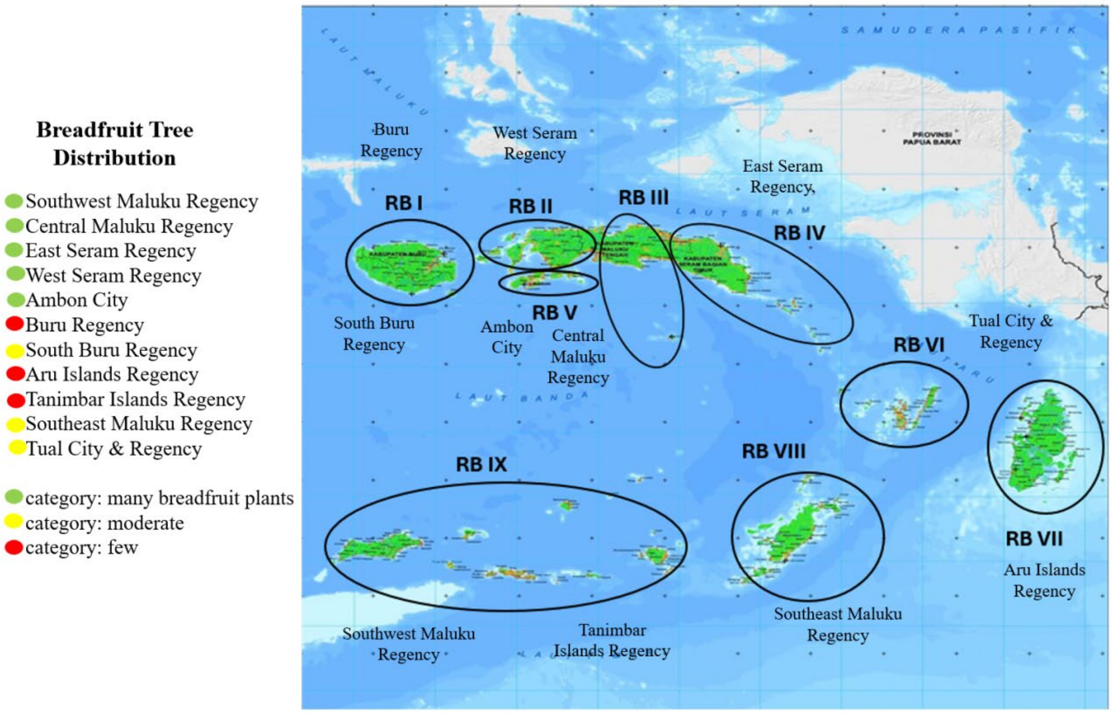

Figure 3. Breadfruit Tree Distribution in Maluku
Source: Maluku Agriculture Service, Maluku Province

According to data from the Maluku Agriculture Service, the most extensive potential breadfruit plantations in the Maluku region are located in Southwest Maluku Regency, Central Maluku Regency, East Seram Regency, West Seram Regency, and Ambon City. The Maluku Agriculture Service is striving to meet the high demand by committing to expanding breadfruit plantation areas in the Maluku region. He continued, developing breadfruit potential not only strengthens Maluku's local food security in anticipation of the global food crisis, but also diversifies local food sources and improves the community's economy. To develop local breadfruit in Maluku, the Maluku Agricultural Instrument Standards Implementation Center (BPSIP) will assist the community in cultivating seedlings and ensuring the legality of breadfruit varieties.

Based on Figure 3, regarding the distribution of breadfruit trees in Maluku, to analyze the potential of breadfruit trees as a food substitute, we must examine the areas with the highest concentration of breadfruit trees. Breadfruit Tree Distribution Map Analysis: Based on the map legend, breadfruit tree distribution is categorized into three categories: 1) green: many breadfruit plants, 2) yellow: moderate, and 3) red: few. To support the availability of substitute food, the placement of breadfruit trees should be prioritized in areas categorized as green.

Identify priority locations using the pattern shown in the image. Identify the Regency or City areas with the highest distribution of breadfruit trees (in green). These areas have the most significant potential as sources of substitute food. Based on the map, the areas that are shown in green (many breadfruit trees) are: 1) Southwest Maluku Regency, 2) Central Maluku Regency, 3) East Seram Regency, 4) West Seram Regency, 5) Ambon City, 6) South Buru Regency, 7) Aru Islands Regency, 8) Tanimbar Islands Regency, 9) Southeast Maluku Regency, 10) Tual City and 11) Tual Regency.

4.2 Risk-Based Recommendations for Sustainability in the Food Supply Chain

Based on the Risk Analysis, the strategy for planting and utilizing breadfruit trees as a substitute food source should prioritize high-risk regional blocks. The Highest Priority with high risk is in RB I (Buru Regency), RB VII (Aru), and RB IX (Tanimbar). These areas require immediate intervention through large-scale planting programs. Medium Priority with moderate risk falls into the yellow category (moderate), specifically RB I (South Buru), RB VI (Tual), and RB VIII (Southeast Maluku), which also require attention to improve food security. On the map, the marked areas are clearly visible in terms of food insecurity risk, unless anticipated by the diversification of breadfruit crops. At the same time, the Lowest Priority with low risk is in RB I (South Buru Regency), RB II, RB III, RB IV, RB V, RB VII, and RB IX (Southwest Maluku). In these areas, the focus is more on management, research on superior varieties, and the development of processed products from breadfruit. Breadfruit is a crop with significant potential for development in these areas due to its high nutritional value and resilience to various environmental conditions. Diversification of breadfruit crops is expected to improve local food security and provide positive economic opportunities. Furthermore, developing processed breadfruit products can also provide significant added value to these areas. With appropriate attention and action, it is hoped that the risk of food insecurity in these areas can be reduced.

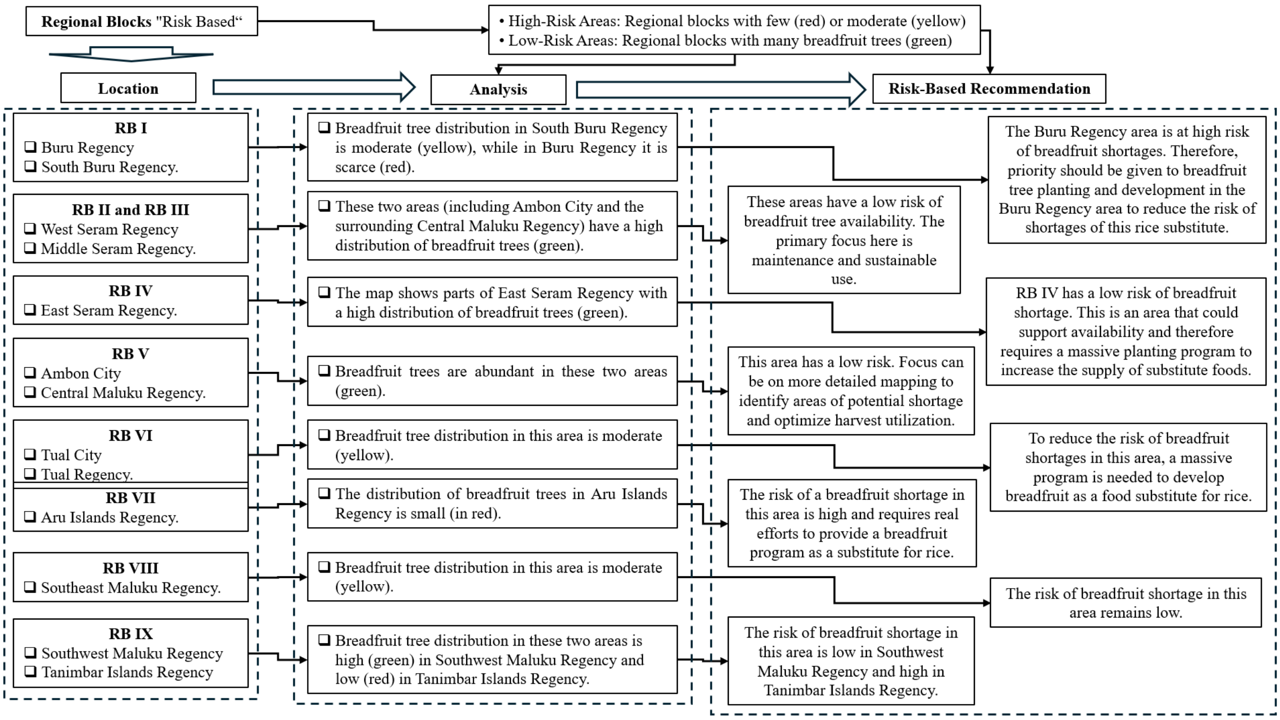

Figure 4. Risk-Based Recommendation

From Figure 4, related to Risk-Based Recommendations, it can be seen that Risk-Based I (RB I) is the disaster risk area code in Buru Regency and South Buru Regency. Both of these areas are prone to natural disasters, including landslides, floods, and earthquakes. RB I is the primary focus of disaster mitigation efforts, with various programs aimed at increasing community preparedness and reducing disaster risks through collaboration among the government, non-governmental organizations, and local communities. From a disaster risk perspective, this area is analyzed for the distribution of breadfruit trees in South Buru Regency, with medium-sized breadfruit trees symbolized by yellow. In the Buru Regency, small-sized breadfruit trees are symbolized by red. Therefore, the Risk-Based Recommendations in the Buru Regency area focus on addressing the high risk of breadfruit shortages, with Priority given to planting and developing breadfruit. The distribution of breadfruit in the region is uneven, with a higher concentration in South Buru Regency compared to Buru Regency.

Risk-Based Areas II and III (RB II and RB III) represent disaster-risk areas in West Seram Regency and Central Seram Regency, respectively. The focus of RB II and RB III is to plant more breadfruit trees in these areas as a priority to reduce the risk of food shortages. Collaboration among local governments, local communities, and various stakeholders is crucial to the success and sustainability of breadfruit supply, ensuring the well-being of local communities. These two areas have a high distribution of breadfruit trees (green). Local governments can provide incentives to local communities to actively participate in planting and sustainably maintaining breadfruit trees. Educational programs need to be enhanced to raise public awareness of the importance of maintaining a sustainable food supply.

Risk-Based Area IV (RB IV) in East Seram Regency indicates that the area has a high distribution of breadfruit trees (green), resulting in a low risk of breadfruit shortage. This area can support increased availability, and therefore requires a large-scale planting program to increase the supply of substitute foods. This large-scale planting program, combined with ongoing maintenance, will help maintain the balance of the region's ecosystem and ensure environmental sustainability, as well as the availability of alternative food sources.

Risk-Based V (RBV) is located in Ambon City and Central Maluku Regency. Breadfruit trees are abundant in these two areas (green), so risk-based recommendations in these areas tend to be low risk. RB V, which operates in Ambon City and Central Maluku Regency, has a large number of breadfruit trees in both areas, indicating a relatively low risk in these areas. This enables more detailed mapping to identify areas that require greater attention and optimize harvest yields.

Risk-Based VI (RB VI) is a disaster mapping effort that utilizes vegetation-based disaster mitigation, exemplified by a case study of breadfruit development in Maluku as a food diversification strategy, located in Tual City and Tual Regency. The distribution of breadfruit trees in this region is classified as medium (yellow). To mitigate the risk of breadfruit scarcity in this region, a comprehensive program is necessary to develop breadfruit as a viable food substitute for rice. This will enable the breadfruit development program, a food diversification initiative, to be implemented optimally, increasing harvest yields and reducing the risk of food scarcity in the region.

Risk-Based Assessment VII (RB VII) is a disaster mapping effort that incorporates vegetation-based disaster mitigation, with a case study of breadfruit development in Maluku as a food diversification program, located in the Aru Islands Regency. Breadfruit trees are rare in the Aru Islands Regency (red). The risk of breadfruit scarcity in this region is high, indicating that breadfruit distribution is very low. Consequently, concrete efforts are needed to implement a breadfruit program as a viable alternative to rice. This effort aims to reduce dependence on rice and increase food security in the Aru Islands Regency.

Risk-Based Risk VIII (RB VIII) is a disaster mapping initiative with a focus on vegetation-based disaster mitigation and management. This study examines breadfruit development in Maluku as a case study for food diversification. This area is located in Southeast Maluku Regency, with a medium distribution of breadfruit trees (yellow). This indicates that the distribution of breadfruit trees in this area is classified as medium, with the risk of breadfruit scarcity still low. However, efforts or programs are needed to increase availability in the green category. RB VIII is a crucial step in vegetation-based disaster mitigation, with a focus on breadfruit development in the Maluku Islands.

Risk-Based VIII (RB VIII) is a disaster mapping initiative with a focus on vegetation-based disaster mitigation and management. This study examines breadfruit development in Maluku as a case study for food diversification. This area is located in Southeast Maluku Regency, with a moderate distribution of breadfruit trees in the area (yellow). This indicates that the distribution of breadfruit trees here is classified as moderate, with the risk of breadfruit scarcity in this area still low. However, efforts or programs are needed to increase availability in the green category. The distribution of breadfruit trees in these two areas is high (green) in Southwest Maluku Regency and low (red) in Tanimbar Islands Regency.

The risk of breadfruit scarcity in these areas is low in Southwest Maluku Regency and high in Tanimbar Islands Regency. This means that in Southwest Maluku Regency, food availability from breadfruit is sufficient for disaster mitigation, while in Tanimbar Islands Regency, food availability from breadfruit for disaster mitigation still requires serious attention due to the still low distribution of this plant. Thus, the potential of breadfruit as a food source for disaster mitigation in the Tanimbar Islands Regency can be optimized.

Table 2. Grouped regions in Maluku based on the risk level of breadfruit scarcity

Regional Risk Code	District/City	Breadfruit Distribution (Indicators and Levels)	Breadfruit Scarcity Risk	Recommendations & Main Focus
RB I	Buru Regency:	Red (Small/Low)	High	Top priorities: A large-scale breadfruit planting and development program to reduce the risk of scarcity.
	South Buru Regency:	Yellow (Medium/Moderate)	Low (needs improvement)	Risk: Needs improvement in South Buru.
RB II & RB III	West Seram Regency & Middle Seram Regency	Green (High)	Low	Focus on sustainable maintenance and utilization.
RB IV	East Seram Regency	Green (High)	Low	Implement an effective management strategy and a large-scale planting program to increase the supply of substitute food.
RB V	Ambon City & Central Maluku Regency	Green (Abundant)	Low	More detailed mapping to identify potential shortages and optimize harvest utilization.
RB VI	Tual City & Tual Regency	Yellow (Medium/Moderate)	Medium	A large-scale program to develop breadfruit as a rice substitute and detailed mapping to improve distribution.
RB VII	Aru Islands Regency	Red (Rare/Very Low)	High	Concrete and urgent efforts for a large-scale breadfruit planting program as a rice substitute (food diversification).
RB VIII	Southeast Maluku Regency	Yellow (Medium/Moderate)	Low (needs improvement)	A sustainable program to increase breadfruit availability to reach the green (high) category.
RB IX	Southwest Maluku Regency:	Green (High/Sufficient)	Low	Low risk in Southwest Maluku, sustainability is needed.
	Tanimbar Islands Regency:	Red (Low)	High	Serious steps to improve distribution, such as increasing planting and developing efficient cropping patterns.

Table 2 explains that the analysis grouped regions in Maluku based on the risk level of breadfruit scarcity as an emergency food product (EFP), indicated by its distribution status, marked red for low or scarce, yellow for moderate, and green for high or abundant. This highlights the need for a differentiated disaster mitigation strategy in Maluku, with a focus on planting in areas with high risk of flooding, such as those marked in red and yellow. In contrast, green areas are prioritized for conservation management and logistics utilization.

High-priority areas require large-scale planting interventions in the High-Risk category. These areas, marked in red, have very low breadfruit distribution and potentially face the highest risk of emergency food shortages during a disaster. The primary focus in these areas is immediate expansion and planting. In Risk-Based Code I (RB I) for Buru Regency, although South Buru has moderate distribution, marked yellow, Buru Regency has low breadfruit distribution, marked red. Therefore, a top priority should be a large-scale breadfruit planting and development program in Buru Regency to reduce the risk of rice substitute shortages. Under Risk-Based Code VII (RB VII) for the Aru Islands Regency, breadfruit distribution is very scarce, as marked in red, placing it at high risk of rice substitute shortages. Concrete and urgent efforts are needed for a large-scale breadfruit planting program as a food diversification strategy. Under Risk-Based Code IX (RB IX) for the Tanimbar Islands Regency, although Southwest Maluku already has a high distribution, the Tanimbar Islands Regency has a low distribution, marked in red. Therefore, serious steps are needed to improve distribution, including increased planting and the development of efficient cropping patterns.

Medium Priority Areas with programs requiring improvement and improvement programs at Medium Risk: This region has moderate breadfruit distribution, marked in yellow, and requires a sustainable program to increase availability and mitigate potential long-term risks. In Risk-Based Code VI (RB VI) for Tual City and Tual Regency, breadfruit distribution is at a moderate level, with a yellow mark indicating moderate risk. A large-scale program to develop breadfruit as a rice substitute, supported by detailed mapping to improve distribution, is recommended. In Risk-Based Code VIII (RB VIII) for Southeast Maluku Regency, breadfruit distribution is also moderate, with a yellow mark. Although the risk of scarcity remains low, a sustainable program is necessary to increase breadfruit availability to the green market, with high distribution, to maximize the benefits of food diversification.

Low-priority areas require a focus on maintenance and optimization due to their low risk. These areas have high or abundant breadfruit distribution, with a green mark. Therefore, the primary focus shifts from planting to conservation, sustainable maintenance, and efficient utilization of harvest. In Risk-Based Codes II and III (RB II and RB III) for West Seram and Middle Seram Regency, distribution is high, with a green mark indicating low risk. So that the area can focus primarily on the maintenance and sustainable use of breadfruit. In Risk-Based Code IV (RB IV) in the East Seram Regency area, which has a high distribution category marked in green and a low risk, this area is recommended for implementing proper management and a large-scale planting program. Although the risk is low, this planting aims to increase the overall supply of substitute food. In Risk-Based Code V (RBV) for the Ambon City and Central Maluku Regency areas, where breadfruit stocks are relatively abundant, this area is marked in green. This area has a low risk of food vulnerability, allowing the focus to be shifted to more detailed mapping to identify potential deficiencies in sub-regions and optimize the use of existing harvests. In Risk-Based Code IX (RB IX), which covers the Southwest Maluku Regency area, where parts of this block exhibit a high distribution, marked in green, the risk of food vulnerability is low. Therefore, the recommended focus is on maintaining the sustainability of the breadfruit supply.

4.3 Multi-agent distribution

The use of multi-agent food distribution during natural disasters simplifies and streamlines distribution by dividing large areas into multiple regions and utilizing coordination algorithms and shortest paths for better performance and faster food delivery. Research has shown that using multiple agents in a distributed environment provides better performance than using a single agent(Manzoor et al., 2014).

The people of Maluku are familiar with breadfruit and process it into various traditional foods. This demonstrates the high level of acceptance of breadfruit as a food ingredient. Economic surveys indicate that breadfruit cultivation has high economic value due to its low maintenance costs, long productive life, and potential for diversification into marketable processed products. Building food and beverage supplies by utilizing empty spaces around disaster-prone areas will increase the capacity to accommodate local evacuees (Kotani et al., 2020).

Overall, this research demonstrates that breadfruit development in Maluku has a strong foundation, both ecologically (in disaster mitigation), socially (through community acceptance), and economically (in terms of food security and income), making it an ideal model for further development. For example, in Peru, after floods destroyed plantain crops, farmers replanted plantains instead of the more flood-resistant breadfruit. Breadfruit was able to survive the floods and provide food when other crops were unavailable due to its low price(Hadley et al., 2023).

In a study titled "Breadfruit as an Alternative Food Source to Replace Rice," Yati Supriati, a researcher from the Center for Agricultural Research and Development (BBPPB) for Biotechnology and Genetic Resources, Bogor, stated that the carbohydrate content of 100 grams of breadfruit flour is equivalent to 100 grams of rice. Breadfruit could potentially serve as a substitute for rice in the future. Breadfruit (Artocarpus sp.) is also a source of carbohydrates other than rice(Raharjo et al., 2020).

Nutritionally, breadfruit can be equal to, or even surpass, rice in certain aspects, making it a valuable food choice, especially in tropical regions, including the Maluku. Breadfruit is rich in complex carbohydrates. According to nutritional data, 100 grams of cooked breadfruit contains approximately 25-30 grams of carbohydrates. This figure is comparable to 100 grams of cooked white rice, which contains approximately 28 grams of carbohydrates, indicating that, in terms of energy content, breadfruit and rice are very similar. Despite their similar carbohydrate content, breadfruit has an advantage in terms of the glycemic index (GI). The glycemic index of cooked breadfruit is between 58 and 65, making it a medium-GI food. In comparison, white rice has a high GI, around 73.

The lower glycemic index of breadfruit means that sugar is released into the bloodstream more slowly, which can help maintain more stable blood sugar levels. Beyond its carbohydrate content, breadfruit offers additional nutritional benefits that make it superior to rice. Breadfruit contains fiber; every 100 grams of breadfruit contains about 4.9 grams of fiber, while 100 grams of white rice only has 0.4 grams of fiber. The much higher fiber content in breadfruit is essential for digestive health and provides a longer feeling of fullness. Breadfruit also has less protein than rice; 100 grams of breadfruit contains about 1.1 grams of protein, while white rice has 2.7 grams. However, breadfruit offers a more comprehensive selection of essential amino acids, providing complete nutrition. Vitamins and Minerals in breadfruit are rich in potassium, vitamin C, and antioxidants, nutrients that are almost absent in white rice. One hundred grams of breadfruit can provide about 10-15% of the daily potassium requirement, which is essential for heart health and blood pressure. Overall, breadfruit is a source of carbohydrates that is numerically equivalent to rice, but with a richer nutritional profile, making it a superior food choice for overall health.

Breadfruit production in Hawaii has seen a significant surge, growing rapidly from fewer than 500 trees in commercial cultivation two and a half decades ago to over 8,000 trees today. Unprocessed fruit can usually be found in season at farmers' markets and some convenience stores. A variety of processed products are made from breadfruit, including baked goods, hummus, chocolate mousse, baby food, chips, flour, and pickles. In the grocery sector, the fruit is marketed in a minimally processed form. Despite the increasing popularity of breadfruit, most people still consume it less than three times a year, and most obtain it through friends and relatives rather than from commercial markets.

Currently, the amount of breadfruit exported from the state is minimal, both in minimally processed and value-added forms. Fresh fruit exports from Hawaii are prohibited by USDA regulations (Lincoln et al., 2021). A comparison of the breadfruit cases in Hawaii and in Maluku, based on the text you provided and focusing on the previous issues (disaster mitigation and food security), highlights the sharp differences in market context, functional role, and logistical challenges. Comparison of Management in Hawaii and in Maluku, the Hawaii case has the primary objective of commercial development and product diversification to meet the growing domestic market demand, developing value-added products (flour, hummus, mousse). While in Maluku, it is intended to enhance food security and disaster mitigation by ensuring emergency food availability during disasters, as well as to provide ecological functions such as vegetation that buffers the risk of abrasion or erosion.

5. Conclusion

In the Risk-Based (RB) breadfruit planting program, the map divides the region into several Area Blocks (RB). Based on the distribution of breadfruit trees (green), RB I, RB II, RB III, RB V, RB VI, RB VII, RB VIII, and RB IX have the most significant potential for planting and utilizing breadfruit as a food substitute because the areas within these blocks have a high concentration of breadfruit trees. Conversely, RB IV has the fewest breadfruit trees (red). Breadfruit planting should be encouraged in this area to increase food availability. In short, to maximize the use of breadfruit as a food substitute, the primary focus is on areas that already have abundant breadfruit trees, namely those labeled green.

Among the islands in Maluku Province, which are centers of breadfruit production, are Ambon, Banda, Namlea, Seram, Tual, Saumlaki, and Moa in the Maluku Islands. Its high carbohydrate content makes it a potential alternative to rice. Breadfruit, also known as Emergency Food Products (FSP), is a processed food product specifically designed to meet daily human energy needs (2,100 kcal) and is consumed in emergencies such as floods, landslides, earthquakes, and other emergencies.

Its potential is expected to address food security challenges through food diversification, which involves processing breadfruit into breadfruit flour. As a local commodity in Maluku, breadfruit cultivation is necessary to alleviate the economic burden on the community as a whole, particularly the Maluku community. Breadfruit cultivation offers opportunities to increase added value for welfare, both as a substitute for rice and as a processed product with economic value that can improve community welfare. The breadfruit cultivation program also aligns with the Disaster Mitigation program to address food security vulnerabilities caused by disasters.

National food security needs to be strengthened through efforts to diversify food sources, utilizing local food resources. This aligns with the 12-Step Guide developed by the Tampa Bay Network to End Hunger (TBNEH) for community organizations managing food programs. This program is designed to prepare for emergencies or disasters and guide local organizations in developing comprehensive emergency response plans or food programs tailored to meet the needs of each program (Network et al., 2020).

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