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Research Article
Decreasing of Paddy, Corn and Soybean Production Due to Climate Change in Indonesia

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Abstract
Background and Objective: Climate change influence crops through its effects on the growing, development and yield. Research on climate change risk in staple food crops has been implemented in South Sumatra, Indonesia. The objective of this study was to assess level of climate change risk in staple food crops production (paddy, corn and soybean). **Materials and Methods:** This study used data of temperature, rainfall, sea level rise, hythergraph, irrigation, production of staple food crops and farmer's socio-economic. Methods of this study were descriptive explanatory that using risks-vulnerability conceptual framework and risks were a function hazard and vulnerability. **Results:** The results of this study indicate that staple food crops were vulnerable to the impacts of climate change, indicated by hazards such as decreasing production of paddy, corn and soybean due to air temperature increase and rainfall change. Some areas of South Sumatra experienced the high risk of decreasing production of staple food crops. Generally, South Sumatera had decreasing wetland of paddy, upland paddy, corn and soybean production, respectively with an average 9.44, 22.00, 10.7 and 10.10% per year. **Conclusion:** South Sumatera Indonesia experienced the high risk of decreasing production of staple food crops due to climate change and had potency to disrupt food security in Indonesia.

Key words: Climate change, production, staple food crops, temperature increase, rainfall change

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Climate change was projected to result in changes in temperature, rainfall patterns and sea levels[1]. Climate change influences various environmental aspects, including precipitation, evapotranspiration patterns and temperature[2,3,4]. Changes in precipitation patterns affect water availability and runoff directly, while changes in temperature, radiation and humidity have an effect on evapotranspiration[5]. The hydrologic impact of climate change can increase occurrences of extreme hydrologic events, heavy rainfall and droughts[6]. In particular, climate change has significant impacts on agricultural water resources such as availability of water supplies, agricultural water management, droughts and floods[4,7].

Climate change influenced crops as the way crops grow, development and yield[8]. As a biological system, the driving force in crop production is photosynthesis. Crops will be directly sensitive to any future changes in sunshine, rainfall, temperature and CO_2 concentration levels[9,10]. Crops is deeply interconnected with weather and climate, the main drivers of crops production but also the dominant factors in the overall variability of food production[11] and a continuing source of disruption to ecosystem services[12]. Rainfall quantity and its distribution are key factors determining the rainy season characteristics, farming systems and field crop production[13]. Inter-annual and intra-seasonal rainfall variability both constrains crop production in the tropics and subtropics[14,15].

Although many uncertainties about the location and magnitude of climate change, there was no doubt that climate change was causing a major threat to agricultural systems. Developing countries are susceptible to this threat because their economies are closely related to agriculture and their livelihoods depend directly on agriculture and natural ecosystems[16,17]. Therefore, climate change has the potential to act as a "risk multiplier" in the poorest parts of the world, where agriculture and natural resource-based systems fail to accommodate the climate change. Thus, agricultural systems in developing countries must adapt to climate change in order to millions of farmers could face the real and direct threat to food availability and livelihoods[18]. Even without climate change, many agricultural systems in developing countries approaching a crisis point[13,19].

Climate change threats crop production systems and therefore, also threats the livelihood and food availability for billions of people who depend on agriculture. Evidence suggests that poor populations more suffer than rich populations, such as industrialized countries[20,21], because of the effects of climate change. Not only the relatively poor countries will experience more severe impacts but the impact also threats those who lacking resources to prepare and overcome environmental risks. Agriculture is the most vulnerable sector to climate change because of its dependencies on climate and weather and the people who involved in the agricultural sector tend to be poorer than their counterparts in the city[22].

As climate is a primary determinant of agricultural productivity, any future changes will influence crop growth and yield, hydrologic balances, input supplies and other components of managing agricultural systems[23]. For global agriculture these projected spatial and temporal changes in climate (precipitation and temperature) will shift agro-ecological zones[24] and have major impacts on the viability of both upland subsistence[25] and irrigated commodity crop production[8].

Indications of climate change to some extent can be felt in Indonesia. These indications were supported by the results of studies on climate change in the Indonesian region in recent years[26-29]. Indonesia experienced climate change shown by the changing patterns of air temperature, rainfall, hythergraph and Oldeman climatic classification[13]. The influence of global climate change, especially on the agricultural sector in Indonesia has been felt and become reality. This climate change was indicated by the floods, drought and the shift of rainy season. In recent years, the shift of rainy season causes the shift of planting and harvesting seasons of food commodities (rice, corn and vegetables). In addition, floods and drought cause planting and crop failures[13].

In Indonesia, change of rainfall patterns was probably the biggest threat, because so many farmers depend directly on rainfall for their agricultural activities and livelihoods. Every changes of rainfall pose a great risk. Rain-fed agriculture was very susceptible to climate change, if the farming activities remain unchanged. Meanwhile, the quality of fresh water will increasingly affect farming systems in coastal areas due to sea water intrusion and unsustainable irrigation activities. High salinity due to increasing sea level becomes a threat to food crop production in coastal areas because many varieties were not resistant to high salinity. Furthermore, high temperature will affect the crops production. Plants are very sensitive to high temperatures during critical stages, such as flowering and seed development. Combined with drought, high temperatures can cause disaster for crops lands. Changes in temperature and humidity can also lead to the development and sprawl of pests and plant diseases. Floods and droughts also affect agricultural productions. Floods and prolonged droughts, caused by bad water management and low capacity, make significant decrease in productions[13].

Risk assessment is a methodology to determine the nature and extent of risk by analyzing potential threats and evaluating existing conditions of vulnerability that could pose a potential threat to property, livelihoods and the environment on which they depend[30,31]. Risk analysis of climate change was potential loss arising from climate change in a region within a certain time, which can be death, injury, illness, life was threatened, loss of sense of security, evacuation, damage or loss of property and disruption of community activities. In the agricultural sector, the concept of risk can be interpreted as a possibility which can lead to losses, represented by the decline in food crop production as a hazard. Furthermore, the hazard may lead to decreased production, directly or indirectly and the decline of the welfare of farmers and reduction in food supply, that was part of food security in Indonesia[13,32].

The study was focused on analyzing the impact of climate change and climate variability, such as temperature and rainfall patterns change monthly as well as increased frequency and intensity of extreme events, such as La Nina and El Nino. In addition, sea level rise will cause a reduction in agricultural land area, especially around the coast. Risk of decreasing production due to low productivity, reduction in harvested area and decreasing agricultural land area was vulnerable to the threat of dangerous climate change and requires a quantitative approach to perform prediction. Thus, the results of the analysis were expected to be consideration in the preparation of guidelines for local adaptation[12,13].

This study assessed the risk of the staple food crops in Indonesia due to climate change based on the integrated assessment approach using risk indicators. This study conducted an empirical analysis the risk of climate change on paddy (rice), corn and soybean production.

MATERIALS AND METHODS

The data required in this analysis was the data of rainfall and air temperature, sea level rise, production of staple food crops, cropping patterns, water resources (irrigation), crops land use and farmer's socio-economic. The data collected through field survey and observation in South Sumatra, Indonesia that was carried out from 2012-2013. Survey and observations were made to systematically record the circumstances of the condition on the pitch and profile production of staple food crops in 15 districts in South Sumatra, Indonesia.

Methods of this study is descriptive explanatory that using concept of risks-vulnerability assessment. In this study, three aspects of the impact of climate change were analyzed, that was the analysis of hazard events, vulnerability and the risk level[31,33]. The flow chart of risk assessment of climate change on agricultural sector is presented in Fig. 1. Risk is a function of hazard and vulnerability[30]. Hazard refers to qualities of and changes to, climate and agricultural variables. Vulnerability is the degree of ability of an individual or groups

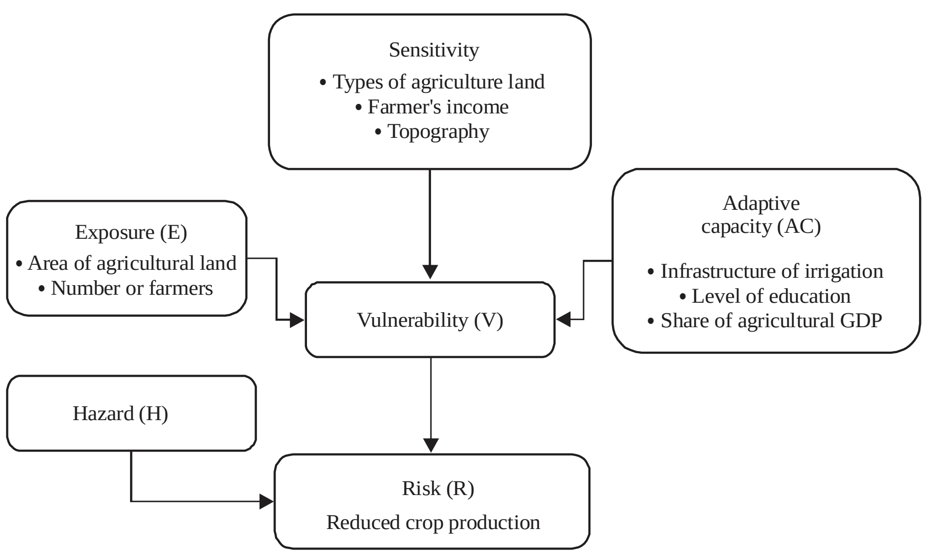

Fig. 1: Flow chart of risk analysis of climate change on staple food crops in Indonesia

of people or communities to anticipate and cope with, maintaining the continuity of life and save themselves from the impact caused by the nature hazard. Vulnerability is always changing along with the changes of farmer's socio-economic conditions and surrounding environments.

In the crops production, concept of risk can be interpreted as a possibility which can lead to loss represented by risk due to decline hazard of food crop production[8,12,17]. Furthermore, the hazard of decreasing production may lead to direct or indirect welfare decline of farmers as well as reduction of food supply, which was a part of food security.

Decreasing productions of staple food crops were considered as multiple climate change hazards in South Sumatera to be analyzed in this study[17,34]. The calculation of risk level on staple food crops used the following equations[13,35-37]:

$$H = f\ (\text{Climatic stimulus}) \tag{1}$$

$$V = \frac{\text{Exposure} \times \text{Sensitivity}}{\text{Adaptive capacity}} \tag{2}$$

$$R = H.V \tag{3}$$

Where:

R = Risk decreasing production of staple food crops
H = Hazard which is calculated on decreased yields of farming production
V = Vulnerability in agricultural sector due to climate change
f = Frequency

Vulnerability and riks of decreasing crops production from every region in South Sumatra then mapped spatially by GIS Software (QGIS version 1.8.0) to know where the most vulnerable and risk to the least significant area so adaptation can be done to overcome.

RESULTS AND DISCUSSION

Hazard on staple food crops: The results of hazard analysis on decreasing staple food crops production such as paddy, corn and soybean in South Sumatera, Indonesia showed in Table 1. The results of hazard analysis on decreasing low land paddy production in South Sumatera, Indonesia with and without sea level rise in showed in Table 2. There are six districts of South Sumatera that can be influenced by sea level rise, namely Musi Banyuasin, Muara Enim, Banyuasin, Palembang, Ogan Ilir and OKI.

Table 1: Results of hazard analysis on decreasing staple food crops production in South Sumatera

	Staple food crops			
Districts	Wetland paddy (t)	Upland paddy (t)	Corn (t)	Soybean (t)
Musi Rawas	-21,235	-5,105	-274	-25
Empat Lawang.	-7,284	-158	-1,037	-52
Lubuk Linggau.	-1,021	-17	-4	-1
Lahat	-11,496	-2,118	-310	-214
Musi Banyuasin	-21,957	-3,477	-4,052	-54
Pagar Alam	-2,270	0	-71	0
Muara Enim.	-11,942	-6,931	-667	-22
Ogan Komering Ulu (OKU)	-1,065	-1,643	-207	-1
South OKU	-7,298	-1,499	-181	-7
East OKU	-56,010	-995	-933	-247
Banyuasin	-42,391	-351	-949	-61
Prabumulih	-56	-784	-386	-2
Palembang	-3,363	-2	-30	0
Ogan Ilir	-22,300	-834	-239	-17
Ogan Komering Ilir (OKI)	-47,611	-1,332	-1,605	-38

Table 2: Hazard on decreasing paddy production in South Sumatera

	Decreasing wetland paddy production (ton)		Decreasing upland paddy production ton)	
Districts	Without sea level rise	With sea level rise	Without sea level rise	With sea level rise
Musi Banyuasin	-22,000	-61,400	-3,500	-3,500
Muara Enim	-11,900	-11,900	-6,900	-23,500
Banyuasin	-42,400	-319,600	-400	-37,500
Palembang	-3,400	-3,700	0	-700
Ogan Ilir	-22,300	-47,100	-800	-800
Ogan Komering Ilir (OKI)	-47,600	-193,100	-1,300	-13,700

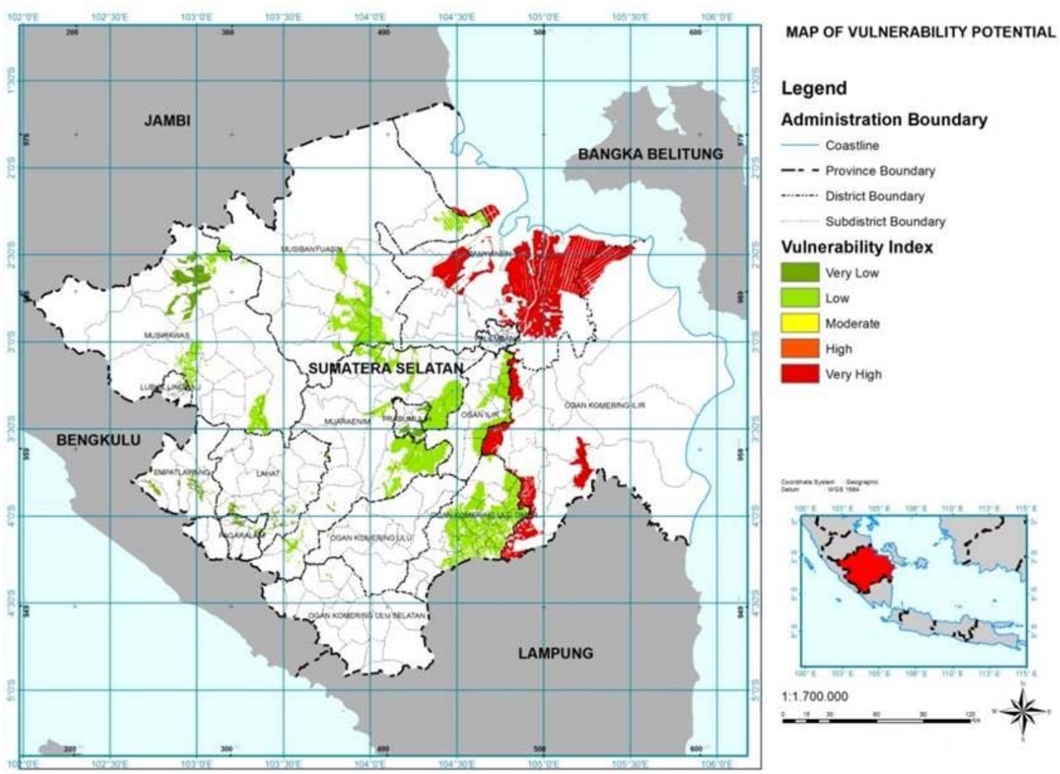

Fig. 2: Map of vulnerability in 2030 (Map was created using QGIS, version 1.8.0)

South Sumatera experienced hazard of crops production such as wetland paddy, upland paddy, corn and soybean, respectively with a total of 257,389 t DG (dry grain), 54, 246 t DG, 10,945 t DG and 741 t DG/year. Generally, South Sumatera have the high level hazard staple food crops such as Musi Banyuasin, East OKU, Banyuasin, Ogan Ilir and OKI. Especially for six areas that influenced by sea level rise (Musi Banyuasin, Muara Enim, Banyuasin, Palembang, Ogan Ilir and OKI), hazard of decreasing production of staple food crops (such as paddy) were higher if sea level rise included in calculating of hazard assessment. Decreasing production of wetland paddy and upland paddy in that area respectively with an average 149,600 and 12,900 t DG/year (without sea level rise) and increased with an average 636,800 and 79,700 t DG/year (with sea level rise).

Climate change and sea level rise in South Sumatera was simply potential to lead production decrease in rice. This was due to the potential decrease in productivity, harvested area and land area of paddy which were the consequences of air temperature increase, rainfall decrease and sea level rise[21,34]. Due to climate change and sea level rise, there were areas that have high hazard for staple food crop production reduction in South Sumatera are Musi Banyuasin, East OKU, Banyuasin, Ogan Ilir and OKI for wetland paddy and Muara Enim, Banyuasin and OKI for upland paddy. In Indonesia and also other countries such as South Korea[4], Ethiopia[17], India[38] and Canada[39] were generally have a high hazard of climate changes on main food crops[40].

Vulnerability of climate change: Vulnerability of climate change showed some area that were dominated by high and very high levels such as in Musi Banyuasin, East OKU, Banyuasin, Ogan Ilir, OKI, Musi Rawas, Muara Enim, Empat Lawang and Prabumulih. Meanwhile, OKU Selatan, Lubuk Linggau, Pagar Alam, and Palembang have very low or low level of vulnerability (Fig. 2). Generally, South Sumatera experienced high level vulnerability of climate change because of high exposure and sensitivity and low adaptive capacity. In that area high rain fed land, low irrigation infrastructure and high poor farmer.

High level of vulnerability indicates that the climate change impact on staple food crop production in Indonesia would be very high. Therefore, adaptation strategy was needed to be improved, so that the vulnerability level will not suppress the agricultural production, food availability, and food sufficiency in Indonesia. The crop production was vulnerable to the impacts of climate change, indicated by hazards such as decreasing productivity,

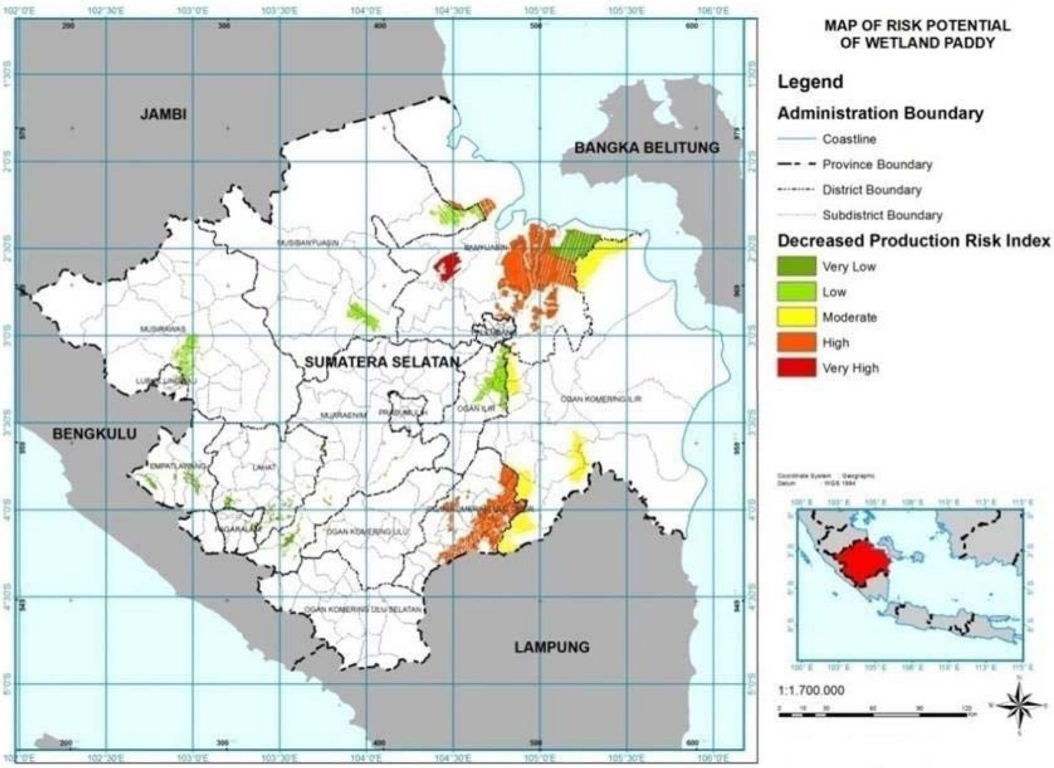

Fig. 3: Risk map of decreasing wetland paddy production in South Sumatera (Map was created using QGIS, version 1.8.0)

Table 3: Index of risk of decreasing production of paddy, corn and soybean in South Sumatera

	Level of risk			
Districts	Wetland paddy	Upland paddy	Corn	Soybean
Musi Rawas	0.188	0.424	0.047	0.082
Empat Lawang.	0.057	0.012	0.159	0.146
Lubuk Linggau.	0.003	0.000	0.000	0.001
Lahat	0.076	0.135	0.040	0.512
Musi Banyuasin	0.250	0.380	0.895	0.220
Pagar Alam	0.000	0.000	0.000	0.000
Muara Enim.	0.127	0.708	0.138	0.085
OKU	0.006	0.097	0.028	0.002
OKU Selatan	0.030	0.061	0.015	0.010
OKU Timur	0.621	0.106	0.201	0.992
Banyuasin	0.516	0.041	0.225	0.269
Prabumulih	0.001	0.071	0.071	0.008
Palembang	0.009	0.000	0.002	0.000
Ogan Ilir	0.226	0.081	0.047	0.061
OKI	0.537	0.144	0.352	0.154

harvested area and production of paddy, corn and soybean due to air temperature increase and rainfall change[13]. Future consequences include declining surplus of food crops. Generally, the region that has high vulnerability trigged risk in staple food crops[41,42]. High vulnerability and risk in staple food crops production will disrupt food security[13,43,44].

Risk of decreasing staple food crops production: The risk analysis result of decreasing staple food crops of paddy, corn and soybean production in South Sumatera without impacts of sea level rise is shown in Table 3. The risk maps of decreasing production of wetland and upland paddy are shown in Fig. 3 and 4.

The risk analysis result shows that some parts of South Sumatera experience the risk of decreasing crops production with moderate to high level. There are districts that experience the risk of decreasing production at moderate level are Banyuasin and OKI (wetland paddy), Musi Rawas (upland

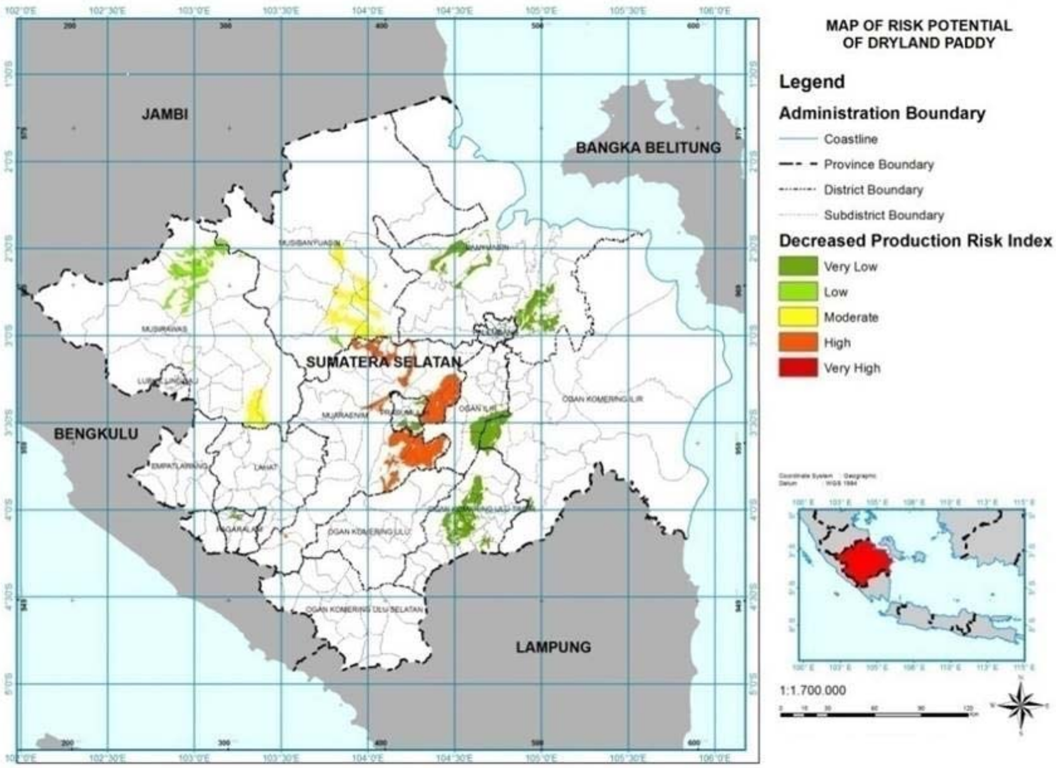

Fig. 4: Risk map of decreasing upland paddy production in South Sumatera (Map was created using QGIS, version 1.8.0)

Table 4: Level of risk on decreasing production of wetland paddy and upland paddy in South Sumatera

	Wetland paddy		Upland paddy	
	Index of risk		Index of risk	
Districts	Without sea level rise	With sea level rise	Without sea level rise	With sea level rise
Musi Banyuasin	0.250	0.365	0.380	0.380
Muara Enim	0.127	0.127	0.708	1.000
Banyuasin	0.516	1.000	0.041	1.000
Palembang	0.001	0.001	0.000	0.004
Ogan Ilir	0.226	0.290	0.081	0.081
OKI	0.537	0.958	0.144	0.449

paddy) and Lahat (soybean). Regions that experience the risk of decreasing production at high level are OKU Timur (wetland paddy) and Muara Enim (upland paddy). Meanwhile, regions which experience the risk of decreasing production at very high level are Musi Banyuasin (corn) and OKU Timur (soybean).

Based on the risk analysis of decreasing production of staple food crops in South Sumatera whitout influence of sea leve rise showed that: (1) OKU Timur has a high risk of decreasing wetland paddy production, (2) Muara Enim has a high risk of decreasing upland paddy production, (3) Musi Banyuasin has a very high risk of decreasing corn production, (4) Musi Banyuasin has a very high risk of decreasing corn production and (5) OKI Timur has a very high risk of decreasing soybean production.

The results of reduction risk analysis of staple food crops (such as paddy) based on climate change and sea level rise in South Sumatera in showed in Table 4. The risk map of production decrease of wetland and upland paddy based on climate change and sea level rise showed in Fig. 5 and 6.

The results of risk analysis of staple food crop production decrease based on climate change with sea level rise show that most parts of South Sumatera generally have the potential risk of decreasing crop production at low levels. The areas that have production decrease risk at very high level are Banyuasin and OKI (for wetland paddy) and Musi Rawas, Muara Enim and Banyuasin (for upland paddy).

Based on the risk analysis of decreasing on staple food crops production based climate change and sea level rise in

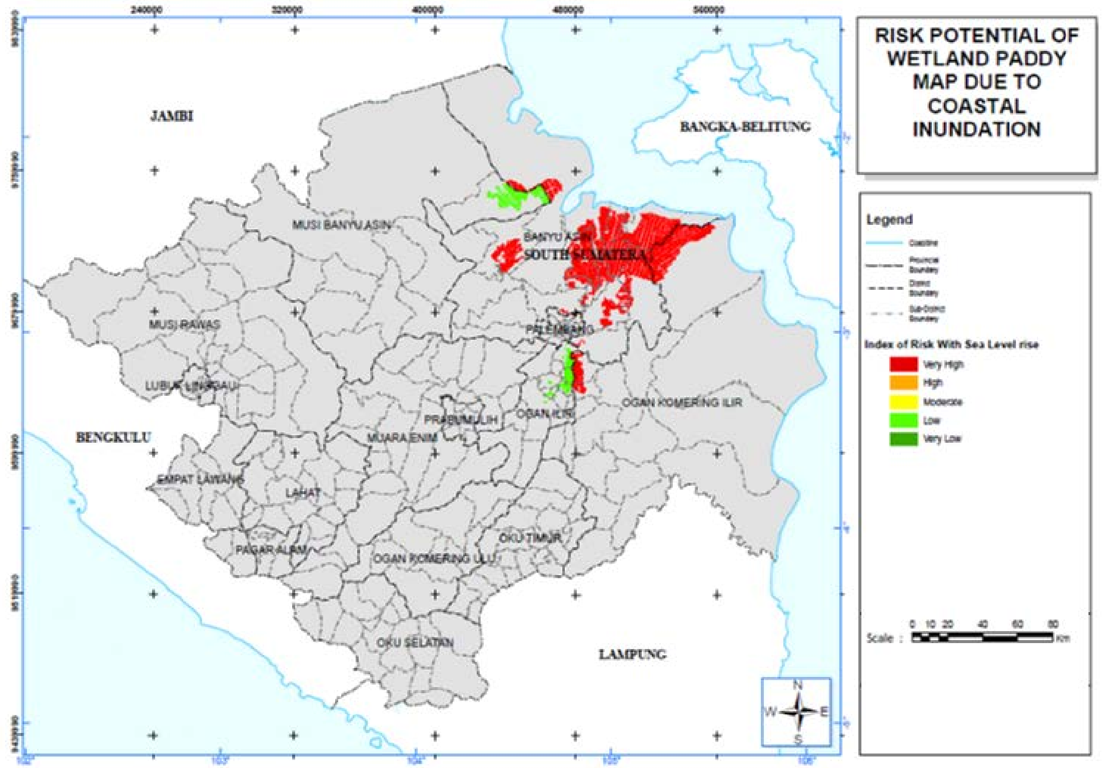

Fig. 5: Risk map of decreasing wetland paddy production in South Sumatera due to sea level rise (Map was created using QGIS, version 1.8.0)

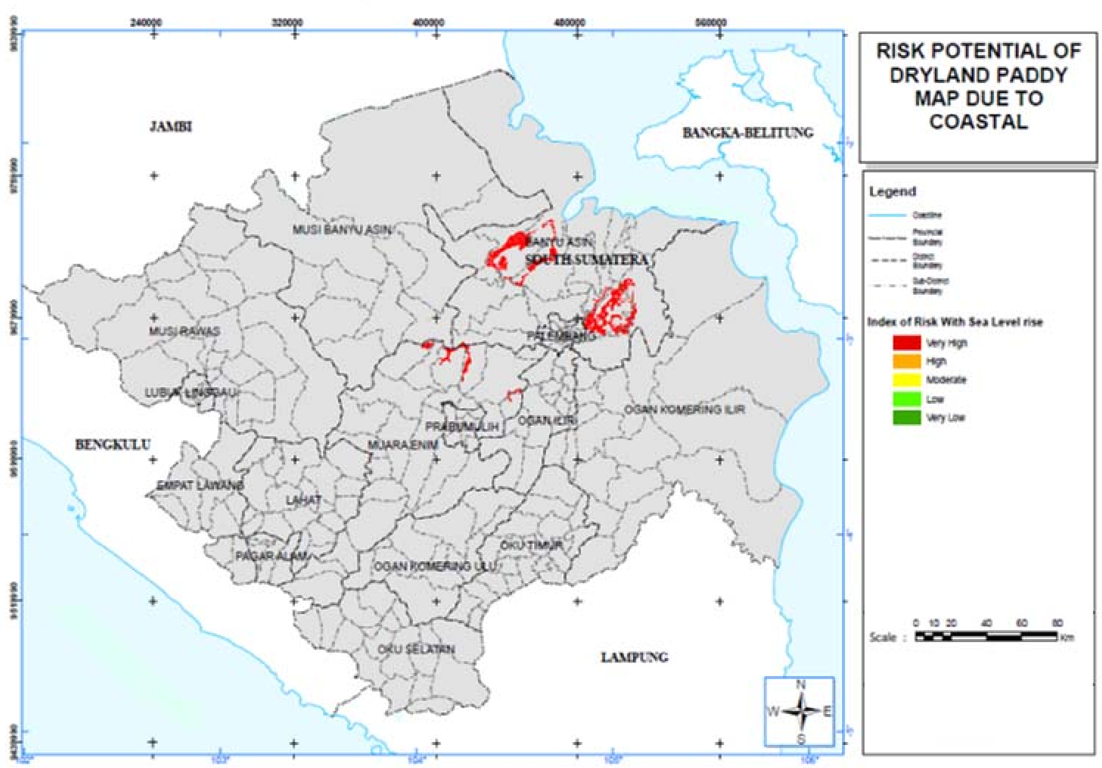

Fig. 6: Risk map of decreasing upland paddy production in South Sumatera due to sea level rise (Map was created using QGIS, version 1.8.0)

South Sumatera showed that: (1) Banyuasin, East OKU and OKI have high decrease risk on wetland paddy production and (2) Muara Enim and Baynuasin have high risk on decreasing of upland paddy production. The analysis results show that Banyuasin, Musi Banyuasin, Muara Enim and East OKU have risks of paddy production decrease due to climate change and sea level rise. Therefore, those districts need more attention for adaptation to overcome crop production decrease due to climate change in low land of South Sumatera region.

In South Sumatera, area that was experienced the risk of decreasing production of staple food crops such as wetland paddy, upland paddy, corn and soybean, respectively are East OKU, Muara Enim, Musi Banyuasin and East OKU. The result of study founded that South Sumatera experiences declining of staple food crops productivity rate with an average of 1.37% (wetland paddy), 0.98% (upland paddy), 0.91% (corn) and 0.86% (soybean)/year and also founded that South Sumatera was experienced decreasing on staple food crops production with an average of 9.44% (wetland paddy), 22.00% (upland paddy), 10.7% (corn) and 10.10% (soybean)/year.

The decreasing staple food crops productivity in South Sumatera, Indonesia have high or very high level of risk of decreasing production of wetland paddy, corn and soybeans. Therefore, attention should be paid on those regions that need a climate change adaptation strategy efforts[45]. The objective was to maintain the production of the crops otherwise there will be a threat of decreasing production of staple food crops in those regions that will disrupt the food self-sufficiency[46,47]. There were several adaptation strategies in facing the risk of decreasing food crops production due to climate change through technological improvements, such as crop cultivation and the use of superior seeds[18,39]. The results of the study the risk of climate change on staple food crops Indonesia showed no difference with the results of similar studies in the other countries that climate change has a risk of decreasing crop production[14,23,36].

CONCLUSION

The impacts of climate change have been felt by the farmer community in Indonesia which is indicated by the shifting of growing season and harvest season of paddy, corn and soybean. Indonesia experienced high level of hazard, vulnerability and risks on staple food crops production. The staple food crops is vulnerable to the impacts of climate change, indicated by hazards such as decreasing production of paddy, corn and soybean due to air temperature increase and rainfall change. Indonesia experienced decreasing on production of wetland paddy, upland paddy, corn and soybean, respectively with an average of 9.44, 22.00, 10.7 and 10.10% per year. High vulnerability and risk of climate change in staple food crops will disrupt food security in Indonesia.

SIGNIFICANCE STATEMENTS

This study discovers the possible effect of climate change decreased on harvest area, productivity and production of staple food crops (paddy, corn and soybean) in the tropical region. This study will help the researcher to uncover the level of hazard, vulnerability and risks of climate change on paddy, corn and soybean production in the tropical regions of Indonesia.

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