Chapter 5

Successful Adaptation Measures for Inland and Coastal Food Security

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CHAPTER 5

Successful Adaptation Measures for Inland and Coastal Food Security

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5.1 Introduction

Climate change has caused difficulty in local weather and widened the gap between the wet and dry seasons in tropical monsoon countries. Both extremely moist and dry weather conditions have become more frequent since El Niño hit in 1978, devastating vast agricultural production in the region. A more massive El Niño occurred in 2015, but its impact was not as severe because governments and society anticipated it and were well prepared to carry out adaptive measures.

Coastal land, which is relatively low altitude, flat, warm, and home to paddy fields, is generally prone to flooding during wet periods (La Niña). The main threats to agricultural production are heavy/less rainfall, less sunshine, high/low temperatures, strong winds, floods, and earthquakes. Lowland paddy fields mostly have enough water, even during dry periods, but the amount of soil water does not always last the whole cultivation period. Inland terrain is higher altitude, sloping, and relatively cold where horticulture is commonly cultivated; and might experience droughts during dry periods (El Niño). Extreme rainfall might not result in prolonged flooding but has the potential to cause landslides.

This chapter identifies types of disasters that have contributed to and threatened food production in some Asian countries, and analyses how the affected countries have carried out countermeasures and anticipated disaster risks caused by climate change. In most cases, extreme weather is the primary threat to agricultural production and related infrastructure. Natural disasters, which frequently happen in Japan, are good examples of how governments and people anticipate, respond, and adapt to catastrophes so that risks can be mitigated and the environmental conditions for production can be restored.

This chapter focuses on risks to food production resulting from extreme weather, which may be caused by climate change. It discusses the cases of Japan and the Republic of Korea (henceforth, Korea) to represent advanced countries, while Indonesia and Viet Nam represent developing countries. Case studies from developing countries are essential to analyse and learn from since their populations are highly dependent on farmland for survival while land productivity is relatively low. Indonesia is focused on since it is the fourth most populous country in the world but is still struggling to increase food production, achieve and maintain self-sufficiency from 2019, and become the world's largest rice producer in 2045.

The System of Rice Intensification (SRI) – a promising method of rice cultivation gaining popularity in Asian countries which can increase rice production and is hardy in extreme weather – is examined. Finally, a policy implication is raised on how to deal with the risks and provide a fast response to minimise damage, as learned from the country case studies in this chapter.

5.2 Threats of Natural Disasters

Since the 1900s, the global temperature has fluctuated around −2° C to +2° C (Intergovernmental Panel on Climate Change (IPCC), 2007). The warmer weather factually supports the increase of agricultural production, but the colder weather in many cases becomes the dominant cause of crop failures and the damage of infrastructure.

Japan experienced recurring bad weather, cold temperatures, and a severe famine in the 18th century, mainly because of frequent volcano eruptions where volcanic ash covered vast areas of agricultural land and caused crop failures. Smaller ash particles remained in the air and hindered solar radiation, triggering cold temperatures over a long period, which damaged crop production and caused famine. The hardest hit region was northern Japan. Low nutrition and starvation caused 920,000 deaths during 1780–1786.

Typhoons are another threat, frequently occurring in the autumn. Strong winds and heavy rains are the leading causes of crop and infrastructure damage.

Table 5.1 shows the types of disasters and the damage they have caused in the agriculture sector in recent years. The heavy rains that follow typhoons and their low-pressure systems are the main hazards. Earthquakes in Niigata (2004), Noto (2007), eastern Japan (2011), and Kumamoto (2016) were amongst the main disasters. As shown in Table 5.1 the damage to agricultural infrastructure in terms of value was significantly higher than that of agricultural production.

Table 5.1: Disasters and Agricultural Damage in Japan, 2006–2015

Year	Disaster	Agricultural production (A) (¥ million)	Agricultural infrastructure (B) (¥ million)	Total (¥ million)	(B)/(A)
2006	Heavy rain, typhoon	59,031	219,727	278,758	3.7
2007	Typhoon, earthquake	25,259	141,864	167,123	5.6
2008	Earthquake, heavy rain	13,621	197,336	210,957	14.5
2009	Heavy rain, typhoon	14,770	72,753	87,523	4.9
2010	Heavy rain in the rainy season	16,249	77,008	93,257	4.7
2011	Great East Japan earthquake	103,882	2,601,606	2,705,488	25.0
2012	Heavy rain in northern Kyushu	26,725	162,316	189,041	6.1
2013	Heavy rain and typhoon	36,395	164,419	200,814	4.5
2014	Heavy snowfall	55,412	257,208	312,620	4.6
2015	Heavy rain in Kanto area	27,266	83,390	110,656	3.1

Source: MAFF (2015).

The agriculture sector has experienced the impacts of climate change in many countries. These have caused crop and livestock losses because of severe droughts and flooding, as well as harvest failures resulting from pest and disease outbreaks, and difficulty in determining the appropriate time to start cultivation. Reports on agricultural failures caused by climate change globally have been compiled elsewhere (IPCC, 2007).

In some Asian countries, such as those listed in Table 5.2 , the impacts of extreme weather on agriculture have differed in magnitude (Amarnath et al., 2017). Drought, accompanied by extreme temperatures, caused harvest failures on about 1.8 million square kilometers

(km^2) of agricultural land in India, 359,000 km^2 in Pakistan, and 91,000 km^2 in Sri Lanka. Meanwhile, agricultural collapses in Bangladesh were mainly due to frequent floods caused by extreme rainfall and sea-level rise, while Nepal and Bhutan suffered more from excessive rain. Amarnath et al. (2017) also introduced four classes (low, medium, high, and extreme) to identify the risks faced by those countries – Bangladesh was categorised as extreme, Bhutan was low to medium, India was medium to extreme, Nepal was high to extreme, Pakistan was medium to extreme, and Sri Lanka was low to extreme.

Table 5.2: Impact of Individual Hazards on Agriculture, 1950–2014

Country	Flood (%)	Drought (%)	Extreme rainfall (%)	Extreme temperature (%)	Sea-level rise (%)	Agricultural area (%)
India	7.0	33.1	8.7	29.1	1.7	1,796,700
Pakistan	8.4	50.4	0.3	33.1	1.4	359,360
Bangladesh	53.1	2.9	42.6	1.8	18.4	91,280
Nepal	6.0	2.7	51.0	0.3	0.0	41,266
Sri Lanka	4.3	25.0	3.6	27.0	2.1	27,300
Bhutan	0.2	0.1	20.0	0.0	0.0	5,196

km^2 = square kilometre.

Source: Amarnath et al. (2017).

5.3 Threats of Climate Change

5.3.1 Japan

The agriculture sector has already experienced impacts of climate change, including crop and livestock loss from severe drought and flooding, large-scale losses from weather-related disasters, and shifts in planting and harvesting times. These impacts have profound effects, often significantly affecting the health and well-being of rural residents and communities (IPCC, 2007). Adaptation efforts require planning, but rural governance structures tend to de-emphasise planning capacity compared with urban areas. If rural communities are to respond adequately to future climate changes, they will need to assess their risks and vulnerability. The effects of global warming on agriculture have been spreading, e.g. high temperatures have caused unmatured grains of rice, grapes and apples are a bad color, bad ripening, tomatoes are of low quality, and the volume and quality of cow milk have decreased.

The Japanese Ministry of Agriculture, Forestry, and Fisheries (MAFF) have instigated countermeasures (MAFF, 2013a) to combat these effects. New varieties of rice were introduced to 55,800 hectares (ha) of paddy field in 2012. Late transplants, improved water management, and a change in fertilisation have also been implemented. New varieties of fruit have been introduced, the stem surface partial removal for ripening acceleration of grapes, and the shadowing method for reducing sunlight has been applied to apples. Shadowing and new varieties have also been introduced for strawberries to combat the late ripening and low quality and quantity. In the livestock sector, the cooling and shadowing techniques were also introduced for cow-milk industries.

The most significant countermeasure, however, is to reduce the emissions of greenhouse gases (GHGs). Emissions from industry and transport are high, at 42%, but emissions from agriculture are also significant. Therefore, the agriculture sector needs to reduce emissions as much as possible. For rice growing, intermittent irrigation is recommended to reduce GHGs and enhance plant strength.

MAFF issued the Overview of the Plan for Global Warming in 2017 (MAFF, 2017). The strategy is a combination of mitigation measures, adaptation measures, and international cooperation in agriculture, forestry, and fisheries. Through comprehensive promotion measures in those sectors, MAFF aims to promote agriculture, forestry, and fisheries that contribute to global environmental conservation.

Matsuo (2011) reported on the implementation of global warming adaptation measures. These include (i) monitoring the impacts of global warming, (ii) establishing a system to support producing areas, and (iii) supporting adaptation measures.

Disasters can be classified in the following categories:

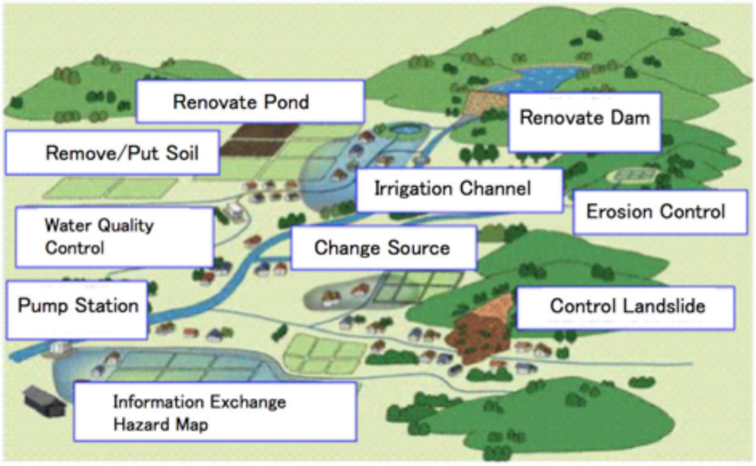
(i) Disasters which are difficult to predict: volcanoes, earthquakes, and tsunami. Preparation and evacuation training is adequate for these disasters. The affected areas are usually limited enough, so neighboring regions can assist. Municipalities, non-governmental organisations, and citizens are aware of the importance of rapid response; and some training has been provided.

(ii) Disasters which can be predicted sometime before: typhoons, heavy rains, strong winds, and extreme temperatures. This type of catastrophe leaves enough time to prepare for the consequences.

(iii) Disasters which can be reduced or stopped: global warming; water pollution; soil contamination; and land subsidence by pumping, floods, and landslides. Countermeasures for global warming have been noted above. Many of the other disasters can be reduced through technical innovation and legal restrictions on GHG emissions.

Villages need disaster prevention facilities for (i) landslides, (ii) wind and snow damage, (iii) fire, (iv) stormwater drainage, (v) waterway and pond safety, (vi) traffic safety, (vii) crime, and (viii) communications (radio). MAFF also executes disaster prevention projects for agricultural and rural infrastructure (Figure 5.1).

Figure 5.1: Disaster Prevention Projects of Agricultural Land

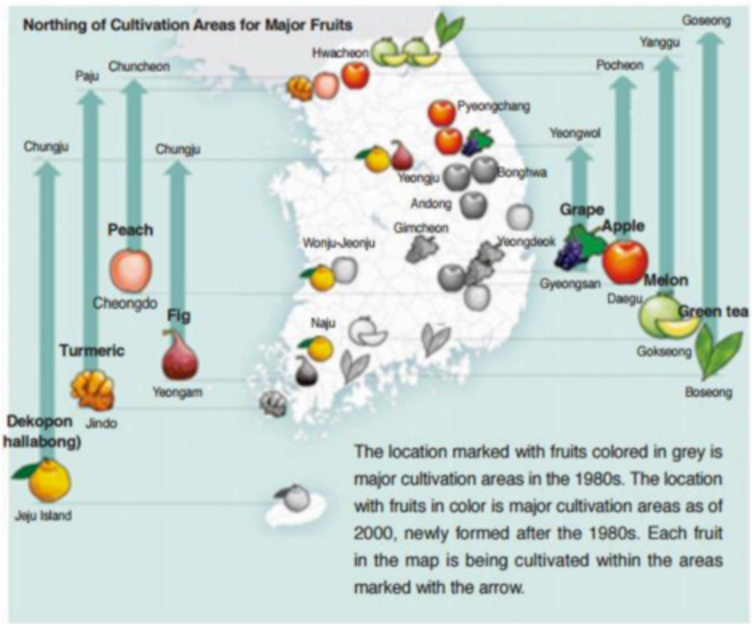


Source: MAFF (2013b).

5.3.2 Korea

Apples are the most cultivated and consumed fruit in Korea, with cultivation mostly occurring in North Gyeongsang Province in southern Korea (Kim, Heo, and Lee, 2010). In the past, most counties in North Gyeongsang Province had adequate annual mean temperatures for apple cultivation (8°C–11°C), but temperatures have increased in recent years for most counties and future temperature rises are expected – requiring careful adaptation measures for such impacts of climate change (Choi and Yamaji, 2016). In Korea, northing (moving to the northern regions) of cultivation areas of fruits had already occurred, as shown in Figure 5.2.

Figure 5.2: Climate Change Impact on Major Crop Cultivation Area



Notes:

1. Grey fruits denote the major cultivation areas in the 1980s. Colored fruits denote the main cultivation areas in 2000.
2. Each fruit is cultivated within the areas indicated by the arrows.

Source: Korea Rural Economic Institute (KREI, 2015).

5.3.3 Viet Nam

Rice is the staple product of Viet Nam, which produced 45 million tons (t) in 2014 and has a 6.1% share of the world's production. However, as a result of climate change, the Government of Viet Nam projects the country's rice production to decrease by 7.2 million t at the end of the 21st century.

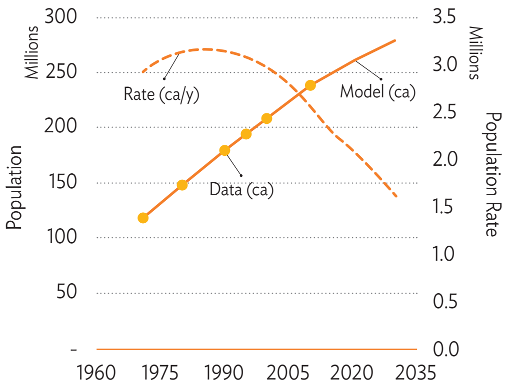
From 2002 to 2017, climate change-oriented natural disasters have increased – affecting the agriculture sector and socio-economic activities in Viet Nam. The Ministry of Agriculture and Rural Development reported that economic losses from natural hazards amount to $900 million or 1.5% of gross domestic product every year. Agricultural specialists have recommended the diversification of crops for adaptation to climate change. However, PanNature, a not-for-profit organisation, notes that diversification is difficult for small-scale farmers and points to farmers' lack of awareness of climate change as a more serious factor (SankeiBiz, 2017).

5.3.4 Indonesia

Overview

Indonesia is a rice-based country with a population of 240 million which is projected to reach 280 million in 2030, although its growth rate has been decreasing since 1990 (Figure 5.3). As rice is the staple food, rice production continues to increase through land intensification and expansion. As shown in Figure 5.4, the harvested area increases over time, mainly thanks to the increase in planting intensity, which is 170% on average and is projected to reach 190% by 2030. The rate of extensification and its contribution to national rice production is very small, but it helps to provide rice for people living in remote and isolated areas such as small islands and borders with neighboring countries.

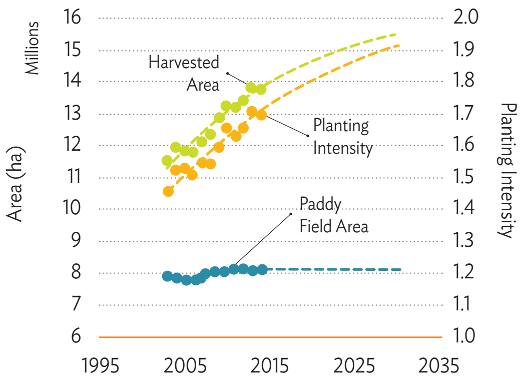
Figure 5.3: Population of Indonesia



ca/y = capita per year.

Source: Statistics Indonesia (2012).

Figure 5.4: Paddy Cultivation in Indonesia



ha = hectare.

Source: Statistics Indonesia (2017).

Seasonal shifting has been apparent since the first El Niño hit the Indonesian archipelago in 1997. Less rainfall from June to August has been detected in western parts of the country such as Java, Sumatera, Kalimantan, and Nusa Tenggara, causing longer dry seasons. Meanwhile, rainfall intensity from December to February in the eastern islands such as Sulawesi has tended to increase over time. Climate change has multidimensional effects on food resilience, agricultural resources, infrastructure, production systems, and farmer welfare. Land vulnerability to drought varies according to location. Paddy fields in Sumatera and Java amounted 74,000 and 1 million out of the total of 5.14 million ha are highly vulnerable to drought. Frequent flooding has intensified pest and disease outbreaks indirectly. Since crops are highly susceptible to extreme weather, efforts have been made to invent new varieties that are more tolerant of the drier and/or wetter conditions and improved cultivation methods and technologies.

National Policy

The Ministry of Agriculture planned to secure food and energy security over 2015–2019 to support national resilience. One of the agricultural development policies is to improve mitigation and adaptation capacities in dealing with climate change by strengthening agricultural infrastructure and applying adaptive methods and technologies. The agriculture sector contributes about 6% of the national GHG emissions in lieu of the target to decrease GHG emissions by 0.008%–0.011% by 2020.

The ministry has published guidelines that state the objectives, targets, and strategies to be followed by all parties (Agricultural Research and Development Agency (Balibangtan), 2011). The objectives are to (i) give direction to enhance understanding of how to identify climate change and its potential impacts, (ii) guide efforts and action programmes to obtain benefits from climate variability and reduce its effects, (iii) identify and register existing technologies that are adaptive to climate change, and (iv) develop a climate information system and disseminate innovative technologies in dealing with climate change.

The guidelines stress the importance of involving stakeholders not only in the agriculture sector but also other related sectors from the central government to the rural community, streamlining research and development programmes to come up with innovate technologies adaptive to climate change, and enhancing the awareness and understanding of farmers and rural society to climate information and how to implement adaptive technologies. There are structural and non-structural strategic approaches. The structural approaches include registering detailed information on the conditions of irrigation networks, rehabilitating irrigation infrastructure, expanding irrigated areas to increase planting intensity, and rehabilitating catchment areas to anticipate incoming extreme climate. The non-structural approaches include empowering the regulation of the prohibition on agricultural land conversion, prioritising the implementation of adaptive programmes in places highly vulnerable to climate change and natural disasters, introducing the integrated planting calendar or *Kalender Tanam* (KATAM) to a broader rural community, expanding the field climate school to empower local communities in reading and understanding and how to anticipate climatic phenomena, and smoothing the distribution of information through the existing related institutions to the end users.

Two factors need to be considered when assessing adaptability to climate change: (i) the capability to adapt and (ii) the significance of the impact caused. The capacity to adapt reflects how crops can survive and produce under climate stress. The significance of the impacts caused measures the physical losses which cause farmers not to reap benefits from their fields. The strength or weakness of the adaptation capability can be seen externally in the bearing capacity of the ecosystem and environment; and internally in the preparedness of regulations, institutions, funding, and human resources. The capability to adapt may reduce the tension generated from the socio-economic issues, climate risk, and climate change.

Successful adaption is determined by how to build a sound programme in applying appropriate technology that can enhance capacity building and the effective funding allocation. The need for technology should be assessed comprehensively, including whether it is available in the country or needs to be imported. Enhancing human and institutional capacities should focus on the adaptation that needs to be carried out. Decisions on funding should consider not only the amount but also how to manage it transparently with full accountability, and whether the source is national or international. There is a strong need to enhance cooperation amongst stakeholders and integrate work mechanisms and decision support systems to develop comprehensive programmes that can avoid failure and substantial losses in terms of energy and time, as well as funding (Ari, 2012). Early implementation of adaption programmes can save or reduce losses substantially.

Water availability is the main issue in dealing with climate change. Water harvesting from the excess of irrigation (run-off) and rainwater is critical to success in water conservation. Water is abundant during the wet season and may cause flooding, while water scarcity is threatening when crops are maturing in the second cultivation season. In general, the most critical period for water availability is 20 days before harvesting. Since 2017, the Indonesian government has constructed dams with the targets of 30,000 units – each with at least 500 cubic meters of water volume capable of flowing at 5 liters per second over 25 ha. The plan is to irrigate more than 4 million ha of paddy field and double the planting intensity, with the potential to add 16 million t of rice production.

Information systems for assessing real-time weather conditions – including the monitoring, analysis, interpretation, and prediction of future weather – are continuously improved. Additional automatic weather stations have been erected, and adaptive technologies have been inventoried and developed. Water resources, including the related infrastructure, have been managed and prepared to deal with unexpected extreme weather that threatens drought and flood events.

To anticipate climate change and its consequences, the ministries of agriculture, public works, and rural development are cooperating to accelerate relevant projects; and they have published a technical manual to fast-track the construction of water reservoirs (Directorate General for Agricultural Structure and Infrastructure (PSP), 2017). The government plans to intensify rice planting from 100% to 200% covering over 4 million ha, out of which 600,000 ha will be irrigated by small dams, 700,000 ha by on-farm reservoirs, 90,000 ha by the long water storage, 2.5 million ha by river water, and 24,000 ha by groundwater. To date, the government has built about 18,000 water reservoirs, which can make water available and enhance food production in places vulnerable to water scarcity during the dry season.

The main activities to sustain food production in the context of climate change are to improve water management, water harvesting, conservation farming, the planting calendar, adaptable crops, climate insurance, and cultivation methods. These countermeasures are described below.

Adaptive Measures

1) Water Management

Paddy cultivation is commonly supported by technical irrigation to ensure the availability of water during the growth period without water fees. In most cases, farmers feel uncomfortable if their fields are not continuously flooded every day. This has caused inefficient or excessive use of irrigation water and makes their fields less productive. Some farmers believe that continuous water ponding can reduce weeds and promote productivity, but instead productivity decreases because of bad soil aeration, nutrient loss, frequent pest and disease attacks, and more methane emissions.

Excessive irrigation is not sustainable in the era of climate change since it depletes the availability of irrigation water. Various modern irrigation methods can reduce the use of irrigation water without jeopardising productivity. The most common methods are covering the soil surface with a thin layer of water (shallow ponding); ponding the soil surface with water on certain days (alternate wetting and drying); rotating from one plot to another (rotating irrigation); and saturating the soil surface without water ponding (saturated irrigation). These techniques can improve land productivity. Saturated irrigation is commonly applied in SRI and has been proven capable of increasing water productivity and decreasing GHG emissions.

2) Water Harvesting

Dryland is another ecosystem with significant potential as farmland for food crops, horticulture, and annual crops as well as animal husbandry. About 25 million ha out of 76 million ha of dry land is arable, but the cultivated area is limited to one season because of water constraints. In some areas, dry land may have limited water resources, but in other areas, it may have excess water in the rainy season although the water is depleted in the following dry season. In these locations, rainwater harvesting is a potential solution through constructing on-farm water reservoirs and/or tapping groundwater if available beneath the land. This supplemental water may not be enough for the whole season of the main crop (paddy), but farmers will obtain additional income when they use the water for cash crop production such as shallots and peppers. Other forms of water harvesting are pumping water from nearby rivers and building dams in small streams, small artificial lakes, long-term water storage facilities, and groundwater wells.

Since 2017, Indonesia has constructed around 30,000 units of these forms of water harvesting, which will cover 4 million ha, and by this time more than 17,000 have been completed. Three ministries (agriculture, public works, and rural development) are working together to implement this project, which is planned to allocate more than Rp20 trillion. For small projects, farmer groups can perform the construction themselves (self-managed) following ministerial guidelines. This scheme will have the added benefit of giving farmers a sense of belonging and encourage them to take care of it and create appropriate management systems for operation and maintenance of the facilities.

From 2015 to 2016, the Ministry of Agriculture increased the planting intensity from 100% to 150% over 90,000 ha with the help of about 3,500 water harvesting units add more 230,000 t of dried paddy production. Since 2017, the ministry planned to build 6,000 more units to increase the planting intensity by 50% on more than 63,000 ha, producing an additional 350,000 t of dried paddy.

3) Conservation Farming

The primary objective of this programme is to conserve irrigation water by supplying water as and when required by plants, and by reducing water losses resulting from evaporation. In some areas, applying up to 60% less water than corn farmers typically use has not lowered productivity, so more farmland can obtain water for cultivation. Keeping the soil moist by enhancing its capacity to hold water can be done through the application of the appropriate amount and composition of manure and biochar. Furthermore, water loss caused by evaporation can be reduced by covering the soil surface with the disposed biomass left in the field after the previous harvest. Using this practice, farmers can increase of corn from 5.7 t/ha to 7.6 t/ha. It also allows farmers to cultivate watermelon, without any extra irrigation water, by reaping the benefits of the moist soil layers during the dry season.

4) Planting Calendar

KATAM is used to determine the appropriate time to start rice cultivation in a specific location (Balitbangtan, 2010). It is constructed based on historical climate information and geographical characteristics. KATAM also specifies varieties that could be adaptable under future climate conditions in the location, including how to manage plants during cultivation periods and how much water is available. Farmers can quickly determine the most appropriate varieties to grow and earn good yields. Online maps allow farmers to see the actual condition of the growth stages if they input the required data (Centre for Data and Information, Ministry of Agriculture (Pusdatin), 2017). Growth analysis is carried out based on the mean cultivated areas every 10 days in each district (kecamatan).

Under actual conditions, KATAM considers the first planting season in a district to begin when farmers have planted more than 8% of the existing paddy fields. The second and third planting seasons start after reaching 6% and 2%, respectively. KATAM also provides information on weather conditions, which informs its determination of the onset of the planting season and the availability of rain and irrigation water. The first planting season is determined when rainfall has exceeded 35 millimeters in 10 days during three consecutive 10-day periods. Under this criterion, Indonesia has eight distinctive planting season zones. In collaboration with the Meteorology, Climatology and Geophysical Agency (BMKG, 2017), KATAM distinguishes three annual rainfall patterns: (i) 'yearly wet', when the annual rainfall is 115% above the mean annual value (La Niña); (ii) 'yearly normal', when the annual rainfall is 85%–115% of the mean annual value; and (iii) 'yearly dry', when the annual rainfall is less than 85% of the yearly mean value (El Niño). This KATAM facilitates determining which actions to take in anticipating extreme conditions.

BMKG undertakes daily climate monitoring and updates this information to related institutions such as the Ministry of Agriculture. However, the results of the analysis are not accurate because of the limited number of reliable climate stations. Improvements are underway to tackle this, including (i) installing more or renewing climate stations in each district; and (ii) developing a method of climate analysis for determining the onset of the planting season more accurately and for providing reliable information on how much water is available during the planting season. Currently, a map is being developed to estimate the dynamic trend of weather conditions and water availability in the whole regions.

5) Adaptable Crops

Improving crop varieties to be more adaptable under extreme climate conditions is becoming a vital research topic. Many varieties now meet that condition. Balitbangtan (2017) released two varieties (INPARI 42 and INPARI 43) which can grow well under extremely wet and dry weather conditions. Their wide range of adaptability has earned these varieties the popular name 'amphibious paddy'. Their productivity may reach 9.2–10.6 t/ha even with limited input of pesticide and chemical fertilisers when they are planted in suboptimal soil with high acidity and waterlogging problems. Other characteristics include faster-growing varieties that can be harvested within 111–112 days after transplanting; stickier rice with an amylose content of about 18.8%–19.0%; a higher ratio of polished rice weight to grain, at 69.4%–70.1%; and increased resistance to pests and diseases common during extreme weather conditions. Seeds of these varieties are now distributed to locations prone to extremely wet and dry conditions.

6) Climate Insurance

Efforts to attain self-sufficiency need to consider the risk of weather-induced crop failure, which could affect farmers financially. To mitigate this risk, the government introduced a weather insurance scheme and accompanying guidelines in 2016 (PSP, 2016) to compensate for losses faced by paddy farmers as a result of flooding, droughts, and pest and disease attacks.

All farmers are eligible to apply for the government weather insurance scheme. The premium is Rp180,000/ha per planting season for insurance cover of Rp6 million. The government provides a subsidy of Rp144,000, so farmers only need to pay Rp36,000. Claims can be submitted if crop failures reach more than 75% of the planted area and the age of the plants is higher than 10 days for transplanted paddies and 30 days for direct seedlings.
Pest and disease attacks affected 76,000 ha of paddy field in 2014, 26,000 ha in 2015 (El Niño), and 35,000 ha in 2016 (La Niña). Most of the impacted areas could be recovered and harvested; however, thanks to a fast response and timely and appropriate treatment. Areas affected by drought totaled 180,000 ha in 2014, 800,000 ha in 2015, and 75,000 ha in 2016. Most of them could also be recovered and harvested thanks to early weather warning systems and the distribution of water pumps. In 2017, the government allocated a subsidy

for 1 million paddy fields; by this time, more than 450,000 ha had been registered, and more than 6,500 ha had claimed amounts totaling Rp40 billion (Irianto, 2017).

7) Cultivation Method

Farmers have implemented many cultivation methods considered adaptive to climate change. These include those related to (i) water management, e.g. intermittent irrigation, shallow ponding, and saturated irrigation, which have been proven to save up to 60% of water without any loss of yield, as well as reducing GHG emissions; (ii) nutrient management, e.g. by increasing fertilisation efficiency, e.g. substituting unavailable nutrients with locally produced nutrients; (iii) variety options, e.g. planting varieties with higher tolerance to extreme weather; and (iv) waste management, e.g. keeping waste biomass in the fields to add organic matter and retain more water in the soil (Balitbangtan, 2012).

SRI, introduced in early 1970 in Indonesia, is another cultivation method deemed adaptive to climate change. Under SRI, a seed is planted in a rice field with a broader planting space of 25–30 centimetres and saturated irrigation are applied to keep the surface soil moist. SRI can grow more shoots and achieve higher productivity (above 8 t of wet paddy per ha) and higher water productivity (2.5 kilogrammes per cubic meter of water) with lower GHG emissions (2.5 ton of carbon dioxide gas equivalent (CO_2e) per each ton of dried paddy). The area planted under SRI increased from 1,100 ha in early 2007 to more than 900,000 ha in 2016.

Another method, known as Salibu, was initially developed in West Sumatra. This method applies ratooning by cutting the harvested plants about 5 centimetres from the soil surface to allow new roots to emerge from the cuts (Puslitbangtan [Indonesian Center for Food Crops Research and Development], 2013; Abdurrahman et al., 2015). After 10 days, the roots touch the soil surface and extend to a deeper soil layer. Days to harvest become shorter (less than 90 days) with yields of more than 7 t/ha of wet paddy. In some locations, the ratooning intensity increased fourfold with yields that were not very different from those of the mother plants. With Salibu, seeds and seedlings are not necessary for the second or subsequent planting seasons, but the soil should be kept moist after harvesting.

The Hazton rice cultivation method is named after Hazairin and Anton Kamarudin, two scientists at the Agricultural Agency of West Kalimantan who invented this technique in early 2012. Hazton uses 20–30 seedlings at an older age (25–30 days) in one planted spot, and each plant generally has a similar age of maturity. Experienced farmers can have yields of 7–14 t/ha of dried paddy. Other advantages include not needing to weed, harvesting crops 2 weeks earlier than usual, higher adaptability to climate and location, and reduced or minimal pest and disease attacks. Hazton is being applied in 24 provinces on more than 50,000 ha (Directorate General for Food Plants (Dirjentanpangan), 2016b).

5.4 The system of Rice Intensification

5.4.1 Basic Features

SRI has spread significantly since the end of the 20th century. Its resource savings and high productivity contribute to food security in normal conditions and can reduce damages when the weather fluctuates. SRI is a rice cultivation method developed in Madagascar in the early 1980s by a French priest, Fr. Henri de Laulanié, S.J. It spread outside Madagascar after 1997 through the support of Norman Uphoff of Cornell University, the World Bank, and some non-governmental organisations. It is now practiced in more than 44 countries around the world (Uphoff and Kassam, 2009).

SRI has innovated rice production systems by raising the productivity of land, labor, water, and capital without increasing external inputs and materials. It is a set of modified practices for managing rice plants as well as the soil, water, and nutrients. SRI can produce more paddy yield with less external inputs and is environmentally friendly. It can be adopted for any type of rice variety (local, high-yielding, or hybrid).

It is based on the following principles: (i) transplant very young seedlings (baby seedlings); (ii) transplant single seedlings at a hill with the utmost care for seed roots; (iii) transplant using wider spacing; (iv) reduce the use of chemicals (fertilisers, pesticides, insecticides, and herbicides); and (v) decrease water use by applying a wet-dry cycle of soil moisture (Stoop, Uphoff, and Kassam, 2002).

Benefits and Impacts of SRI

SRI methods generally have the following benefits and impacts compared with conventional methods of paddy cultivation: (i) paddy yields increase by 20%–50% and sometimes 100% or more, especially with improved cultivation methods; (ii) the seeds required for transplanting decrease by 60%–80%; (iii) the use of chemical fertilisers and agrichemicals can be reduced; (iv) irrigation water can decrease by 25%–50%; (v) production costs usually decline by 10%–20%; and (vi) farmers' net incomes increase with higher outputs and reduced costs. Table 5.3 compares the SRI method with the green revolution (rice) approach.

Table 5.3: Comparison Between the Green Revolution and the System of Rice Intensification

Item	Green revolution (rice)	SRI
History	In the 1960s, a new high-yielding variety of rice (IR-8) developed by the International Rice Research Institute caused remarkable yield increases and was accepted internationally as a key to solving food shortages.	In the 1980s, an innovative paddy cultivation method was developed in Madagascar then disseminated worldwide.
Principle	The increased unit yield of paddy by using a high-yielding variety with increased use of chemical fertilisers and water.	The increased unit yield of paddy by any rice variety by reducing seeds, chemical fertilisers, and water.
Environment	Heavy burden on the environment because of the high use of chemical fertiliser and agricultural chemicals.	Environment-friendly because of the reduction in greenhouse gases through intermittent irrigation and chemical use.
Water use	High consumption of irrigation water	25%–50% less use of irrigation water
Evaluation	No rice yield increases in recent years. Shortage of water resources and overuse of chemicals have caused problems.	Rice yield can increase with less input of external resources and can lower production costs.

Source: Arranged from Uphoff, N. and A. Kassam (2009).

5.4.2 Mechanism of Soil Condition Improvement

The following two techniques contribute not only to plant growth but also to reducing GHGs.

1) Aerobic Soil Conditions

Using very young (baby) seedlings is the most important contributor to higher SRI yields. The second most important factor is keeping the paddy soil moist but not continuously saturated or flooded, as this can avoid the suffocation and degeneration of rice plant roots and supports more abundant and diverse populations of aerobic soil organisms that provide multiple benefits to the plants. This condition can be achieved through alternate wetting and drying cycles or keeping the surface soil moist but not flooded. The operative principle is to provide both roots and soil biota with optimising amounts of both water and oxygen. The result is larger and deeper root growth, which gives rice plants more resilience to adverse climatic conditions such as droughts, storms, or extreme temperatures.

2) Active Soil Aeration

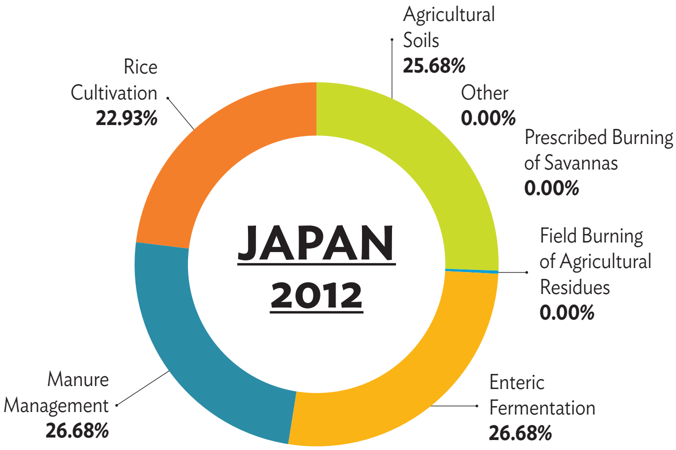
Not flooding fields is conducive to passive soil aeration, allowing biological processes to improve soil structure and functioning. Beyond this, SRI promotes mechanical measures to aerate the soil. When paddy fields are not kept flooded, weed growth becomes a more significant problem. SRI results depend substantially on maintaining mostly aerobic soil conditions. Good soil aeration can be obtained through biological means via the activity of the soil biota. Instead of weeding and throwing the weeds outside the plot, a rotary weeder can be used to turn the weeds into the soil. This technique creates the following benefits: (i) the soil becomes aerated and (ii) the weeds decompose in the soil and turn into organic matter. This causes the roots and plant to grow healthily, and higher yields can be achieved.

5.4.3 Advantages of SRI

1) GHG Emissions in Japan

In 2017, annual GHG emissions amounted to 1.3 billion t of CO_2 base, with Japan contributing around 3%. The share of agriculture is not very large within Japan’s GHG emissions. However, every sector should decrease their emissions regardless of the size of their share. Figure 5.5 shows the breakdown of GHG emissions in the agriculture sector. The share of rice cultivation is about 23%. By introducing SRI, GHG emissions from rice cultivation will decrease.

Figure 5.5: Greenhouse Gas Emissions in the Agriculture Sector

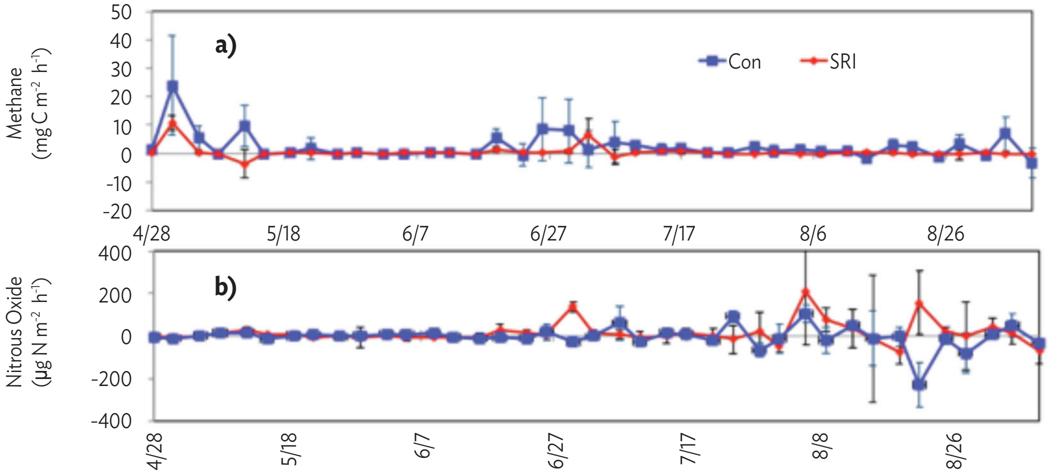


Source: MAFF (2017).

2) GHG Reduction by Adopting SRI

Not flooding rice cultivation can decrease methane emissions. This has been shown by researchers such as Setiawan et al. (2014) through measurements in SRI fields. shows the methane and nitrous oxides emitted from SRI paddy fields in Indonesia (Motomura and Yamaji, 2009). At the experimental fields in Puyung village, Sulawesi island in Indonesia, gases from SRI and conventional growing fields were collected and analysed every 3–4 days for a complete growing season. If converted to global warming potential, the conventional paddy field emitted 250 gCO_2 m^{-2} while the SRI paddy field emitted only 100 gCO_2 m^{-2} in one season. With SRI, methane emissions decreased significantly – about five times – while nitrous oxides increased 50 times, though their value was considerably small. The exciting part is that the proportion of methane and nitrous oxides to global warming potential is almost the same, at 50%.

Figure 5.6: Methane and Nitrous Oxide Gas from SRI Paddy Field



Con=Conventional, SRI=System of Rice Intensification.

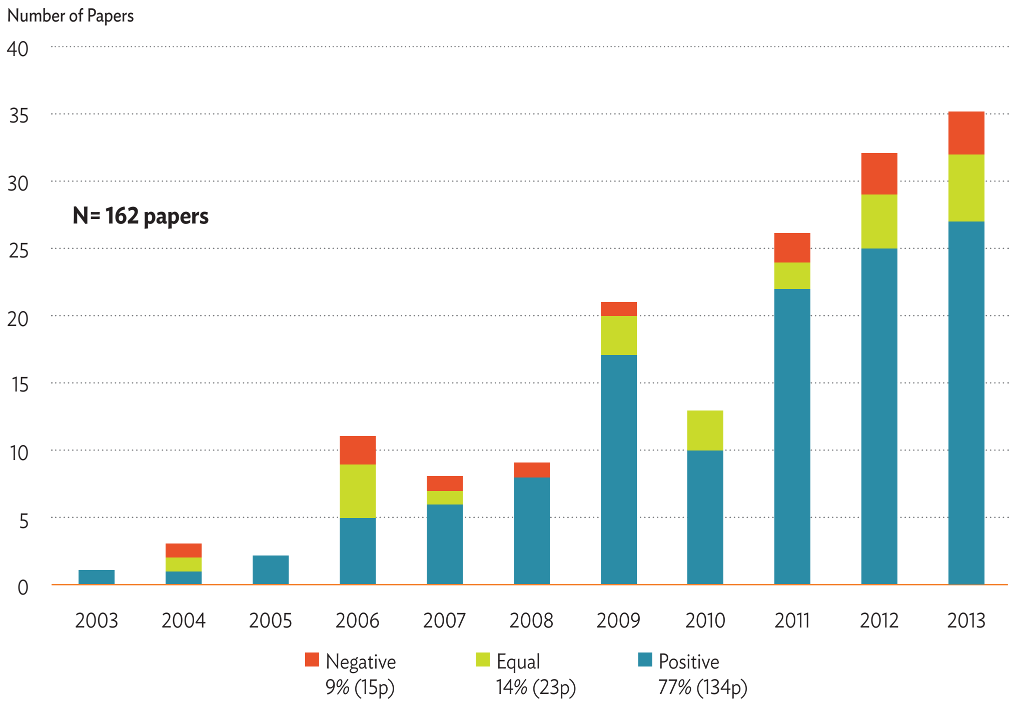
Source: Motomura and Yamaji (2009).

3) Other Effects of SRI

As SRI effect of yielding increase stated previously, however, there were some disputes found in scientific articles elsewhere during 2004–2005.

Figure 5.7 shows the number of articles that discuss the yield in the reviewed articles (Styger, 2015). Some 77% of the articles are positive regarding the yield increase, while only 9% report a decrease in yield. This suggests that SRI can provide farmers with higher yields in many cases. In Cambodia, SRI increased yields 30% more than the conventional method (Ches and Yamaji, 2015). SRI paddy also has more robust and stronger tillers, with thicker and denser roots, making it considerably more resistant to stronger winds and heavier rainfall (Chapagain, Riseman, and Yamaji, 2011). In Japan, where farmers prefer to grow a tasty variety that is vulnerable to strong winds and rainfall, the SRI method is a recommendable option for rice cultivation.

Figure 5.7: Yield Effect for SRI System in Comparison Trials



SRI = System of Rice Intensification.

Source: Styger (2015).

5.5 Concluding Remarks

This chapter has described the threat of natural disasters and the risks caused by climate change on food production in some Asian countries, paying attention to the different effects on inland and coastal areas. Successful adaptation measures carried out by each state to anticipate and minimise the risks were highlighted for lessons learned and further consideration in identifying adaptive measures. Table 5.4 summarises the common threats of climate change to food production, along with recommended structural and non-structural adaptive measures.

Table 5.4: Threats to Agriculture and Adaptation Measures

Areas	Threats and Adaption Measures		
	Drought	**Flooding**	**Seasonal Uncertainty**
Inland	Structural: • Groundwater extraction • Closed system irrigation • Efficient irrigation system Non-structural: • Weather monitoring • Insurance • Drought-tolerant cultivars • Integrated pest management	Structural: • Drainage system • Water harvesting • Groundwater recharge • River embankment • Checkdam • Efficient drainage system Non-structural: • Weather monitoring • Insurance • Delineation of high-risk areas • Amphibious cultivars	Structural: • Irrigation and drainage system • Distributed water reservoir • Pumping station Non-structural: • Weather monitoring • Insurance • Planting calendar • Tougher cultivars to weather fluctuation • Shorter age cultivars
Coastal	Structural: • Groundwater extraction • Closed system irrigation • Water storage system Non-structural: • Weather monitoring • Insurance • Drought-tolerant cultivars • Saline-tolerant cultivars • Integrated pest management	Structural: • Drainage canals • Groundwater recharge • River embankments • Sea embankments Non-structural: • Weather monitoring • Insurances • Amphibious cultivars • Integrated pest management	Structural: • Irrigation and drainage system • Groundwater extraction • Closed system irrigation • Water harvesting Non-structural: • Weather monitoring • Insurance • Amphibious cultivars • Integrated pest management • Planting calendar • Shorter age cultivars

Source: Anbumozhi, et al. (2018).

5.6 Policy Implications

All Asian states are facing the impacts of climate change on food production, which could cause food shortages and disturb the food supply chain within and amongst countries. Therefore, mutual precaution and cooperation need to be prioritised. In this era of connectivity, food problems in one country can generate adverse impacts on relations with others, trade imbalances, and regional security if not appropriately solved. Thus, it is essential to introduce an enhanced methodology for disaster risk and climate prediction at the regional level; and to strengthen early warning systems for international river basins and economic impact assessments of collective cross-border actions.

As the threats of climate change are more severe in developing countries, advanced countries should take the lead to ease the tensions caused by climate change in the region as they are more prepared in terms of human resources, technology, and management systems. Each developing country needs to develop an agricultural policy that is compatible with the real threats of climate change faced, which may differ from one place to another. Thus, it is essential to share and promote regional best practices in mainstreaming adaptation practices in the agricultural sector.

As farmers will bear the direct impacts of disasters in their fields, governments – from central to local authorities – should work closely with them and respond quickly when unexpected trends could be severe to plant growth. It is highly advisable for farmers to be protected with insurance to cover possible losses or lower quality products so that they can recover more easily. Thus, it is essential to provide training and capacity building to farmers and private sector operators for better no-regret adaptation management, focusing on internationally accepted best practices that are locally appropriate.

Finally, each country needs to share and integrate their adaptation roadmaps on appropriate guidelines, amongst others, on how to promote public awareness, improve scientific capacity, set feasible standards/benchmarks for structural measures, develop new programmes to strengthen non-structural measures, improve cross-sectoral coordination, augment financial resources, and strengthen capacity for regional cooperation (Anbumozhi et al., 2018).

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