Adaptation strategy for sustainable food sovereignty based on vulnerability and climate risk assessment: a case study of Sulawesi Island

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Abstract. Food is an important element to human life. Food availability is a main factor to support sustainable agricultural activities. Concrete efforts are urged to support the Indonesian government targets to become the world food basket by 2045. Extreme climate events leading to climate related hazards such as floods and drought that significantly impact negatively planting area, harvesting, and production must be addressed so the risks can be minimized. Vulnerability and risk assessment of climate impacts on food farming system are completed to provide information on the vulnerability level in each district/city to determine contributing factors that influence the vulnerability level. Data on climate, land, and water resources as well as socio economic were selected to represent the indicators for vulnerability assessment. The indicators were grouped into Exposure and Sensitivity Index-Indeks Keterpaparan dan Sensitivitas (IKS) and Adaptation Capacity Index-Indeks Kapasitas Adaptasi (IKA). The vulnerability and risk assessments to floods for Sulawesi Island explain that there are about 8% of districts/cities grouped into the level of very high category and about 17% of the districts/cities grouped into the level of high category. As for the vulnerability and risk to drought, the assessments show that about 1% of districts/cities are included into the level of extreme high category, about 8% grouped into the level of very high category, and about 17% classified into the level of high category. The contributing factors to the IKA are the length of the road based on surface conditions and the ratio of the number of farmer groups per paddy area. The IKS dominant determinants that must be addressed are climate. The level of vulnerability and determinant factors are useful to assist in preparing strategies and recommended programs of adaptation actions compounded with priority districts/cities whose levels of vulnerability are categorized into high, very high, and extreme high.

1. Introduction
Indonesia is committed to becoming the world's food barn by 2045. To realize that goal will certainly meet various challenges. One of them is climate change and extreme climate events. The effects of climate change are multidimensional in the agricultural sector, specially resources, agricultural infrastructure, and agricultural production systems. The agricultural sector receives a significant impact due to extreme climate change and events. Therefore, agriculture is increasingly becoming a major sector for adaptation and mitigation initiatives that address climate change and help ensure food security for a growing global population [1]. Three main factors associated with climate
change/extreme climate events that affect the agricultural sector are: 1) changes in rainfall patterns, 2) increasing extreme climate events and 3) increases in air temperature and sea level [2]. The results of research by [3] showed a very strong relationship between ENSO and rice production in Indonesia especially in Java. The effect of climate change on rice production is caused by rising temperatures [4], [5], [6] and impact climate change on crops [7], [8], [9], [10], [11]. The decrease in production is more due to reduced biomass formation, shorter growth periods and increased respiration [12]. In addition, the decline in production can also be caused by reduced planting area and harvested area due to flooding, drought and crop pest organisms. On a national scale, disruption to food farming due to climate change will affect food sovereignty in Indonesia.

As well known, food has an important role and function in achieving the goals of the State of Indonesia. Food is not just a commodity and basic necessities of life, but also has a large role, namely the role of the welfare of the Indonesian people, the interests and national security of the Indonesian state [13]. Therefore, food sovereignty needs to be studied strategically both current and future conditions of food security, influencing factors, and also recommendations for achieving food sovereignty. Food problems in Indonesia cannot be avoided along with the increasing population. In addition, the reduction in agricultural land due to being converted into settlements and industrial land is also a challenge in the effort to realize food sovereignty. Food sovereignty is the right of every nation and people to have the ability to produce basic food needs independently. Food sovereignty is a prerequisite for food security. Food security will only be created if food sovereignty is owned by the people [14]. Food sovereignty and food productivity programs are indeed able to increase the quantity of production, but have not experienced an increase in the aspect of production value. This can be seen from the increase in production which is not directly proportional to the reduction in hunger and malnutrition. The development of food agriculture is expected not only to be oriented towards increasing production but also the value of its production. Therefore it is necessary to develop programs and actions and strategies to increase resistance to various shocks and pressures due to extreme climate / climate change that threaten food sovereignty.

Programs and actions that can be taken to reduce the impacts of climate change and extreme climate events for the Agriculture Sector are more focused in the form of adaptation with co-benefit adaptation (mitigation). The main purpose of adaptation is to reduce vulnerability, increase adaptive capacity and increase resilience to climate change. Adaptation efforts can be made through three types, namely: community based, national policy and programs & projects [15]. The key questions of the adaptation of the agricultural sector to climate change are: 1). How to identify climate risk levels for agricultural production areas, 2) What should be programmed for the region. The approach that can be taken for the first question is: Development of a climate risk assessment method, identification of key indicators of the focus of the agricultural sector that contribute to vulnerability, mapping the level of vulnerability and regional climate risk. The second question is approached with recommendations for climate change adaptation measures focusing on the agricultural sector [16].

In this study, the adaptation strategy in order to reduce risk is through the analysis of the level of vulnerability of food farming and climate risk. Vulnerability is the tendency of a system to experience negative impacts which include sensitivity to negative impacts and lack of adaptive capacity to overcome negative impacts [17]. According to the IPCC [18] the level of vulnerability is assessed based on three indicators, namely: exposure, sensitivity and adaptive capacity. Land resource data (climate, water and soil fertility) and economic social data can be used to represent the level of exposure, sensitivity and adaptation capacity. In the study of food farming vulnerability and climate risk, determinants can also be determined which can be used as a reference in program planning and adaptation actions [19], [20].

The selection of Sulawesi Island is based on the consideration that Sulawesi Island is one of the 10 largest rice producing provinces in Indonesia. In addition, in the future Sulawesi Island will also become Indonesia's food granary amid increasing the rate of conversion of agricultural land in Java as the main rice production center [21]. Therefore program strategies and planning related to food adaptation and sovereignty are very relevant and important for food center locations such as Sulawesi
Island. The purpose of writing this paper is to provide information on the results of studies of food crop vulnerability and climate risk at the district/city level as a basis for program planning and adaptation actions to support food sovereignty.

2. Methodology

This research conducted on Sulawesi Island in Indonesia. Having an area of about 174,600 square kilometres. Sulawesi is the 11th largest archipelago in the world. In the country of Indonesia, the area is ranked 4th after Papua, Kalimantan, and Sumatera. Sulawesi is divided into 6 provinces namely, West Sulawesi with the capital of Mamuju, Central Sulawesi with the capital of Palu, South Sulawesi with the capital of Makassar, Gorontalo with the capital of Gorontalo, North Sulawesi with the capital of Manado, and Southeast Sulawesi With the capital Kendari (Figure 1).

Vulnerability research and studies are carried out with a focus on food farming vulnerability and climate risk. Vulnerability rates are assessed based on indicators of exposure, sensitivity and adaptation capacity, while climate risks are assessed based on flood and drought trends. The data used include data: 1) type and slope of the land to determine the level of soil fertility, 2) discharge, population, area, area of paddy and dry land, number of industries to determine the level of water availability, 3) rainfall to determine the type climate and 4) socioeconomic factors such as production, consumption etc. Overall data is disaggregated to represent the adaptive capacity index (IKA) and exposure and sensitivity index (IKS).

Flood and drought trends were analyzed based on data on the area of paddy fields which were flooded or drought in the period 1989-2015 sourced from the Directorate of food crop protection at the Ministry of Agriculture. Vulnerability is a function of exposure, sensitivity and adaptation capacity. \( V = f(\text{exposure, sensitivity, adaptive capacity}) \). Vulnerability level analysis is done by the quadrant method [22] which results in 5 classes of vulnerability. Furthermore, from 5 classes combined with flood and drought trends, 3 classes so that the combination of the two results in 7 classes of level of vulnerability (Table 1). The determinant factor is determined from the input data variables based on the results of the analysis with spider diagrams for each IKA and IKS indicator. The flow diagram of the analysis phase is presented in Figure 2.

![Figure 1. Study area in Sulawesi Island](image-url)
Table 1. Classification of Food Farming and Climate Risk Vulnerability

| Vulnerability | Flood and Drought Tren |
|---------------|------------------------|
|               | Increase       | Fixed Value | Decrease       |
| Very High     | Extrem High    | Very High   | High           |
| High          | Very High      | High        | Moderate       |
| Moderate      | High           | Moderate    | Low            |
| Low           | Moderate       | Low         | Very Low       |
| Very Low      | Low            | Very Low    | Extrem Low     |

Figure 2. Step of analysis

3. Results and Discussion
Sulawesi Island consists of 5 provinces namely South Sulawesi, Southeast Sulawesi, Central Sulawesi, North Sulawesi, West Sulawesi and Gorontalo with a total number 78 districts/cities. Sulawesi Island vulnerability analysis is focused on vulnerability assessment related to food farming and climate risk (flooding or drought) at the district/city level. Based on the map of food farming vulnerability and flood risk on Sulawesi Island (Figure 2a), there are 6 districts / cities on Sulawesi Island (8%) with a "very high" vulnerability level and 13 districts/cities (17%) "high". While for the results of the analysis of the vulnerability of food farming and the risk of drought (Figure 2b) shows that there are 1 district/city (1%) with a "high extreme" vulnerability level, 6 districts/cities (8%) "very high" and 13 districts/cities city (17%) "high". Districts/cities identified as having high levels of vulnerability to food farming and high to extreme flood risk in general also have a high risk of drought. This means that districts which often experience floods in general also often experience drought. Based on the identification results, out of 23 districts that have high to extreme high levels of vulnerability, 21.7% of them have "very high" and 39.1% "high" vulnerabilities both at the risk of flooding and drought. There are also areas that are safe for flood risk but vulnerable to drought, which is 17.4%, or conversely safe in drought conditions but vulnerable to flood risk, which is around 13%. This area should be a priority in adaptation programs and actions (Table 2).

Determinants identified from 23 district/cities with high to extreme high levels of vulnerability indicate that 30% of them are determinants of road length based on surface conditions to be the factor that contributes most to the still low adaptation capacity. For this reason, the general recommendations given are to improve and build road infrastructure and to organize education and training in adaptive technology skills. High exposure and sensitivity were more dominant due to determinant factors, namely climate (30%). Proposed general recommendations include: adapting, providing alternative water sources, adjusting farming to climate conditions, implementing an Integrated Cropping Calendar, developing irrigation and water harvest infrastructure and using alternative water resources. Determinants can be identified for each district/city as a reference in the proposed recommendation.
Implementing an adaptation strategy for agriculture is a fundamental thing that needs to be done both by farmers and with the help of other parties. However, practical adaptation activities by farmers are often based on reason and experience in the field, not yet juxtaposed with empirical studies or scientific research. On the other hand, government assistance both in terms of scientific research and facilities and infrastructure has not been fully supported by farmers' capacity [16]. Therefore, knowing the determinant factors can be used as a basis in knowing the dominant factors that influence the level of vulnerability.

Table 2. Status of vulnerability of food farming and flood or drought risk

| No | District/City       | Vulnerability of Food Farming and Flood Risk | Vulnerability of Drought Risk | No | District/City       | Vulnerability of Flood Risk | Vulnerability of Drought Risk |
|----|---------------------|---------------------------------------------|-------------------------------|----|---------------------|-----------------------------|-------------------------------|
| 1  | Luwu                | VH                                         | VH                           | 13 | Konawe Utara       | H                           | VH                           |
| 2  | Toraja Utara        | VH                                         | VH                           | 14 | Bombana            | VH                          | VH                           |
| 3  | Mamuju Tengah       | VH                                         | VH                           | 15 | Konawe             | H                           | H                            |
| 4  | Bulukumba           | NV                                         | H                            | 16 | Wakatobi           | H                           | H                            |
| 5  | Jeneponto           | H                                          | H                            | 17 | Kolaka             | H                           | NV                           |
| 6  | Bantaeng            | NV                                         | H                            | 18 | Siau               | Tagulandang Biaro           | VH                           |
|    |                     |                                             |                               |    |                     |                             |                               |
| 7  | Bone                | NV                                         | H                            | 19 | Gorontalo          | H                           | H                            |
| 8  | Wajo                | H                                          | H                            | 20 | Pohuwato           | H                           | H                            |
| 9  | Minahasa Selatan    | NV                                         | H                            | 21 | Gorontalo Utara    | H                           | H                            |
| 10 | Soppeng             | H                                          | NV                           | 22 | Polewali Mandar    | VH                          | EH                           |
| 11 | Sidenreng Rappang   | H                                          | NV                           | 23 | Mamasa             | H                           | H                            |
| 12 | Poso                | H                                          | H                            |    |                     |                             |                               |

EH=Extrem High, VH=Very High, H=High, NV=Not Vulnerable

The results of the identification of these determinant factors form the basis of program planning and adaptation actions. Program priorities and adaptation actions at both the Island, Provincial and
Regency levels can be determined based on the main determinant factors in each of these regions. The data and information are expected to make it easier for local governments to prepare plans related to adaptation to climate change. Assessment of adaptation success can be done by monitoring the level of vulnerability whether after adapting the level of vulnerability increases or decreases. This is an indicator that adaptation programs and actions can increase adaptation capacity and reduce exposure and sensitivity so that the level of vulnerability decreases.

In this study adaptation recommendations are based on determinants that aim to reduce the level of vulnerability. Therefore, recommendations are site-specific and can be implemented in the regions. To strengthen recommendations, surveys and interviews were conducted with a number of stakeholders, namely the Institute for Assessment and Application of Agricultural Technology (BPTP), the Regional Planning Agency (Bappeda), the Agriculture Office, the Plant Protection and Pest Control Center (BPTPH), the Agricultural Extension Office (BPP) and Food Security Agency in districts that have a high level of vulnerability to extreme high. For Sulawesi Island, as a sample survey and interview are in Polewali Mandar Regency and Central Mamuju, West Sulawesi Province. The survey results and interviews show that the dissemination of adaptation related to climate change has been carried out at the provincial level for district level extension agents which is carried out together with other relevant agencies such as the Meteorology, Climatology and Geophysics Agency (BMKG) and BPTPH. Regional programs in supporting adaptation include: making reservoirs, irrigation networks, pumping and structuring water resources and infrastructure cooperation between the Water Resources Office and the Agriculture Office, land development for annual and annual crops, planning planting time and determining varieties with related agencies. In addition, seed, fertilizer and pesticide assistance programs for areas prone to flooding or drought and agricultural equipment assistance programs, the Integrated Pest Control Field School Program (SLPHT) by the Integrated Pest Program Extension (PPHT), post-disaster management programs, especially in flood-prone areas and drought, the use of certified superior varieties such as Mekongga, Inpari 13, Inpari 8, and Inpari 6 with the Padi-Padi-Palawija cropping pattern. This is also in line with the adaptation strategy developed by the Agricultural Research and Development Agency [23].

Determinants of food vulnerability are needed to determine the form of adaptation programs and activities that need to be done to reduce the level of vulnerability. Improvement of indicators of food farming vulnerability will have a direct or indirect impact on food availability. The ideal condition to be achieved related to adaptation programs and actions is to reduce the level of vulnerability to moderate / very low / extreme low. For this reason, some of the general recommendations proposed are:

1) Increasing the ability of the community (farmers) in managing climate risk, especially smallholder farmers as the main food producers
2) Increased adoption and application of adaptive technology to increase food production
3) Food diversification to meet food needs other than rice to reduce rice needs
4) Strengthening policies and programs to support farmers in dealing with the effects of climate change
5) Optimization of Climate Information Systems and early warning of threats and information technology.

As comparator, the Ministry of Agriculture through an echelon 3 or 2 working unit has produced various technologies in order to adapt to climate change. For example, Indonesia Agroclimate and Hydrologi Research Institute (IAHRI) has been implemented technical guidance with topic is the “Utilization of climate information for agriculture sector”; Held in several locations (Gorontalo, Purwokerto, Manado, Sorong, Makassar) which is followed by the Agriculture Service; Department of Irrigation; Universities; Meteorological, Climatology and Geophysics Agency (BMKG) and the Center for Agricultural Technology Assessment (BPTP). The area of sustainable food house program that is being encouraged by the Ministry of Agriculture is an effort to fulfill nutrition and food diversification. Integrated Cropping Calendar which is the product of the Ministry of Agriculture that
provides information to farmers about the determination of early planting, the needs and types of fertilizers, varieties and so on. This information is already accessible via Web, Android and SMS.

In addition, some specific recommendations based on the level of food vulnerability and climate risk and their determinants are as follows:

1) Areas with high levels of food vulnerability and extreme climate risk, very high and high need to be given major attention in terms of flood and drought prevention such as access to information, early warning systems, allocation of disaster management costs and others because the disaster trends in this region are increasing.

2) At the district level, in order to increase adaptation capacity, determinants need to be taken into account, namely: the ratio of agricultural land to food / population, education, income distribution, percentage of poor population and rice production / population. These variables affect consumption and production. Increasing the number of extension agents per agricultural area of food is conducive to reducing the level of food vulnerability.

3) Adaptation capacity is enhanced by working on agricultural lands that are still displaced, reducing land conversion rates, increasing education, reducing poverty and food diversification to reduce dependence on rice and the need for agricultural land.

The success of adaptation efforts can be helped by answering questions about: 1). What programs or activities can be coordinated, integrated, synergized and synchronized, 2). Where the priority location is, this can be answered with a map of food vulnerability and climate risk, 3) When the implementation period, in this case must be on time and target, 4) Who is involved, which of course in this case must involve both central and regional governments and local community and 5) How the monitoring and evaluation is carried out in order to find out the success and effectiveness of the implemented program. FAO 2017 provides guidance on how to track adaptation to the assessment of whether adaptation programs and actions taken before and after the project are categorized as low, medium or high [24]. To support and realize the adaptation strategy, the Government of Indonesia has issued several regulations, namely: The law states that the role of the government is needed, one of which is support in the form of regulations [25], [17], [26]. Finally, in its implementation, adaptation requires monitoring and adaptation monitoring processes require continuous data and information collection to enable stakeholders to check whether adaptation processes and results are in line with the objectives expected to support food sovereignty.

4. Conclusion
Research on food farming vulnerability and climate risk on Sulawesi Island provides information on the existence of several districts / cities included in the category of “high”, “very high” and "extreme high" vulnerability to both flood and drought risks. The dominant determinant factor that causes the low adaptation capacity is the length of the road based on surface type, while the cause of high exposure and sensitivity is climate.

Adaptation strategies proposed based on determinants are improving and building road infrastructure and providing education and training in adaptive technology skills, whereas to reduce exposure and sensitivity it is recommended to adapt, provide alternative water sources, adapt farming to climate conditions, implement Integrated Planting Calendars, develop infrastructure irrigation and water harvesting and the use of alternative water resources. Proposed recommendations need to be aligned with programs and action plans of the Regional Government supported by the Central Government to support food sovereignty.

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