ABSTRACT

Climate-change related hazards, including drought, floods, extreme temperatures, and sea-water level rise have impacted Indonesia’s agriculture and these associated with economic losses. Therefore, it is increasingly important for farmers to be able to proactively anticipate the impact of weather and climate risks to protect their livelihoods through climate risk management (CRM) and to practice the sustainable agricultural production systems. Sustainable agriculture practices are needed to enhance resilience to adverse climate change events. This paper attempts to provide a review of agricultural risks related to climate change, principles and current CRM practices, and CRM practices at farm level based on agro-ecosystems, as well as approaches in enhancing agriculture CRM for sustainable agriculture development. The key technologies for lowland rice farming include alternate wetting and drying irrigation systems, and the use of drought, saline, and submergence tolerant rice varieties. For upland farming, water storage facilities such as water retardation pond, long storage, and channel reservoir are important. Subsequently, efficient water distribution systems such as drip irrigation, sprinkler irrigation, as well as capillary irrigation need enhancement. Various soil management technologies including minimum tillage and organic matter application are essential. For swampland one-way water management and conservation blocks, the “surjan” system, planting of adaptive varieties, and soil amelioration and fertilization are among the key treatments. Accurate climate forecasts may allow decision makers and farmers to make decisions to reduce negative impacts or take advantage of expected favorable climate. Finally, engagement of various actors, and capacity building is an integral part of CRM.

Keywords: Climate, management, agriculture, sustainable, agro-ecosystem.

INTRODUCTION

Agriculture and food production is strongly influenced by adverse weather and climate change, especially if experienced during critical stages of growth. It influences food production directly through changes in agro-ecological conditions and indirectly by affecting the
growth and the distribution of incomes, and thus the demand for agricultural production (Schmidhuber and Tubiello 2007; Tun Oo et al. 2020; Boer and Surmaini 2002). Climate change is likely to contribute substantially to food insecurity in the future, due to increasing food prices, and reducing food production.

In recent decades, numerous weather and climate-related natural disasters have impacted Indonesia’s agriculture. Changes in the frequency and severity of droughts and floods could pose challenges for farmers and threaten food safety. The Indonesian Ministry of Agriculture reported that during El Niño years of 1989-2015, paddy damaged area by drought ranged between 350 and 870 thousand ha, while during La Niña damage area due to flood ranged from 145 to 330 thousand ha (Surmaini and Susanti 2016).

In the future, it is predicted that climate change will alter climate variability with increases expected for most locations. IPCC (2014) reported that all aspects of food security are potentially hit by climate change, including food access, utilization, and price stability. In order to be able to cope with the negative impact of climate change, it is becoming increasingly important for farmers to proactively manage weather and climate risks to agriculture to protect their livelihoods.

Sustainable agriculture practices and adaptive adjustment to agriculture practices are needed to cope with the impact of climate, its variability and projected change (Selvaraju 2012, Singh and Singh 2017). Sustaining agricultural productivity will require more than a simple modification of traditional ad hoc techniques. The development of self-sufficient, diversified, economically viable, small-scale agro-ecosystems come from novel designs of cropping and/or livestock systems managed with technologies adapted to the local environment that are within the farmers’ resources (Loucks 1977).

For that reason, farmers need strategies for managing climate risks that enable them to enhance their livelihoods by increasing their farming system’s resilience. Therefore, the state of knowledge and experience to date implies that we need to think of different strategies to manage climate risk at the farm level (Shannon and Motha 2015). In this article, review focus specifically on agricultural risks related to climate variability and global climate change, principles of climate risk management, and current CRM practices at farm level at specific agro-ecosystems.

**CLIMATE CHANGE HAZARD IN AGRICULTURE**

The agriculture land in Indonesia are vast and the weather and climate varies significantly across regions. Local variables such as latitude, elevation, and proximity to water bodies also have a significant influence on the weather and climate at individual locations. In addition, with the broad spatial extent and widely varying terrain in the region, agricultural sector is likely to be affected more directly by climate change than any other sectors. In the future, extreme weather events as climate change progresses, such as droughts, heavy precipitation and floods are expected to become more frequent (Parry et al. 2007; Hansen et al. 2012).

Agro-ecosystems in Indonesia are divided into lowland rice (irrigated and rainfed), upland agriculture (semi-arid and humid areas), and swamplands (tidal and non-tidal swamp). Hazard due to climate change based on agriculture ecosystems are described as follow:

### Lowland Rice

Flooded rice cultivation in general, is called lowland rice systems. Rice is cultivated in both under flooded and non flooded upland area. Under flooded condition rice cultivation in the upland areas are typically being rainfed, while lowland rice mostly irrigated. Irrigated rice is heavily concentrated in Java and Bali, part of Sumatera, Sulawesi and Nusa Tenggara. Due to climate change, rice growing areas are vulnerable to drought, flood, or salinity, especially during the long dry season.

Indonesia consistently experiences long period of dry spell and drought during the warm phase of the El Niño Southern Oscillation (ENSO) cycle (El Niño), with significant consequences for agricultural production (Naylor et al. 2007; Surmaini et al. 2015). Droughts arise from combinations of five factors: (1) delays of the onset of the wet season; (2) early cessation of the wet season; (3) prolonged periods of the dry seasons, (4) below normal amount of cumulative rainfall over the growing season; and (5) water and soil moisture deficits during critical stages of crop growth (Salack et al. 2016).

The Southern and eastern parts of Indonesia are relatively more prone to drought than the northern and western parts. Rice growing area in Indonesia are mostly located in these regions. Figure 1 shows paddy drought impact index (PDII) map, i.e. the map outlining the ratio of the total damaged area due to drought of rice crops to the total planted area. Lower index of the PDII in semi-arid areas such as East Nusa Tenggara, occur due to fallow of most of rice field during the dry season. The map shows that the provinces that are most prone to drought are West Java and South Sulawesi (Surmaini et al. 2015).

Climate change is associated with higher intensity rainfall to a level far exceeding the soil infiltration capacity that cause floods. The extreme rainfall of up to 400 mm/month (as per BMKG) may cause excessive run-off in watershed, such as rivers, and higher water level in ponds, dams, etc. In some cases, floods are related to landslides. According to BNPB (2012)/National Agency for Disaster
Management, high level flood hazard in Indonesia mostly located in coastal areas such as eastern-coast of Sumatera, north-coast of Java, west-coast and south-cost of Kalimantan, and south-coast and North-coast West Papua, west-coast and south-coast of Papua (Figure 2). Moreover, climate change is predicted to result in about 2 to 3% more rainfall in Indonesia each year (Sari et al. 2007).

Over-abundant water due to heavy rainfall can result in reduced plant growth due to poor seed distribution, germination and emergence, soil and nutrient erosion, soil water logging, siltation of water storage areas, and floods. For rice, it is especially harmful when heavy rain falls on freshly seeded fields, and is worse if the field has been wet direct seeded. According to Lassa (2012) more than 3900 flood event during 1970-2011, has associated with pusoi harvest failure.

Furthermore, most important rice growing areas in Indonesia are located in coastal zones. Sustainability of rice production in those areas is challenged by the increase of soil salinity as the result of sea water inundation. Moreover, rice in these areas are not only facing salinity problem but also other abiotic stresses such as submergence during rainy season and drought during dry season (Hairmansis et al. 2016). Research conducted by Förster et al. (2011) concludes that the most
affected provinces in term of paddy harvest area loss due to one meter sea level rise are West Java, East Java, Central Java, West Kalimantan and North Sumatera. The total harvest area lost is estimated about 114,980 ha.

According to Erfandy and Rachman (2011), most rice fields in the North Coast of Java was potentially affected by sea water intrusion. This area had moderate to very high salinity level ranging between 1.37 to 16.38 dS m⁻¹ while the Electric Conductivity (EC) ranged between 1.11 to 17.40 dS/m. These range of salinity is not recommended for planting rice. Rice responses to salinity stress varies during the development stage with the EC threshold of 3 dS/m. The seedling and reproductive stages are considered as the most sensitive to salinity, while rice is more tolerant during the germination and vegetative stages (Lie et al. 2007; Hosseini et al. 2012). According to Hariadi et al. (2015) the effect of salinity on rice production in Indonesia can be as high as 50% of the rice fields along the north coast area of Java.

Hill et al. (2013) estimated that that combined sea level rise of 25 cm and effect of high tide, may cause the total area inundated to be 25-30% of the total area of the coastal cities such as Jakarta, Medan, Semarang, and Surabaya and affects about 2.6 million people along the coast of the four cities. This, in turn, would also cause the total economic loss of about $ US 871 million due to damage to settlement, infrastructure, and agriculture.

### Swampland

Total area of swampland in Indonesia is about 34.9 million ha which consist of peatland, acid sulfate soil, saline soil and tidal swampland (Balai Besar Litbang Sumberdaya Lahan Pertanian (BBSDLP) 2015). A land evaluation conducted by BBSDLP (2015) estimated that area of swampland suitable for agriculture is about 10.87 million ha consisting of 2.34 million ha inland swampland and 8.54 million ha tidal swampland.

Climate change in swamp lands affect the planting area, biophysical processes, soil properties, plant pests and diseases and greenhouse gases (GHG) emissions. In the inland swampland, El Niño decreases inundation, thereby increases the areas that can be cultivated, especially for lowland rice. However, El Niño in peat land could increase carbon emissions both due to peat decomposition and fires, whereas in acid sulfate soil it can increase oxidation of pyrite. On the contrary, during La Niña a decline in area planted occurs in swampy wetlands, whereas in tidal land it causes a of cropping patterns. Some problems were found among others, unpredictable water fluctuations that cause drought and flood. In acid sulfate swamplands El Niño may cause an increase in pyrite oxidation that lead to high acidity and iron toxication.

### CLIMATE RISK MANAGEMENT FOR SUSTAINABLE AGRICULTURE

Climate risk in agriculture denotes the probability of the climate related hazards, particularly the extremes such as floods, droughts, and extreme temperatures affecting the livelihood of farmers. Farmers to some extent understand the risks and uncertainties of climate at their location and optimize the management practices based on years of experience. However, growing demand, changing climatic conditions, extent of agriculture to marginal production environments warrants improved climate risk management (CRM) to enable best practices and strategies for future climate risks. The CRM approach focuses on a synchronized response for addressing climate risks with committed engagement of farmers, extension workers, agricultural services, and policy-makers to build resilient agriculture to climate risks.

### Definition

According to The International Research Institute for Climate and Society - IRI (2010), climate risk management (CRM) refers to the use of climate information in a multi-disciplinary scientific context to cope with climate’s impacts on development and resource management problems. Further, IRI elaborates that climate risk
management covers a broad range of potential actions, including early response systems, strategic diversification, dynamic resource-allocation rules, financial instruments, infrastructure design and capacity building. According to Martinez et al. (2012), the World Meteorological Organization (WMO) defines CRM as a systematic and coordinated process in which climate information is used to reduce the risks associated with climate variability and change, and to take advantage of opportunities, in order to improve the resilience of social, economic and environmental systems. The approach brings together the synergies of adaptation to climate change and disaster risk reduction by focusing on actions that can be taken to improve adaptive capacity and preparedness to cope with the current climate variability and to build resilience to better respond to the impacts of climate change.

**Component of Climate Risk Management**

International Research Institute for Climate and Society - IRI (2010) describes the CRM as a process that informs decision making through the application of climate knowledge and information. CRM consists of four components as seen in Figure 3.

The first component is to identify vulnerabilities and potential opportunities posed by climate variability or change. For example, extended drought or a delayed rainy season could have serious impacts on farmers who grow rain-fed crops. On the other hand, there might be periods of above-normal rainfall they could take advantage of, if they had access to information about when and where those rains would occur. This process begins with stakeholder analysis to identify their climate challenges, and then proceeds with modeling of the system to identify other vulnerabilities and/or opportunities (Baethgen 2010).

The second component is to quantify uncertainties in climate information. Climate prediction information can be utilized to reduce the impact of adverse climate events. Climate prediction is inherently uncertain and information about such uncertainty should be helpful to users in their decision making. Uncertainty is a fundamental characteristic of weather, seasonal climate and hydrological prediction, and no forecast is complete without a description of its uncertainty (Slingo and Palmer 2011; Wood et al. 2016). The best approach is by effective communication to help understand the value of uncertainty information and work with users to help them effectively incorporate this information into their decisions.

The third component is to identify technologies and practices. Adaptation to the climate change is a must in agriculture as one of the most vulnerable sectors. Adaptation actions require changes of cropping pattern and land management to increase its resilience to adapt to climate change. Various farming practices to reduce the negative effects caused by the climate change have emerged, for example crop diversification, crop rotations, improved tillage systems, increased water soil storage, improved crop water use efficiency, drought resistant cultivars (Bodner et al. 2015). Promoting such strategies will be crucial, since these practices will allow farmers to reduce the cost of production (Oleson and Bindi 2004; William et al. 2019) and the risk of harvest failure.

The fourth component is to identify interventions, institutional arrangements and best practices. The agricultural support services and institutions at the

---

![Figure 3. Four components of climate risk management (Source: IRI 2010).](image-url)
national and local levels need risk information for planning their activities and providing timely services to the ultimate beneficiaries. Additionally, strengthening of community networks, local institutions and norms and relationships is critical for managing climate risks. Local networks shape the farmers’ social interactions leading to better participatory decisions (Meinke et al. 2006). Farmers’ knowledge sharing mechanisms relevant to local context are the key for effective communication of value-added climate information (Selvaraju 2012).

Improving risk management approaches with concepts of farm level optimization techniques would be more suitable to manage risks of climate variability and change at farm level. Farm-level CRM should focus on optimization of management practices to reduce yield gap due to the impacts during extreme climate years and enhance the opportunities during better than average years. Therefore, current agriculture systems need to enhance by considering a broad range of potential management interventions in a more focused way (Mueller et al. 2012; Pradhan et al. 2014).

THE USE OF CLIMATE INFORMATION FOR RISK MANAGEMENT IN AGRICULTURE

Recent advances in climate prediction and climate information services offer a huge potential for optimizing management practices, bridging yield gaps and sustainable production. Climate information that reduces the uncertainty that farmers face during a given season has potential to improve the effectiveness of production technologies and input use efficiency (Selvaraju 2012; Brown et al. 2019; Thornton et al. 2018). The use of climate information in agriculture are describe below.

Seasonal Climate Prediction

Agricultural production is highly dependent on weather, climate and water availability, and is adversely affected by weather and climate-related disasters. A timely seasonal forecast of could permit farmers to adjust cropping patterns and input use in order to benefit fully from these conditions (Sivakumar 2006). According to (Mjelde et al. 1998), earlier forecast may be more valuable than an accurate but late forecast. With the availability of weather/climate prediction, a better scheduling of farm operations can be managed more efficient such as the use of inputs, primarily nitrogen fertilizer and water management.

Agriculture requires more specific seasonal predictions such as dry spell of more than 10 consecutive days, decadal rainfall amounts, and standardized precipitation index (SPI). Indonesia Agro-climate and Hydrology Research Institute has developed probabilistic prediction for agriculture purpose. The prediction is updated every three months in form of prediction maps. These maps are available in national and province level and can be accessed on http://balitklimat.litbang.pertanian.go.id/. An example of dry spell prediction map for more than 10 consecutive days is presented in Figure 4.

![Figure 4. Prediction of dry spell for>10 consecutive days in June 2020 (balitklimat.litbang.pertanian.go.id). Area with orange hues indicate high probability of dry spell.](image-url)
Prediction of Drought Risk of Lowland Rice

Further application of the seasonal prediction has been developed by linking the onset and trend of standardized precipitation index (SPI) with drought on paddy rice by means of double analogue scheme. SPI is one of drought index that mainly considers the rainfall data. Cartesian diagram was used to illustrate the combination of onset and trend of SPI-3 and the paddy drought damage area for categorizing level of drought (Surmaini et al. 2019). The method makes it possible to produce probabilistic maps of predicted drought on paddy during the coming season. The maps can be used to establish the prediction of paddy drought with lead time that is adequate for preparing additional adaptive measures to retain profitable rice farming for the coming planting season (Surmaini et al. 2020). The information can be accessed on http://katam.litbang.pertanian.go.id/katam_terpadu/prediksi_kekeringan-pdf/. The maps available for province and district level. An example map of prediction of risk drought on paddy rice for September 2018 presented in Figure 5.

Integrated Cropping Calendar

The onset of the rainy season is the most important variable for agricultural management (Ingram et al. 2002; Ziervogel and Calder 2003). It directly affects farming management practices, especially planting which, in turn, significantly affects crop yield. For sowing, it is important to know whether the rains are continuous and sufficient to ensure enough soil moisture during planting and whether this level will be maintained or even increased during the growing period to avoid total crop failure (Walter 1967; Barron et al. 2003). One common approach is changing the planting date or adjusting the cropping calendar, i.e., synchronizing the crop growing period to coincide with sufficient rainfall for crop growth and development.

Indonesian Agency for Agricultural Research and Development (IAARD) has designed an Integrated Cropping Calendar Information System (ICCIS) Technology. In detail, the technology contains recommendation of adaptive technology with integrated-web-based according to climate prediction. Recommendation in the ICCIS consist of (1) time of

Figure 5. Paddy drought forecasting maps for December 2019 were accessed from http://katam.litbang.pertanian.go.id/_. The areas with hues of yellow and green indicate moderate and low risk of drought, consecutively.
planting and cropping patterns; (2) potential planting area for each season; (3) adaptive technology on varieties, fertilization systems, and control of crop pests and diseases (Runtunuwu et al. 2013; Yulianti et al. 2016). The recommendation is available up to sub district level to reduce the risk of decrease and failure of rice harvest due to flood, drought, and pest and diseases attack. ICCIS can be access from http://katam.litbang.pertanian.go.id/, through smart phone and short message services, as well as through social media.

**CLIMATE RISK MANAGEMENT AT FARM LEVEL**

Climate risk management is an ideal option to effectively reduce the risks and narrow the farm-level yield gaps. Herewith, improving agronomic management and input use efficiency are the most important means to reduce the yield gaps. Farmers’ practices must be addressed by agro-ecosystem and location-specific cropping management practices (Kettle et al. 2012) Recommended technologies regarding CRM for agriculture sector based on agro-ecosystem are describe below:

**Lowland rice**

Increasing drought, flood and salinity problems have been observed in many areas of rice agricultural areas in Indonesia. Drought, saline, and submergence-tolerant rice varieties and water management practices are fundamental when it comes to climate risk management in rice-based systems both for irrigated and non-irrigated lowland rice areas.

To address the more serious problems of the changing climate, research agencies under the Ministry of Agriculture have developed a number of crop varieties which are tolerant to such environment stresses. Rice varieties that have been tested for their tolerant to drought are Inpari-18, Inpari-19, Inpari-20, Inpago-4, Inpago-5, Inpago-6, Inpago-8, and Inpago Lipigo-4. Rice varieties that is relatively tolerant to drought in irrigated rice field are Inpari-13, Inpari-18, Inpari19, and Inpari-20 with yield potential of 8.0-9.5 t/ha. These four varieties are also resistant to brown plant hopper (WBC) and bacterial leaf blight (HDB) [PUSLITBANGTAN 2015].

Submergence-tolerant rice varieties are Inpari-29 Rendaman, Inpari-30 Ciherrang Sub-1, Inpara-3, Inpara-4 and Inpara-5. These varieties are developed for inland swampland agriculture areas. Inpara-4 and Inpara-5 are tolerant to submergence for 14 days in vegetative stage with yield potential of 7.6 t and 7.2 t/ha, respectively, and resistant to HDB pathotypes IV and VIII. Inpara-5 also tolerant to salinity. Inpari-29 is tolerant to flooding and Inpari-30 Ciherrang Sub-1 can be developed on flood-prone irrigated rice fields with yield potential of 9.5 t and 9.6 t/ha, respectively [PUSLITBANGTAN 2015].

Rice varieties tolerant to high salinity are Margasari, Dendang, Lambur, Lalang, Indragiri, Air Tenggulang, Banyuasin [BALITBANGTAN 2011], Inpari-34 and Inpari-35. In contrast to other Inpari varieties, Inpari-34 Salin Agritan and Inpari-35 Salin Agritan are tolerant to salinity in the seedling phase. These two varieties have a yield potential of 9.5 and 9.6 t/ha, resistant to blast and somewhat resistant to WBC.

Because of the increasing scarcity of water, farmers and researchers alike are looking for ways to decrease water use in rice production and increase its use efficiency using alternate wetting and drying (AWD) technique (Rejesus et al. 2011; Price et al. 2013). The principle of AWD is water saving technology which reflooded rice field after the disappearance of surface water around one day to more than 10 days. The AWD could be started from 1 to 2 weeks after transplanting, and the field is naturally drained until the water level reaches 15 cm below the soil surface, and then re-flooded up to 5 cm above the surface (IRRI 2013; Setyanto et al. 2017). According to Setyanto et al. (2017), the volume of irrigation water was reduced by AWD by 17-20% compared to continuous flooding with no significant effect on the yield. This result is consistent with the concept of safe AWD (Lampayan et al. 2009).

**Upland**

Uplands are extremely vulnerable to climatic variations and exploitative human activities such as overgrazing and unsustainable agricultural practices. The consequences of these include accelerated soil erosion, the loss of soil nutrients, reduced soil carbon stock, nitrogen loss and the change in water balance. To cope with water scarcity, site-specific water and soil management technologies have been developed and introduced. These include rainfall and run off harvesting technologies and various soil management technologies.

Water harvesting includes the construction of water reservoir (embung), and channel reservoir (dam parit). These have been developed in a number of areas in Indonesia such as in Java Island, South Sulawesi, and Nusa Tenggara (Heryani et al. 2013). Water that is collected, can be channeled to the lower irrigation target areas. According to Heryani et al. (2013), rainfall and run-off harvesting can be realized in various forms of practical technology with relatively inexpensive cost of construction. Application of rainfall and run off harvesting is more useful when climate extreme event especially El Niño occurs.

Along with water harvesting technology, water-saving technologies needs to be applied in suitable cropping system. These technologies include drip
irrigation, sprinkler irrigation, and capillary irrigation for upland areas. Drip irrigation is suitable for semiarid upland areas. It allows precise application of small amounts of water directly to the root zone. However, this type of irrigation is not suitable for large areas, for coarse sands, and severely crusting soils (Laker 2006).

Sprinkler irrigation distributes water through a network of pipes usually by pumping. It is then sprayed into the air and irrigate entire soil surface through spray nozzles so that it breaks up into small water drops which fall to the ground. Sprinklers provide efficient coverage for small to large areas and are suitable for use on all types of annual crops and young perennial tree crops with various soil types.

Capillary irrigation system uses porous membrane with different negative pressures. The water drawn into the root zone from this irrigation system was controlled exclusively by the plant water demand. The capillary irrigation can save substantial amount of water while maintaining better biomass yield and improving fruit quality in pepper production, particularly in areas where water shortage is acute (Nalliah and Ranjan 2010).

There are various soil management technologies that can readily be applied to lessen the negative impact of climate change including conservation tillage and vegetative soil conservation techniques (Agus et al. 2015). Conservation tillage methods include various kinds of reduced tillage including no-till, strip-till, ridge-till and mulch-till (Willekens et al. 2014). Conservation tillage have positive effects on soil properties, such as the increase of soil organic matter content, reduction of soil erosion because of medium and macro-soil pores formation, increased activity of soil microbes, minimized water evaporation, and increased soil organic matter, and hence soil carbon content (Agus and Widianto 2004, (Aikins and Afuakwa 2012; Khursheed et al. 2019).

Vegetative soil conservation technique can improve the vegetation cover on soil surface and hence protect the soil from direct rain drops. There are various kinds of vegetative soil conservation measures, including agroforestry, vegetative grass strips, cover crop and cropping pattern. By integrating perennial trees into a conventional agricultural system, agroforestry promotes efficient use of sunlight, moisture, plant nutrients, as well as providing environmental services such as erosion and sedimentation reduction, and increased carbon storage in plant biomass and in soil. There are wide ranges of agroforestry models including alley cropping, contour hedgerow systems, live fences, traditional multi-strata farming, silvipasture and intercropping. The perennial crops are useful in dissipating the rainfall kinetic energy before reaching the soil surface (Agus and Widianto 2004; Tanaka et al. 2015).

Vegetative grass strips are narrow strips (approximately 1.2 m wide) of tall, erect, stiff-stemmed, native perennial grasses planted on the field contour (Kemper et al. 1992). Vegetative grass strip reduces run off and promote infiltration (Meyer et al. 1995), and enhance deposition of soil and organic matter (Melville and R.P.C. 2001). Due to their low-cost, narrow grass strips are becoming popular as a means of controlling soil erosion.

Cover crops are commonly used to suppress weeds, help build and improve soil fertility and quality, and control diseases and pests, reduce the amount of water that drains off a field, and protect waterways and downstream ecosystems from erosion. Popular cover crops of leguminous species, include Centrosema pubescens, Calopogonium mucunoides, Mucuna bracteata, Centrosema plumeri, and Arachis pintoi (Agus and Widianto 2004; Fageria et al. 2005).

Swampland

The specific characteristics of the swampland requires appropriate farming system to suit their unique environmental conditions. The Agricultural Research and Development Agency has produced innovative technologies to cope with climate change in swampland, among others; one-way water management and conservation blocks, the surjan system, adaptive varieties and amelioration and fertilization.

One-way water management and conservation blocks serves to dispose water during high tide and retain water at low tide. This system is very useful for removing toxic compounds, increasing planting index, increasing crop production, and conserving ground water (Maftuah et al. 2016). The one-way flow system water management can increase yields in the dry and wet planting season respectively by 46% and 55% compared to two-way flow system (Annisa 2014).

The practice of growing secondary crops (e.g. maize, soybean, cassava) in the so-called surjan system is becoming increasingly common among farmers in swamp areas. Surjan is small raised dikes separating the rice fields and are suitable for planting crops under non flooded condition. The surjan system is recommended for back swamp types A, B, and C land with pyrite depth> 60 cm (Maftuah et al. 2016).

Rice varieties in swampland is not only adaptive, competitively high yield, but also low in greenhouse gas (GHG) emissions. Inpara-3 cultivated in swamps released the lowest methane emissions of only 30.76 kg/ha/season compared to Inpari-30 with methane emission of 68.51 kg/ha/season (Annisa 2014). It’s important to note, however, that the use of high yielding superior varieties must be balanced with sufficient amelioration and fertilization, because the land is intrinsically very poor in nutrients. Application of ameliorant pugam, a peat fertilizer composed of phosphate and lime, and biochar into peat soil reduce GHG emission (Mukherjee and Lal 2013; Annisa et al. 2015).
ENHANCING CRM IMPLEMENTATION FOR ACHIEVING SUSTAINABLE AGRICULTURE

The climatic conditions are major external factors affecting crop growth and yield at the field level. The internal factors generally relate to decisions on allocation of resources, application of inputs and management. A number of technologies have been established for improving agronomic management and input use efficiency is the most important means to reduce the yield gaps in farm level. However, inadequate link between farmers, extension and applied research, results in ineffective technology transfer to farmers. Thus, it is crucial to educate and empower farmers to adopt suitable agricultural technologies while encouraging local extension and research institutions to adapt the technologies to local conditions. On the other hand, farmers need to promote technology them selves to motivate others. The government also needs to recognize that certain technologies are indigenous products of farmers and it’s important to integrate the CRM into local practice and to district level planning.

CRM practices in Indonesia are still limited and need to enhance. Several actions can be taken to improve current strategies and to expand their use by farmers. These include (i) educating farmers about weather and climate impacts on agriculture and the benefits of practicing risk management strategies, (ii) improving agronomic management, (iii) input use efficiency, and (iv) improved water and soil management techniques. Each of these steps can help improve farmers’ capabilities to manage weather and climate risks, but the level of success ultimately be determined by how well the communication with farmers is taking place, whether the means of implementation is available at local level, and whether the implementation can improve farmer’s short and long term livelihood.

As concluded by Altieri et al. (1983), the requirements of sustainable management implementation are not only biological or technical, but also social, economic, and political. CRM cannot be promoted without comparable changes in all other related areas of society. The final requirement for ecological agriculture is an attitude toward nature of coexistence, not of exploitation.

CONCLUSIONS

Droughts, floods, and other forms of severe weather have devastated local agriculture within the country. Although threats vary among places, no areas is immune to extreme weather. Therefore there is a pressing need to manage weather and climate risks to achieve sustainable agriculture management.

A number of technologies have been established to cope with climate change for each agro-ecosystem to reduce the yield gaps in rice field, upland and swampland. The key technologies to unlock the potential production of lowland rice include alternate wetting and drying irrigation systems, and the use of drought-, saline and submergence-tolerant rice varieties.

Managing water availability is crucial for upland farming. Management practices that can reduce drought risks include establishment of integrated water storage facilities such as farm water retardation pond, long storage, and channel reservoir. From the perspective of water distribution, water saving irrigation systems such as drip irrigation, sprinkler irrigation, as well as capillary irrigation need enhancement in their implementation. Various soil management technologies including conservation tillage and vegetative soil conservation techniques can readily be applied to decrease soil loss and increase soil health.

Adaptive technologies for managing swampland include one-way water management and conservation blocks, the surjan system, planting of adaptive varieties, and soil amelioration and fertilization.

The implementation of CRM need to focus with committed engagement of farmers, extension workers, agricultural services, and policy-makers to build resilient agriculture to climate risks. Increasing capacity building of Indonesian institutions toward climate risk management is also an important action.

REFERENCES

Agus, F., Husnain and Yustika, R.D. (2015). Improving Agricultural Resilience to Climate change Throught Soil Management. Jurnal Lihatang Pertanian 34(4):147–158.
Agus, F. and Widianto (2004). Petunjuk Praktis Konservasi Tanah Lahan Kering (Practical Guidelines for Upland Soil Conservation). World Agroforestry Centre (ICRAF) Southeast Asia, Bogor. p. 102.
Altieri, M.A., K., D., Letourneau and Davis, J.R. (1983). Developing Sustainable Agroecosystems. BioScience 33(1):45–49.
Annisa, W. (2014). Peran Bahan Organik Dan Pengelolaan Air Terhadap Kelarutan Besi, Emisi GRK Dan Produktivitas Padi Di Lahan Sulfat Masam. Disertasi. Fakultas Pertanian UGM.
Annisa, W., Jumberi, A., Koesrini and Nursyamsi, D. (2015). Pengaruh Biochar Terhadap Emisi CH4, CO2, Pertumbuhan Dan Hasil Tanaman Padi Di Tanah Sulfat Masam. Laporan Hasil Penelitian 2015. Kegiatan Pengelolaan Lahan Rawa Ramah Lingkungan. Balittra. Banjarmbaru.
Atkins, S.H. and Afuakwa, J.J. (2012). Effect of four different tillage practices on soil physical properties under cowpea. Agriculture and Biology Journal of North America 17:7–24.
Baethgen, W.E. (2010). Climate Risk Management for Adaptationio Climate Variability and Change. Crop Science 50:70–76.
BALITBANGTAN (2011). Inovasi Mengantisipasi Perubahan Iklim Untuk Kemandirian Pangan. Laporan Tahunan 2010. ISBN 978-602-8218-83-2. Badan Penelitian dan Pengembangan Pertanian. Jakarta.
Climate risk management for sustainable agriculture .... (Elza Surmaini and Fahmuddin Agus) 59

Meyer, L.D., Dabney, S.M. and Harmon, W.C. (1995). Sediment-trapping effectiveness of stiff-grass hedges. Trans. ASAE 38:809–815.

Mjelde, J.W., Hills, H.S.J. and Griffiths, J.F. (1998). A review of current evidence on climate forecast and their economic effect in Agriculture. American Journal of Agricultural Economics 80(5):1089–1095.

Mueller, N.D., Gerber, J.S., Johnston, M., Ray, D.K., Ramankutty, N. and Foley, J.A. (2012). Closing yield gaps through nutrient and water management. Nature 490(7419): 254–257.

Mukherjee, A. and Lal, R. (2013). Biochar impact on soil physical properties and green house gas emissions. Agronomy 3:313–339.

Mulyani, A., Nursyamsi, D. and Syakir, M. (2017). Strategi Pemanfaatan Sumberdaya Lahan untuk Pencapaian Swasembada Beras Berkelanjutan. Jurnal Sumberdaya Lahan 11(1):1–11.

Nalliah, V. and Ranjan, R. (2010). Evaluation of a Capillary-Irrigation System for Better Yield and Quality of Hot Pepper (Capsicum annuum). Applied Engineering in Agriculture 26(5):807 816.

Naylor, R.L., Battisti D.S., Vimont, D.J., Falcon, W.P., and Burke, M.B. (2007). Assessing the risks of climate variability and climate change for Indonesian rice agriculture. Proceeding National Academic Science 104:7752–7757.

Oleson, J.E. and Bindi, M. (2004). Agricultural impacts and adaptation to climate change in Europe. Farm Policy Journal 1(3):36–46.

Parry, M.L., Canziani, O.F., Palutikof, J.P., Linden, P.J. van der and Hanson, C.E. (2007). Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK.

Pradhan, P., Lüdeke, M.K.B., Reusser, D.E. and Kropp, J.P. (2014). Food self-sufficiency across scales: How local can we go? Environ Sci Technol 48(16):9463–9470.

Price, A.H., Norton, G.J., Salt, D.E., Ebenhoeh, O., Meharg, A.A. and Meharg, C. (2013). Alternate wetting and drying irrigation for rice in Bangladesh: is it sustainable and has plant breeding something to offer? Food Energy Sec 2:120–129.

PUSLITBANGTAN (2015). Varietas Padi Toleran Kekeringan. Rendaman, Salinitas, Dan Tanah Hana Penyakti Utama.http://www.litbang.pertanian.go.id/info-teknologi/2413/[diakses 9 Mei 2020].

Rejeus, R.M., Palis, F.G., Rodriguez, D.G.P., Lampayan, R.M. and Bouman, B.A. (2011). Impact of the alternate wetting and drying (AWD) water-saving irrigation technique: Evidence from rice producers in the Philippines. Food Policy 36:280–288.

Runtanuwu, E., Syahbuddin, H. and Ramadhan, F. (2013). Kalender tanam sebagai instrumen adaptasi perubahan iklim. hlm. 271–291. Dalam Soeparno, H., E. Pasandaran., M., Syawwani, A., Dariah., S.M. Pasaribu, N.S. Saad (Ed). Politik Pembangunan Pertanian Menghadapi Perubahan Iklim. IAARD Press. Jakarta.

Salack, S., Klein., C., Giannini, A., Sarr, B., Worou, O.N., Belko, N., Liefernicht, J., Kunstman, H. (2016). Global warming induced hybrid rainy seasons in the Sahel. Environ. Res. Lett. 11:104008.

Sari, A.P., Maulidia, M., Butarbutar, R.N., R.E.Sari and Rusmantoro, W. (2007). Executive Summary: Indonesia and Climate Change. 45 Working Paper on Current Status and Policies. The World Bank and London, UK. Department for International Development (DFID).http://www.conflictrecovery.org/bin/PEACEClimateChange-ExecSum.pdf.(Diakses 7 Februari 2018).

Schmidhuber, J. and Tubiello, F.N. (2007). Global food security under climate change. Proc. Natl. Acad. Sci 104(50):19703–19708.

Selvaraju, R. (2012). Climate risk assessment andmanagement in agriculture. In Meybeck A., Lankoski, J., Redfern, S. Azzu, N. and Gitz, V (Eds). Building Resilience for Adaptation to climate change in the Agriculture Sector. Proceedings of a Joint FAO/OECD Workshop. FAO. Rome. p. 346.

Setyanto, P., Pramono, A., Adriany, A., Susilawati, H., Tokida, T., Padre, A. and Kazunori Minamikawa, K. (2017). Alternate wetting and drying reduces methane emission from a rice paddy in Central Java, Indonesia without yield loss. Soil Science and Plant Nutrition 64(1):23–30.

Shannon, H.D. and Motha, R.P. (2015). Managing weather and climate risks to agriculture in North America, Central America and the Caribbean. Weather and Climate Extreme 10:50–56.

Singh, R. and Singh, G.S. (2017). Traditional agriculture: a climate-smart approach for sustainable food production. Energy. Ecology and Environment 2:296–316.

Sivakumar, M. (2006). Climate prediction and agriculture: Current status and future challenges. Climate Research 33(1):3–17.

Slingo, J. and Palmer, T. (2011). Uncertainty in weather and climate prediction. Philos Trans A Math Phys Eng Sci. 369(1956):4751–4767.

Surmaini, E., Ramadhan, F., Syahputra, M.R., Dewi, E.R. and Apriyana, Y. (2020). Development of a paddy drought hazard forecasting system to cope with the impact of climate change. IOP Conf. Series: Earth and Environmental Science 484 (2020) 012056.

Surmaini, E. and Susanti, E. (2016). Keberkalingan Pertanian: Penyebab, Dampak, dan Penanganan. Hal. 231-244: in Surmaini, E., Redjekinningrump, P., Heryani, N., Suciantini, Susanti, E, Sarvina, Y (Eds). Membangun Kapasitas Adaptasi Menghadapi Perubahan Iklim melalui Climate Smart Agriculture. Prosiding Simposium VIII Perhimp. Bogor.

Surmanii, E., Susanti, E., Syahputra, M.R. and Hadi, T.W. (2019). Exploring standardized precipitation index for predicting drought on rice paddies in Indonesia. IOP Conference Series 303:012027.

Surmaini, E., T.W., H., Subagyono, K. and Puspito., N.. (2015). Early detection of drought impact on rice paddies in Indonesia by means of Niño 3.4 Index. Theoretical and Applied Climatology 121:669–684.

Tanaka, N., Levia, D., Igarashi, Y., Nanko, K., Yoshifuji, N., Tanaka, K., and Kumagai, T. (2015). Throughfall under a teak plantation in Thailand: a multifactorial analysis on the effects of canopy phenology and meteorological conditions. Int. J. Biometeorol 59(9):1145–115.5

Thornton, P.K., Kristjanson, P., Förch, W., Barahona, C., Cramer, L. and Pradhan, S. (2018). Is agricultural adaptation to global change in lower-income countries on track to meet the future food production challenge? Global Environmental Change 52:37–48.

Tun Oo, A., Van Huylenbroeck, G. and Speelman, S. (2020). Measuring the Economic Impact of Climate Change on Crop Production in the Dry Zone of Myanmar: A Ricardian Approach. Climate 8(1):9. doi: https://doi.org/10.3390/clim8010009.

Walter, M.W. (1967). Length of Rainy Season in Nigeria. Niger. Geogr. J: 123–126.

Willekens, K.B.V., Buchan, D. and De Neve, S. (2014). Soil quality is positively affected by reduced tillage and compost in an intensive vegetable cropping system. Appl. Soil Ecol. 82:61–71.
William, P.A., Crespo, O. and Abu, M. (2019). Adapting to changing climate through improving adaptive capacity at the local level – The case of smallholder horticultural producers in Ghana. *Climate Risk Management* **23**:124–135.

Wood, A.W., Hopson, T., Newman, A., Brekke, L., Jeff Arnold, J. and Clark, M. (2016). Quantifying Streamflow Forecast Skill Elasticity to Initial Condition and Climate Prediction Skill. *Journal of Hydrometeorology* **17**(2):651–668.

Yulianti, A., Sirnawati, E. and Ulpah, A. (2016). Introduction Technology of Cropping Calendar-Information System (CC-IS) for Rice Farming as A Climate Change Adaptation in Indonesia. *Int. J. of Advanced Science Engineering Information Technology* **6**(1):92–96.

Ziervogel, G. and Calder, R. (2003). Climate variability and rural livelihoods: assessing the impact of seasonal climate forecasts in Lesotho. *Area* **35**(4):403–417.