THE IMPACT OF CLIMATE CHANGE ON AGRICULTURE IN INDONESIA AND ITS STRATEGIES: A SYSTEMATIC REVIEW

Hafidha Asni Akmalia
Department of Biology, Faculty of Science and Technology,
UIN Walisongo Semarang, Jl. Prof. Dr. Hamka, Ngaliyan Semarang
**Correspondent Author:* akmalia.h.a@walisongo.ac.id

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ABSTRACT

Agriculture in a time of climate change is very wary of various countries in the world because it can threaten food security. Indonesia faces this problem based on data and reported news. This paper aims to provide some information about the potential threats of climate change towards crop production in Indonesia to initiate innovations that can be done to maximize crop production amid climate change. We compile this literature review to develop thoughts related to adaptation strategies undertaken to maximize the productivity of food crops under climate change, especially in Indonesia. Several studies that were reviewed showed that there was a decrease in food crop production due to factors in the environment that were changing because of climate change. Therefore, the provided strategy is an example that can be applied and developed to maintain national food productivity. Continued research is needed to provide other plans that are integrated with existing strategies.
***Keywords**: agriculture; climate change; food productivity; strategy*

INTRODUCTION

Climate change is a theme that is increasingly becoming a worldwide concern. It is due to the effects of climate change on several life segments such as rising sea level (Singh et al. 2019), giving adverse impacts on biodiversity (Heilmeier 2019), decreasing soil moisture (Dorji et al. 2020), increasing pathogen attack on plants (Pandey and Choudhary 2019), also reducing food crop productivity (Ruminta 2016). Study in 2018 gave a fact that climate change has already affected global food production especially in Australia, Europe, and Southern Africa meanwhile in Asia and North and Central America have a varied impact (Ray et al. 2019). Some scountries effort to overcome the negative effects of climate change, including a conference that produced a joint agreement to reduce carbon emission. So far, the industrial revolution began to emit gasses such as carbon dioxide, carbon monoxide, and sulfur, which caused global warming to impact climate change.

Climate change changes rain patterns, also increases extreme events such as floods and droughts, air

temperatures (Surmaini and Runtunuwu 2015; Perdinan et al. 2019) as well as pests and plant diseases (Asnawi 2015; Burritt 2018) so it can threaten the success of food production (Hidayati and Suryanto 2015). With this climate change, local farmers who depend on conventional agriculture are very vulnerable to get a yield that is not optimal because they cannot predict climate change. Furthermore, according to (Tripathi and Mishra 2017) climate change can threaten a country's national food security program. Climate change influences climatic factors such as temperature and rainfall resulting in physiological changes in crops and, ultimately a decline in productivity.

In Indonesia, adaptation to climate change in peat and wetland ecosystems including mangroves seems to have received attention starting in 2011. Human adaptation to rising sea levels due to global warming caused by climate change has been carried out in Semarang (Harwitasari and van Ast 2011). Residents raised their houses, built embankments, also improved drainage which of course cost a lot of money. Based on this, of course we cannot continue to take temporary preventive measures because it will cost a lot of money. Therefore, the issue of overcoming the negative effects of climate change cannot be underestimated. In the same year, (Murdiyarso and Kauffman 2011) provided adaptation recommendations by emphasizing the importance of conservation and reducing tropical land degradation. (Sidik et al. 2018) stated that mangrove conservation is one of the mitigation efforts to deal with climate change because of the role of mangroves as carbon sinks. The impact of climate change is not only on human habitation but also on agricultural land as the main livelihood of farmers. Research reports from 2003 – 2008 state that floods and droughts have damaged rice fields. This indicates that disasters resulting from climate change in Indonesia have actually had an impact (Rohma 2020).

The agricultural sector is very dependent on the water and weather cycle (Grisvia Agustin and Ro'ufah Inayati 2015). If climate change cannot be anticipated, then agricultural productivity will be vulnerable. (Hidayati and Suryanto 2015; Rasmikayati and Djuwendah 2015) stated that conventional farmers' perception of climate change is not good enough even though they have felt the impact on their crops. In Indonesia, the existing agricultural problems will affect national food security. Case study in the village of Buntoi, Central Kalimantan, show that there is a tendency for people to switch planting rubber rather than rice because the season is increasingly difficult to predict and it is also more profitable to

grow rubber in terms of income (Fandy, Setyasiswanto, and Muhajir 2012). If staple food agriculture is no longer in demand by the Indonesian people, it is feared that the supply from local farmers will be reduced then an import become the answer to food fulfillment. (Timmer 2011) states that food security in Indonesia becomes an interesting topic. The government tries to elevate the price of rice in order to push the people to use a local rice. But prediction said that there is a possibility that food productivity is reduced and it will drag the food security as a domino effect. The study done in 2017 using a secondary data show that almost more than half of Indonesia face food insecurity (Widada, Masyhuri, and Mulyo 2017). Maluku, East Kalimantan, and Papua become a top three-province that are lack of food. These studies prove a critical evidence about food security in Indonesia. Therefore, there is a need to do in-depth study of the negative effects of climate change, especially for agriculture in Indonesia, so it can be a warning for stakeholders to make anticipatory efforts.

METHOD

We collected a scientific database of scientific articles containing information related to agricultural productivity under climate change and its strategies. Scientific articles used are from sources of Google Scholar, Science Direct, Taylor and Francis, Mendeley, Springer link and Wiley online library in the span of 2011 to 2021. The keywords are agriculture, climate change, food productivity, and strategy. We analyzed representative articles systematically and gave the possible way to solve the problem.

RESULT AND DISCUSSION

Cases in Plant Response to Climate Change

Climate change begins with global warming due to emissions of gas, especially carbon dioxide. Indonesia is a member of the French Charter and it has a right to reduce carbon dioxide emission because according to (Singh et al. 2019) the gas is the main contributor that causes climate change. Each species has a temperature range that is suitable for its life. In the tropics, species diversity is relatively higher than in subtropics and polar regions because the warmer temperature gives more extensive opportunities for many species to survive. However, global warming is happening, causing the subtropics also to start to warm up. In North America, in 2013, there was a massive beetle attack in a pine forest so that the pine trees that existed mostly died (National Geographic, 2015). Before global warming occurred, the beetle

habitat was confined to the central forest. The existence of global warming causes beetles to start expanding their habitat towards woods in the northern region. Thus, an increase in temperature provides an opportunity for pathogens to attack plants. A similar case was seen in the potato crop in the Dieng plateau (Turasih and M Kolopaking 2016) which suffered from liptotera and whitefly infestation pests during the rainy season. Meanwhile, the high rainfall intensity, which caused flooding in West Java, also increased the attack of golden snail pests in the rice fields (Asnawi 2015).

According to (Pandey and Choudhary 2019), we must understand the response of cultivated plants to changes in climate variations because of the needs imposed on the agricultural sector increase amid the threat of climate change. Therefore, there needs to be a shared awareness related to agriculture under the conditions of climate change. The government, farmer, and other stakeholder must be on the lookout for elevation of pathogenic attacks on crop plants which can thwart harvest. By predicting seasonal changes, farmers can prepare themselves to face the possibilities that will occur. There is some effect of changing climatic factors in crop productivity.

1. Impact of temperature

Each plant has a minimum and maximum temperature for its development. In agricultural commodity crops, the maximum temperature limit so the productivity is maintained at 29º C for corn, 30º C for soybeans, and 32º C in cotton (Nurhayanti and Nugroho 2015). The phenomenon of climate change seems to cause an increase in temperature so it is feared that if it lasts longer it will reduce productivity. An increase in atmospheric temperatures to 5ºC reduces corn production by 40% and soybeans in 10-30% range. Meanwhile, if the temperature rises 1 - 3º C from current condition, it can reduce rice production by 6.1 - 40.2% (Putra & Indradewa, 2011). (Liu et al. 2020) formulated a prediction using a model construction of the effect of temperature on the agricultural productivity in China. The result is an increase in temperature of 1ºC will reduce rice productivity by 8.98% and corn 8.02%. Similarly, the construction model by (Ureta et al. 2020) in Mexico predicts a decrease in corn production under an increase in temperature due to climate change. (Ruminta 2016) examines the potential danger of a

reduction in rice production caused by an elevating temperature accompanied by changes in rainfall in Bandung. It is estimated that in 2030 there will be an average decline of 6706 tons in most districts of Bandung, Indonesia. In principle, the effect of rising temperatures which can accelerate the seed filling phase (Mall, Gupta, and Sonkar 2017) also causes the onset of flowering or damages the plants' reproductive structure (Gray and Brady 2016). Early flowering reduces the ability of plant to accumulate nutrient sources for the success of gamete production. Pollen viability decreases due to an increase in temperature marked by the premature death of tapetum cells (Gray and Brady 2016). Eventually, environmental stresses that occur during the flowering and seed filling phases contribute to crop failure (Lesk, Rowhani, and Ramankutty 2016).

2. Impact of Drought

The water crisis due to climate change is also another threat. Agriculture in Indonesia, similar to agriculture in Burkina Faso (Waongo, Laux, and Kunstmann 2015), still largely relies on conventional method such as depending on the season. Climate change causes an uncertain climate so it will be difficult to predict the suitable planting season. Moreover, the diminishing water supply is a limiting factor for successful harvests. Theoretically, water is a supporting factor for plant growth. Studies show that drought stress in rice causes rice weight to decrease due to reduced endosperm cells and starch accumulation (Yang et al. 2004). (Ruan et al. 2010) states that the gene expression of the invertase coding gene decreases during a drought so the degradation of sucrose is not optimal, even though this degradation of sucrose is essential for starch synthesis. Besides, the stabilization and mineralization of organic compounds and nutrient cycles are also not optimal during drought (Mall, Gupta, and Sonkar 2017). The adaptation that can be done by plant is by deepening the penetration of roots to find water sources (Espeland and Kettenring 2018). Nevertheless, the adjustment that is done is undoubtedly racing against the condition of plant that quickly

wither so that there is not enough energy to support the reproductive phase. It means that plant transfers their energy to defense mechanism rather than to grow (Mall, Gupta, and Sonkar 2017) so the crop productivity will also be reduced. Studies in several regions in Central Java Province namely Semarang, Sragen, Cilacap, Banyumas, Pati, and Kebumen have experienced dry land resulting the decline of rice productivity, coupled with pest attacks such as rats, tungro, stem borer and planthopper which are increasing (Sumastuti and Pradono 2016). Another case in drought can elevate soil salinity. Research by (Taufiq and Purwaningrahayu 2013) show that there is a significant loss in sum of *Vigna radiata*'s seed (mungbean) and its weight because of soil salinization driven by drought. According to (Hopmans et al. 2021), salinity in soil can be caused by climate change which causes evaporation of groundwater. This increases the concentration of salt contained in the soil because groundwater decreases in quantity.

3. Impact of Rainfall

In addition to pests and drought, the changes in rainfall pattern that are increasingly unpredictable will also reduce crop yields. In Bali, (Sudarma and As-syakur 2018) found the fact that there was a narrowing of agricultural land which was originally very agro-climate for rice plants decreased by 20%. The study (Turasih and M Kolopaking 2016), in Dieng Plateu, Central Java, found that potato farming is very vulnerable in the rainy season because the potato plants wither quickly alongside prone to landslides. Also, potato farmers invest higher costs for buying pesticides because during the rainy season pests come. Even then, the risk of failure in dealing with pests should also be watched out because pesticides are not good enough to be used during the rainy season.

Climate change is driving the phenomenon of El Nino and La Nina. Drought and flooding are serious problems for the success of Indonesia's harvest. Reduced productive land due to this phenomenon is very likely to occur. Global warming as a result of greenhouse gases will also increase sea level (Zikra, Suntoyo,

and Lukijanto 2015; Swarnam et al. 2018) so that productive land in the coastal areas or near the coast is threatened. (Juanda 2015) stated that in 2010, agricultural land on the coast of Gorontalo was inundated due to sea-level rise. Rising sea level also causes salinity problems. In Las's (2007) study, agricultural lands on the coast of Java, Bali, North Sumatra, Lampung, West Nusa Tenggara, and Kalimantan experienced shrinkage due to salinity thereby reducing productive land.

Adaptation Strategy

The existence of external pressures such as increased temperatures, pest attacks, drought, flooding, and other natural factors do not make plant static in dealing with them. Adaptation is a natural response by plants to survive. Even so, we as humans who depend on the existence of crop productivity cannot rely on plant adaptation alone so that productivity remains stable. Plant productivity is greatly influenced by biotic and abiotic factors, both of which depend on climate conditions. Therefore, harvests for human consumption are also very dependent on future climate (Burritt 2018). We have to do non-conventional efforts such as the use of non-chemical organic fertilizer (Sudarma and As-syakur 2018), the production of seeds that are tolerant to stress while maintaining their quality (Perdinan et al. 2019), also the adjustment of planting time in each region due to variations in rainfall. because a different rain determines cropping patterns (Nugroho and Nuraini 2016). In a study belongs to (Muslim 2013) in Indramayu district, the adjustments to drought and floods were carried out by planting variations of inundation-resistant and drought-resistant rice, also maintenance of water through dams and drainage cleaning. In response to elevating temperature, the farmers can plant under a canopy or provide shading to decrease the air temperature so their crop is in suitable temperature for growth. The latest news shows that the adaptation of farmers in Kebumen, Central Java, namely replacing agricultural crops with varieties that are more tolerant of climate change, even changing jobs by no longer being a farmer (Sekaranom, Nurjani, and Nucifera 2021). Based on those circumstances, the adaptation strategy is quite effective in dealing with existing disasters.

The synergy between the government, the community and all elements of stakeholders is needed to reduce the negative effects of climate change so it does not affect the Indonesian agricultural sector. Developing countries are so affected by climate change that their

agricultural adaptation needs are higher than in established countries (Elum, Modise, and Marr 2017). According to (Henry 2019), agricultural adaptation efforts to climate change are not enough to use only one strategy. Several strategies are needed to support each other. We also need a comprehensive knowledge about the selection of adaptation on cultivated plants to continue to improve quantity and quality (Gunathilaka, Smart, and Fleming 2018). One example is a planting intercropping system because it has benefits such as nutrient exchange, reducing grass competition and controlling pests (Swarnam et al. 2018). The strategy to adjust the planting season is also one of the farmers' choices. (Laux et al. 2010) revealed that planting too early will cause crop failure while planting too late also reduces plant growth and yields. Meanwhile, the farmers in the Dieng Plateau during the dry season have difficulty in getting water so they have to take distant lake water. Even farmers whose homes are far from ponds or rivers are forced not to plant potatoes (Turasih and M Kolopaking 2016). Therefore, the construction of a dam not far from the agricultural area is a great option for maintaining water availability. Farmers in West Java and East Java are already utilizing dam water as a source of irrigation during drought (Rasmikayati and Djuwendah 2015). Efforts to prevent groundwater loss can use mulch and the provision of organic material to prevent water evaporation and fertilize the soil (Nurdin 2011). Improved irrigation systems can also be supported by building water reservoirs so we can harvest rainwater and save it in the right place (Gomez-Zavaglia, Mejuto, and Simal-Gandara 2020). It is now necessary to use the water footprint as an analytical tool used to guide policies related to sustainable water management so that we can apply equity in the use of water resources. In China, farmers' adaptive strategies are adapted to existing conditions because each region has a difference in average temperature rise (Liu et al. 2020). Meanwhile, Australia implemented moving rice farming strategy, which was originally in the southern region to the northern region with more rainfall. Other than that, Australia also develops rice varieties that are resistant to pests because in the northern region there are pests that can threaten rice (Henry 2019).

Looking at the strategies used by other countries, Indonesia needs to map each region’s characteristics in terms of soil type, rainfall, and average air temperature so it can determine the right strategy. As a policymaker, the state can make breakthroughs such as the

development of agricultural insurance that can ease farmers in the matter of supplying farm capital and financial losses as a result of climate change (Hidayati and Suryanto 2015). Communication strategies must also be involved in education about climate change. Based on Irwansyah's study (Irwansyah 2016), the problem of climate change is not interesting enough to be published in the Indonesian media. In fact, the issue is very strategic and its communication needs to be extended not only to the science box. In Gunung Kidul, Yogyakarta, farmers have a traditional agricultural calendar, Pranoto Mongso, which is compiled based on observations of the seasons since time immemorial but climate change causes the disappearance of signs of seasonal change. Most farmers cannot find out the reason for the disappearance of the mark (Retnowati et al. 2014). (Masud et al. 2017) discover that the ability of farmers to recognize climate change as a contributing factor is the main requirement for carrying out adaptation in agriculture. Therefore, the use of media needs to be maximized to educate farmers in understanding climate change which affects agricultural production and provides choices for farmers to adapt to climate change.

The era of the industrial revolution has now increased technological sophistication. Of course, existing technology can be used as a strategy to deal with climate change that threatens crop production. A model called SaltMod that can predict the effect of irrigation on soil salinity, drainage and groundwater, then the mitigation strategies can be formulated (Gomez-Zavaglia, Mejuto, and Simal-Gandara 2020). Another example is the MONICA model (Model for Nitrogen and Carbon dynamics in Agro-ecosystems) which can simulate the growth and development of crops, soil flow and temperature, nitrogen transport and the replacement of soil organic compounds (Hampf et al. 2020). MONICA can also predict the effects of climate change and land management on agricultural productivity, carbon balance, and nitrogen efficiency (Nendel 2014). Other models such as HERMES can be used to estimate crop growth, soil water, and N dynamics in arable land (Hlavinka et al. 2014). The use of such modeling can predict the effects of climate change on agriculture before it occurs so that the government in particular can formulate risk management, take the necessary steps and policies, and carry out agricultural education to farmers. Other than technology, providing adequate internet access for farmers is a good enough so that the information they have on climate change increases so that farmers have readiness to plant (Hasibuan, Gregg, and Stringer 2020). From now on,

the government must budget for sustainable agricultural research to minimize the negative effects on this changing world. This role must be carried out and synergize with the world for a better human future. This work will be in line with Sustainable Development Goals planned by countries around the world to end the problems in climate, poverty, education, including responsible consumption and production. (Thornton et al. 2018) urge the government to make a policy to secure food productivity for example an investment in infrastructure to prevent continuing losses also raise the awareness and information to get the data of food lack and waste. Mitigating the crop land by reducing emissions of Green House Gases (GHG) is another effective method (Smith and Gregory 2013). As we know, climate change is caused by elevating GHG. Carbon dioxide alongside with carbon monoxide is one of GHG that will allow sunlight to enter but at the same time will trap the heat in the atmosphere causing instability in climate (Lone et al. 2017). We have to cut the consumption of fossil energy step by step and switch to electrical energy in our daily life. In 2015, carbon emissions were observed from agricultural residues of rice, sugar cane, cassava and corn in Lampung (Andini et al. 2018). 85-96% CO_2 carbon dioxide and 3 -13% carbon monoxide are released into the air as a result of burning post-harvest crop residues. This greenhouse gas emissions contribute to climate change events, so burning is certainly not recommended for crop residues. By decreasing this gas, we hope the climate is more suitable to crop plant. No less important, the other strategy is the investment in research related to food productivity under climate change. (Campbell et al. 2016) recommend that the research should be directed to inform action in developing strategies to reduce GHG in all aspects.

CONCLUSION

This literature review provides comprehensive information on the impacts of climate change on agriculture that has occurred in several areas so that it can be a reference for stakeholders to prepare agricultural adaptation efforts. This study encourages other researchers to study and develop other adaptation strategies that can accompany existing strategies to maximize the crop's productivity under climate change. We assume that increasing communication about climate change through mass media is also a breakthrough that needs to be intensified even more because spesific information drives us to handle the problem effectively.

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