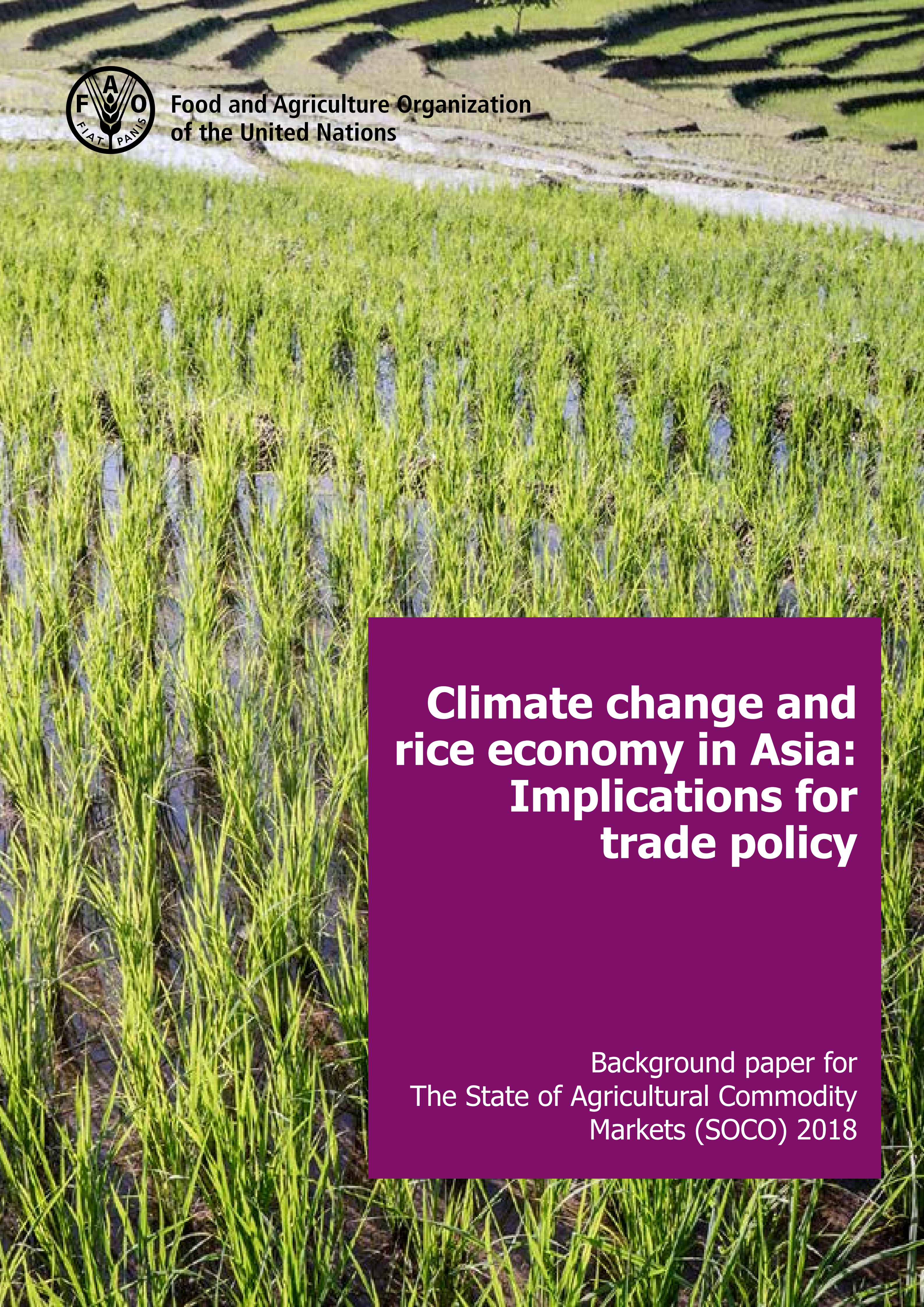

Food and Agriculture Organization
of the United Nations

Climate change and rice economy in Asia: Implications for trade policy

Background paper for
The State of Agricultural Commodity Markets (SOCO) 2018

Climate change and rice economy in Asia: Implications for trade policy

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The State of Agricultural Commodity
Markets (SOCO) 2018

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Acronyms

AR5	Fifth Assessment Report
AWD	Alternate-Wetting and Drying
CSA	Climate Smart Agriculture
CO_2	Carbon dioxide
FCI	Food Corporation of the Republic of India
GHG	Greenhouse gas
GPP	Government purchase price
GVA	Gross value added
HRS	Household Responsibility System
IAM	Integrated assessment model
IRW	Internal renewable water
IWSR	Irrigation water supply reliability
IGP	Indo-Gangetic Plains
IPCC	Intergovernmental Panel on Climate Change
MMA	Minimum market access
PPD	Probability of a production decrease scenarios
SRES	Special report on emissions scenarios
TRQ	Tariff-rate quota
MEP	Minimum export price
MSP	Price support system for farmers
PDS	Public distribution system
PHP	Philippines Piso
R&D	Research and development
SGD	Singapore Dollar
SRI	System of Rice Intensification
THB	Thai Baht
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States Dollar
VFA	Viet Nam Food Association
VND	Vietnamese Dong
WTO	World Trade Organization
WUE	Water use efficiency

Summary

The present study analyses rice economy in Asia in the context of climate change. Major rice producing and trading countries are included in the analysis. The main focus of the study is on the existing policy framework in these major countries, with particular focus on the role of trade policy in adapting to and mitigating the adverse impacts of climate change on the rice economy. Initial results suggest that Asian countries – both importing and exporting- have intensified efforts to attain self-sufficiency through domestic production in recent years, particularly after the world food crisis in 2008. This is because of the perceived non- reliability of international market for sourcing supplies during emergencies. Therefore, there is a greater need for dovetailing trade policies in the region and refrain from disruptive policies such as sudden export bans. There are also other complementary policies of increasing cooperation - building regional reserves for emergencies, developing reliable early warning systems and propagating new technology and best practices.

Background

Rice is the basic staple food for about one-half of the world's population and provides over 20 percent of the global calorie intake. Asia accounts for more than 80 percent of global rice production and 75 percent of global consumption, and 70 percent of exports (FAO, 2017). Although rice is widely grown and consumed, only eight percent of world production is traded annually compared to about 18 percent for wheat and 25 percent for soybeans

The bulk of rice production occurs in the monsoon land of Asia, stretching from the Islamic Republic of Pakistan (hereafter Pakistan) to Japan and covering countries that are densely populated and major consumers of rice. The convergence of production and consumption is quite high relative to wheat. World exports are largely concentrated in Asia, with the exception of the United States of America. The Kingdom of Thailand (hereafter Thailand), the Socialist Republic of Viet Nam (hereafter Viet Nam) and the Republic of India (hereafter India) are the major exporters controlling more than 60 percent of the world market during the last decade. World imports are more widely distributed as compared to exports, although most of the imports are destined to Asian countries.

Climate change has added a new dimension of uncertainty to world rice production. The projected adverse impacts of climate change on crop productivity could have serious consequences for food availability in the future. However, the potential impacts are not very clear at regional level but there is consensus that climate change could aggravate food insecurity in regions currently vulnerable to hunger. Economic access to food could also be affected adversely due to price increases arising out of supply shocks. There is a considerable need for investment in adaptation and mitigation strategies to soften the adverse effects on food security. The present work attempts to shed light on what can be the potential role for rice trade in this adaptation/mitigation framework, and how trade can be used as an effective policy instrument to cushion the climate-induced shocks in global supply of rice. Section two provides an overview of rice production, consumption and trade patterns in the major countries. Section three sketches a review of literature on climate change impacts on rice during the last decade and a half. This is followed in section four by a delineation of current sets of policies, including those related to adaptation and mitigation of climate change across countries. The role of trade and stockpiling in addressing the climate-induced supply shocks is discussed in the subsequent two sections. The final section presents the brief summary, conclusions and policy implications. Since most of rice production occurs in Asia, we have confined our analysis to Asian countries.

1 Production, consumption and trade patterns of rice: an overview

The bulk of rice production occurs in the monsoon land of Asia, stretching from Pakistan to Japan and include a number of densely populated countries that are major consumers of rice. The convergence of production and consumption is quite high relative to other cereals such as wheat. The People's Republic of China(hereafter China) and India are the major countries in the world rice market with a cumulative share of 48 percent to 51 percent of world production as well as consumption during the period 2000 to 2013 (Table 1). The other major producers/consumers are the Republic of Indonesia (hereafter Indonesia), the People's Republic of Bangladesh (hereafter Bangladesh), Viet Nam and Thailand. The Republic of the

Philippines (hereafter the Philippines) is also a major consumer although its share in production is minimal.

World exports are largely concentrated in Asia, with the exception of the United States of America (Table 2). Thailand has been a major exporter for a long time with a share ranging from 16 percent to 33 percent since 2000. Viet Nam, India, the United States of America and Pakistan are the other major exporters in the world market. Thailand, Viet Nam and India have together contributed more than 60 percent to the world market during this period. The shares of India and Viet Nam have been rising in recent years while Thailand's share has seen a decline. India's exports have been particularly impressive in the recent past and the country has emerged as the topmost exporter since 2012.

World imports are more widely distributed as compared to exports, although bulk of the imports still occur from Asian countries. China, the Philippines, Bangladesh and Japan are presently the major importers of rice in the world market (Table 2). However, their cumulative share is less than 20 percent since 2000, showing that the import dependency of Asian countries is quite low. Indonesia has been a major importer for a long time although their import dependency ratio (imports/consumption) has steadily come down mainly because of its emphasis on domestic production. A number of sub-Saharan African countries have emerged as major importers of rice in recent years. Important among these are the Federal Republic of Nigeria (hereafter Nigeria), the Republic of Senegal, the Republic of South Africa, the Republic of Côte d'Ivoire, the Republic of Ghana, The Republic of Cameroon, the Republic of Kenya, the Republic of Guinea, the Republic of Madagascar (hereafter Madagascar) and Burkina Faso. Also, Asian countries such as Malaysia, the Islamic Republic of Iran, the Republic of Iraq, the Kingdom of Saudi Arabia, the United Arab Emirates and some European countries are also importers of rice. With the exception of Nigeria's National Food Security Program, none of the African countries mentioned above appear to have long-term rice production enhancement programs. Most of the measures by these countries are short-term and trade-related in nature, such as, relaxation of export bans, lowering of import duties, and bilateral agreements to ensure imports, which do not address long-term food deficits. Therefore, it is possible that sub-Saharan Africa will remain a major rice importer in the coming decades.

At the global level, the consumption has been lower than production in recent years, as indicated by the consumption-to-production ratio, which has decreased from 0.98 in 2005 to 0.96 in 2013 (Table 3). However, the share of imports to consumption has increased from seven percent to eight percent during the same period, showing that countries are importing mainly to build stocks.

Exporting countries

Among the world's major exporters, Thailand, has maintained a sizeable exportable surplus[1] of about 40-45 percent of domestic production during the last decade or so (Table 3). This is also reflected in the share of exports to production, which ranged between 30-55 percent of production, during the same period. Similar is the case of Viet Nam, although its exportable surplus is lower, in the range of 18-28 percent of domestic production. Correspondingly, Viet Nam's exports have also ranged between 15-28 percent during this period. Pakistan and the United States of America also show comfortable exportable surpluses in the range of 32 percent-61 percent and 41 percent-51percent of their domestic production respectively. However, the United States of America exports a much larger share of its production, as the

[1] Exportable surplus = {1- (consumption /production)}*100

country is not a major consumer of rice. India is different from other major exporting countries in this respect. India's exportable surplus is quite low touching a maximum of 11 percent in the last decade. Most of the surpluses are evident only since 2011 because of a substantial increase in production. However, because of a large base, even a relatively small percentage translates into large quantum of exports, making India the largest exporter in the world market.

Importing countries

China, Bangladesh, Indonesia, the Philippines and Japan are some of the major rice importing countries in Asia. Among these, two traditional importers – Bangladesh and Indonesia – have intensified their efforts to increase domestic production after the world food crisis in 2008. This is clearly evident in the declining consumption-to-production ratios of these two countries (Table 4). Bangladesh turned from a food-deficit country into a food-surplus country since the crisis. Similar is the case with Indonesia, although the country's production fell short of domestic production in some of the years. The Philippines, though not managing to achieve self-sufficiency through production, nonetheless reduced imports substantially since 2011, resulting in a decline in percentage of imports in consumption. Japan has consistently shown consumption higher than production, necessitating imports, ranging from 7-11 percent of domestic consumption. However, some of these imports are due to the minimum market access (MMA) commitments of the country under the World Trade Organization's (WTO) agreements. One country that has substantially increased its imports is China. Imports by China have increased from 0.6 million tonnes in 2011 to 2.2 million tonnes in 2013, increasing its share in world imports by three times – from two percent to six percent - in these three years. However, the domestic consumption-to-production ratio has actually fallen below one during these years. This is likely due to a decline in consumption, and increase in domestic production, or both. The large increase in imports, together with the falling consumption-to-production ratio, leads to the conclusion that China is undertaking imports to strengthen stock building efforts.

Rice import tariffs in major countries

The applied tariffs (average of the latest three years for which data is available) and the bound tariffs for the major countries in world rice market are presented in Table 5.It can be seen that all the three major rice exporting countries imposed high *ad valorem* tariffs on rice imports – Thailand (52 percent), India (70 percent) and Viet Nam (40 percent) – underlining the emphasis laid by these exporting countries on protecting domestic production. What is noteworthy is that the applied tariffs in all the three countries are equal to the respective bound rates showing that maximum possible protection has been accorded to domestic production in these countries. Another major exporter, the United States of America, also has applied a tariff rate equal to the bound rate, although the tariff binding, at 11.2 percent, is much lower than other exporters. Not only the exporting countries but also some of the major importing countries, such as China (60 percent) and Malaysia (40 percent), have high import tariffs which are equal to the bound rates.[2]Other major importers such as Nigeria (30 percent), the Philippines (50 percent) and the Republic of Korea (513 percent), despite the

[2] Since 1999, Japan has used a tariff-rate quota (TRQ) system for rice imports. Within the quota, the tariff is zero. However, since the state trading agency has the exclusive right to import rice within the quota, the tariff level is irrelevant. Imports outside the quota are legally allowed and not subject to state trading, but are effectively prohibited by high tariffs. The tariff for imports outside the quota was calculated by Japan's government as the tariff equivalent to the nontariff barriers that protected Japan's rice in the 1986-88 base period used by the Uruguay Round of negotiations by the WTO.

reliance on imports, have high applied tariffs. Such high level of tariffs on rice imports, even by net rice importing countries, indicate the level of importance given to domestic production in these countries in order to attain self-sufficiency.

Table 1: Share of various countries in global rice production and consumption

Share of World Production (percent)

	Bangladesh	China	India	Indonesia	Japan	Pakistan	Philippines	Thailand	United States of America	Viet Nam	Total
2000	6	31	21	9	2	1	2	4	1	5	84
2001	6	30	23	8	2	1	2	5	2	5	84
2002	7	31	19	9	2	1	2	5	2	6	83
2003	7	27	23	9	2	1	2	5	2	6	83
2004	6	30	21	9	2	1	2	5	2	6	83
2005	6	28	22	9	2	1	2	5	2	6	82
2006	6	28	22	9	2	1	2	5	1	6	82
2007	7	28	22	9	2	1	2	5	1	5	83
2008	7	28	22	9	2	2	2	5	1	6	82
2009	7	28	20	9	2	2	2	5	1	6	82
2010	7	28	21	9	2	1	2	5	2	6	82
2011	7	28	22	9	1	1	2	5	1	6	83
2012	7	28	21	9	1	1	2	5	1	6	83
2013	7	27	21	10	1	1	2	5	1	6	83

Share of World Consumption (percent)

	Bangladesh	China	India	Indonesia	Japan	Pakistan	Philippines	Thailand	United States of America	Viet Nam	Total
2000	6	32	21	9	2	1	2	3	1	4	81
2001	7	32	20	9	2	1	2	3	1	4	81
2002	7	32	20	9	2	1	2	3	1	5	81
2003	7	31	20	9	2	1	3	3	1	5	80
2004	7	30	21	9	2	1	3	3	1	5	79
2005	7	29	21	9	2	1	3	3	1	5	79
2006	7	29	21	9	2	1	3	3	1	4	78
2007	7	29	21	9	2	1	3	3	1	4	78
2008	6	28	21	9	2	1	3	3	1	5	78
2009	6	29	20	9	2	1	3	3	1	4	78
2010	6	28	21	10	2	1	3	3	1	4	78
2011	6	29	20	10	2	1	3	3	1	4	78
2012	6	28	20	10	2	1	3	3	1	4	78
2013	6	28	20	10	2	1	3	3	1	4	77

Table 2: Share of various countries in global rice exports and imports

Share in World Exports (percent)

	India	Pakistan	Thailand	United States of America	Viet Nam	Total
2000	6	8	26	12	15	80
2001	8	9	28	10	14	78
2002	18	6	26	12	12	81
2003	12	6	30	14	14	84
2004	16	6	34	11	14	84
2005	13	9	25	13	18	82
2006	15	12	24	11	15	81
2007	19	9	27	10	14	81
2008	8	9	33	12	16	80
2009	7	9	28	11	20	76
2010	6	12	26	12	20	78
2011	13	9	28	9	19	79
2012	26	8	16	9	20	80
2013	27	9	17	8	17	80

Share in World Imports (percent)

	Bangladesh	China	Indonesia	Japan	Philippines	Total
2000	2	1	6	3	3	17
2001	1	1	3	3	4	14
2002	4	1	7	2	5	21
2003	5	1	6	2	3	20
2004	4	3	2	2	4	17
2005	3	2	1	3	7	17
2006	2	3	2	2	6	17
2007	2	2	5	2	6	19
2008	3	1	1	2	8	18
2009	0	1	1	2	6	14
2010	2	1	2	2	8	18
2011	4	2	8	2	2	20
2012	0	6	5	2	3	19
2013	1	6	1	2	1	14

Source: FAOSTAT, 2017.

Table 3: Production, consumption and trade patterns in the major rice exporting countries

	Consumption to Production Ratio	Percentage of Imports to Consumption	Percentage of Exports to Production
		World	
2000	0.99	5	6
2001	1.00	6	7
2002	1.06	7	7
2003	1.03	7	7
2004	1.01	7	7
2005	0.98	7	7
2006	0.99	7	7
2007	0.98	7	8
2008	0.98	7	7
2009	0.99	6	7
2010	0.98	7	7
2011	0.97	7	8
2012	0.96	8	8
2013	0.96	8	8
		Thailand	
2000	0.61	0	36
2001	0.55	0	42
2002	0.56	0	40
2003	0.55	0	44
2004	0.57	0	54
2005	0.57	0	38
2006	0.59	0	38
2007	0.55	0	43
2008	0.59	0	49
2009	0.58	0	41
2010	0.57	0	39
2011	0.54	0	45
2012	0.55	0	27
2013	0.57	0	29
		Viet Nam	
2000	0.82	0	17
2001	0.80	0	18
2002	0.81	0	15
2003	0.81	0	17
2004	0.80	0	17
2005	0.79	0	23
2006	0.79	0	20
2007	0.79	0	20
2008	0.78	0	19
2009	0.78	0	24
2010	0.75	0	27
2011	0.74	0	26
2012	0.72	0	28
2013	0.73	0	24

Source: FAOSTAT, 2017.

Table 3: Production, consumption and trade patterns in the major rice exporting countries (cont.)

	Consumption to Production Ratio	Percentage of Imports to Consumption	Percentage of Exports to Production
		India	
2000	0.97	0	2
2001	0.88	0	2
2002	1.12	0	7
2003	0.92	0	4
2004	1.02	0	6
2005	0.96	0	4
2006	0.95	0	5
2007	0.93	0	7
2008	0.93	0	3
2009	1.02	0	2
2010	0.98	0	2
2011	0.90	0	5
2012	0.90	0	10
2013	0.89	0	11
		USA	
2000	0.54	14	51
2001	0.57	16	43
2002	0.59	16	55
2003	0.51	21	66
2004	0.56	17	47
2005	0.50	19	61
2006	0.51	28	62
2007	0.53	28	56
2008	0.49	29	60
2009	0.58	24	51
2010	0.55	20	56
2011	0.53	30	62
2012	0.55	27	59
2013	0.54	30	61
		Pakistan	
2000	0.52	0	42
2001	0.68	1	62
2002	0.56	1	37
2003	0.63	0	37
2004	0.59	0	36
2005	0.44	0	52
2006	0.39	0	68
2007	0.48	0	56
2008	0.42	0	40
2009	0.49	0	40
2010	0.60	0	86
2011	0.46	1	55
2012	0.52	0	62
2013	0.43	2	56

Source: FAOSTAT, 2017

Table 4: Production, Consumption and Trade Patterns in Major Rice Importing Countries

	Consumption to Production Ratio	Percentage of Imports to Consumption	Percentage of Exports to Production
		World	
2000	0.99	5	6
2001	1.00	6	7
2002	1.06	7	7
2003	1.03	7	7
2004	1.01	7	7
2005	0.98	7	7
2006	0.99	7	7
2007	0.98	7	8
2008	0.98	7	7
2009	0.99	6	7
2010	0.98	7	7
2011	0.97	7	8
2012	0.96	8	8
2013	0.96	8	8
		China	
2000	1.02	0	2
2001	1.09	0	2
2002	1.10	0	2
2003	1.17	0	2
2004	1.02	1	1
2005	0.99	0	1
2006	1.02	1	1
2007	0.99	0	1
2008	0.99	0	1
2009	1.00	0	1
2010	1.00	0	0
2011	1.00	0	0
2012	0.98	2	0
2013	0.98	2	0
		Bangladesh	
2000	0.97	2	0
2001	1.07	1	0
2002	1.05	4	0
2003	1.06	5	0
2004	1.13	4	0
2005	1.02	3	0
2006	1.02	2	0
2007	1.00	2	0
2008	0.93	3	0
2009	0.91	0	0
2010	0.89	2	0
2011	0.88	4	0
2012	0.90	0	0
2013	0.89	1	0

Source: FAOSTAT, 2017

Table 4: Production, Consumption and Trade Patterns in Major Rice Importing Countries (cont.)

	Consumption to Production Ratio	Percentage of Imports to Consumption	Percentage of Exports to Production
		Indonesia	
2000	1.04	4	0
2001	1.04	2	0
2002	1.05	5	0
2003	1.05	5	0
2004	1.01	1	0
2005	1.00	1	0
2006	1.01	1	0
2007	0.99	4	0
2008	1.03	1	0
2009	0.99	1	0
2010	0.99	2	0
2011	1.02	6	0
2012	1.01	4	0
2013	0.99	1	0
		Japan	
2000	1.04	7	0
2001	1.08	7	6
2002	1.08	8	0
2003	1.22	8	0
2004	1.07	8	1
2005	1.03	9	0
2006	1.08	7	0
2007	1.07	8	0
2008	1.02	8	1
2009	1.05	9	0
2010	1.06	8	1
2011	1.06	9	0
2012	1.14	10	1
2013	1.14	11	1
		Philippines	
2000	1.11	7	0
2001	1.09	9	0
2002	1.13	12	0
2003	1.12	9	0
2004	1.15	10	0
2005	1.21	16	0
2006	1.18	15	0
2007	1.17	15	0
2008	1.18	19	0
2009	1.16	15	0
2010	1.15	20	0
2011	1.12	6	0
2012	1.08	8	0
2013	1.06	3	0

Source: FAOSTAT, 2017.

Table 5: Tariffs on Rice imports in Major Countries

Reporting Country	HS code	Applied Duty (AV)	Bound Duty (AV)
(1)	(4)	(8)	(9)
Bangladesh	100630	0.0	200.0
Cambodia	100630	7.0	40.0
China	100630	65.0	65.0
Egypt	100630	0.0	20.0
India	100630	70.0	70.0
Indonesia	100630	N.R.	160.0
Japan	100630	0.0	N.R.
Korea, Republic of	100630	513.0	N.R.
Kuwait, the State of	100630	0.0	100.0
Malaysia	100630	40.0	40.0
Mynmar	100630	5.0	10.0
Nigeria	100630	30.0	150.0
Pakistan	100630	10.3	100.0
Philippines	100630	50.0	N.R.
Saudi Arabia, Kingdom of	100630	0.0	5.0
Thailand	100630	52.0	52.0
United Arab Emirates	100630	0.0	15.0
United States of America	100630	11.2	11.2
Viet Nam	100630	40.0	40.7

Note: NR denotes 'not reported'.
Source: WTO (2017)

2 The impact of climate change on rice production: A brief literature review

The most common approach to predict patterns of climate change and its impact is by using an integrated assessment model (IAM). Literature on IAMs has exploded in the last several years - particularly in the last two and half decades. These IAMs differ on several dimensions and the objectives of these models range from impact assessment of climate change to policy evaluation to resource optimization. The geographical coverage (global, regional, country-specific, highly aggregated, or fairly disaggregated), treatment of climate uncertainty and responsiveness of agents are highly varied.

The two common outcomes on agriculture of climate change predicted by the literature are increase in carbon dioxide (CO_2) concentration and increase in temperature. These two outcomes are likely to result in opposite effects. *In general, an increase in CO_2 level is found to increase crop yields (carbon fertilization effect) while increases in temperature reduced yields.* These effects hold for rice as well. Since our focus is on rice crop here, we mainly confine to the literature on climate change impacts on rice. Ainsworth (2008), in a meta-analysis synthesizing the research on rice response to rising atmospheric CO_2 concentration and rising tropospheric ozone concentration, shows that on average elevated CO_2 levels (627 ppm) increased rice yields by 23 percent. However, higher resultant temperatures annulled the enhancement in rice yield. Matthews *et al.* (1997) estimate that, on an average, rice production in the Asian region may decline by 3.8 percent due to climate changes expected up to 2100. Declines in yield are predicted, under various scenarios, for Thailand, Bangladesh, southern China and western India, while increases are predicted for Indonesia, Malaysia, and Taiwan Province of China and parts of India and China. Masutomi *et al.* (2009) show that probability of a production decrease (PPD) is high in the 2020s for all Special Report on Emissions Scenarios (SRES), because the negative impacts of climate change are larger than the positive effects of CO_2 fertilization in almost all climate scenarios in the near future. This suggests that it will be necessary to take immediate adaptive actions, regardless of the emission scenario. Most agronomic operations to minimize the impact of increased temperatures involve early sowing or the use of early maturing rice cultivars to avoid high temperatures at grain filling. Korres *et al.* (2017) caution that although these measures are feasible, they are inadequate as periods of increased temperature become more frequent and severe, particularly in regions where temperatures are already above optimum for rice growth. The study recommends use of rice germplasm from exceedingly warm environments for selecting traits which are appropriate for the development of high temperature stress-tolerant rice cultivars. The study concludes that germplasm development and improvement in agronomic practices are the centrepieces of climate change adaptation in rice farming systems.

Chhetri *et al.* (2017) used a participatory Climate Smart Agriculture (CSA) prioritization approach to provide information on climate change adaptation planning at local level[3]. They show that the most preferred technologies by local farmers are crop insurance, weather-based crop agro-advisories, rainwater harvesting, site-specific integrated nutrient management, contingent crop planning and laser land levelling. The other adaptation measures could be to build embankments to protect rice farms from floods and production and distribution of new drought and submergence-tolerant varieties of rice and distributed by government institutions and the private sector (FAO, 2010). The development of advanced modelling techniques, mapping the effect of climate change on rice growing regions and providing crop insurance are other examples of managing risks and reducing vulnerability. Another technique gaining popularity is the Alternate Wetting and Drying (AWD) technique, which is shown to generate multiple benefits related to methane emission reduction (mitigation), reducing water use (adaptation where water is scarce), increasing productivity and contributing to food security (Bouman *et al.,* 2007).

[3] A list of CSA technologies was developed based on a review of past studies conducted in similar study areas and in consultation with researchers in the region. Any practice or technology that supports at least one of the three pillars: productivity, resilience and mitigation in agriculture under climate change and variability - is considered to be a CSA technology. Detailed information about existing CSA technologies suitable for local conditions were provided to all farmers. Then the most suitable CSA technologies which can minimize the climatic risks in each village have been identified in discussion with the farmers. This study used a stated preference method to analyze farmers' choice of CSA technologies as against the revealed preference method (see Chhetri *et al.* 2017 for details).

AWD Technology

The ‘Alternate Wetting and Drying’ (AWD) technology for rice is a water-saving technology with a high greenhouse gas (GHG) mitigation potential.In AWD, irrigation water is applied at certain intervals leading to periods of non-flooded soil conditions in the fields. The non-flooded periods can vary from one day to over ten days depending on the soil and climate conditions. In almost all field experiments, AWD resulted in slightly lower yields. However, AWD is consistently increasing water use efficiency (WUE), that is, the amount of grain produced per unit of water input. The efficiency of AWD also depends on the soil type. AWD is appropriate for lowland rice areas with heavy soils and shallow ground water tables (which occur in parts of China, for instance). In loamy and sandy soils with deeper groundwater(e.g., in Northern India) water inputs can be reduced by up to 50 percent, but yield losses are generally high (over 20 percent) as compared to flooding. AWD is also an integral part of the System of Rice Intensification (SRI), an approach developed in Madagascar and now intensively advocated in many rice-growing countries.

Wassman *et al.* (2009) provide a comprehensive review of climate change impacts on rice in Asia. The review assessed the spatial and temporal vulnerabilities of different rice production systems to climate change impacts in Asia. The review discusses the risks due to increasing heat stress and maps the regions where current temperatures are already approaching critical levels during the susceptible stages of the rice plant. These regions are Pakistan and Northern India (Oct.), Southern India (April, Aug.), Eastern India and Bangladesh (March-June), Myanmar, Thailand, the Lao People’s Democratic Republic and the Kingdom of Cambodia (March-June), Viet Nam (April/Aug.), the Philippines (April/June), Indonesia (Aug.) and China (July/Aug). Possible adaptation options are derived from regions where the rice crop is already exposed to very high temperatures including Iran and Australia. A map superimposing the distribution of rainfed rice and precipitation anomalies in Asia highlights especially vulnerable areas in Eastern India and Bangladesh, and the Republic of the Union of Myanmar (hereafter Myanmar) and Thailand.

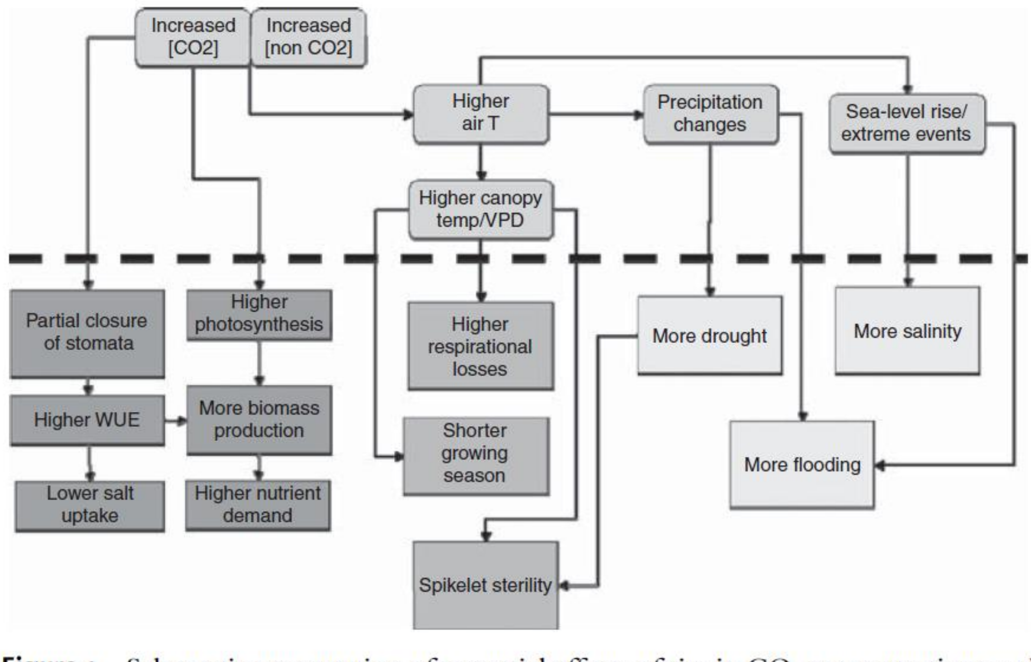

Figure 1 Schematic presentation of potential effects of rise in CO_2 concentrations and temperatures on rice and its growing environment.

The review focuses particularly on two rice growing environments that have outstanding importance for food supply in Asia and are particularly vulnerable to climate impacts. The first region – the mega-deltas in Viet Nam, Myanmar and Bangladesh– is the backbone of the rice economy in their respective countries and is likely to experience climate change impacts due to sea level rise. Significant improvements of the rice production systems such as resilience to flooding and salinity are crucial for increasing, or even maintaining, the yield levels in these productive regions. The second 'hotspot' with especially high climate change risks in Asia is the Indo-Gangetic Plains (IGP), encompassing most of northern and eastern India, eastern parts of Pakistan, and Bangladesh. This region will be affected by the melting of the Himalayan glaciers. The dominant land use type in the IGP is rice-wheat rotation. Agricultural production in South Asia and IGP could fall by 30 percent by 2050 if no action is taken to combat the effects of increasing temperatures and hydrologic disruption (IPCC, 2007). The relevant adaptation options include developing cultivars tolerant to heat, drought, flood and salinity stress; improving water management; adopting new farm techniques such as resource-conserving technologies (RCTs); crop diversification; improving pest management; better weather forecasts and crop insurance and harnessing indigenous technical knowledge of farmers. Geo-spatial vulnerability assessments may become crucial for planning targeted adaptation programs and appropriate policy frameworks.

South East Asia

An IAM was developed by the Research Institute of Innovative Technology for the Earth (RITE) in Japan to study the impact of climate change in Southeast Asia (ADB 2009). The model takes into account emissions of various GHGs and estimates global annual mean temperature change, change in precipitation, and sea level rise, and their impact on water resources, agriculture, forestry, and human health.

The study considered three timelines: the short term (2020), the medium term (2050) and the long term (2100). It also considers two emission scenarios. The first, A1FI, is fossil-intensive and assumes very rapid economic growth; peaking of global population in 2050 and a decline thereafter; rapid introduction of new and more efficient technologies; and primary reliance on fossil fuels. The second, B2, assumes local and *in situ* solutions to economic, social, and environmental sustainability, with an intermediate increase in population, economic and technology development, and balanced use of energy sources. In terms of GHG emissions, climate change, and its impact, A1FI represents the most pessimistic scenario, and B2 represents a medium case.

Climate change is projected using this model for four countries – Indonesia, Philippines, Thailand, and Viet Nam. The two scenarios use 1990 as the baseline. Without mitigation efforts, the region's mean temperature toward the end of this century is projected to increase by 2.5°C under B2 and 4.8°C under A1FI. With stabilization, the projected mean temperature increase would be substantively lower at only 2.3°C at 550 ppm and only 1.8°C at 450 ppm under the two scenarios. Indonesia, Thailand, and Viet Nam are likely to experience increasingly drier weather conditions in the next two to three decades, although this trend is projected to reverse by the mid-century. Precipitation patterns appear largely similar under the two scenarios and stabilization cases before 2050, but become significantly different thereafter, underscoring the difficulty of predicting precipitation over a longer time horizon. Global warming is likely to worsen water stress in some parts of the region, particularly in Thailand and Viet Nam, in the coming decades. Water resources in Indonesia, Thailand, and Viet Nam are projected to be most vulnerable to climate change, threatening lives and livelihoods of millions.

Under the most pessimistic scenario without adaptation or technical improvements, rice yield potential in the four countries is likely to decline about 50 percent by 2100. Declining rice yield could be partially offset by yield improvements and adaptation. But even with productivity improvements and adaptation, the declines in rice yield potential would remain significant without progress in stabilization efforts. Overall, the assessment suggests that climate change will significantly undermine crop production in Southeast Asia, posing a serious threat to future food security.

Adaptation options and practices

Southeast Asian countries have made major efforts to build adaptive capacity. However a lot more is needed. Climate change adaptation needs to be mainstreamed into development planning. This means that adaptation must be considered not only as a technical solution, but also as an integral part of sustainable development and poverty reduction policies. Among the immediate priorities for Southeast Asian countries are stepping up efforts to raise public awareness of climate change and its impact, with a view to building consensus for public action and engaging all stakeholders including households, businesses, government agencies, nongovernment organizations, civil society, and development partners in combating climate change.

Erratic rainfall patterns, El Niño episodes, and drought have exacerbated growing water stress in the region. Southeast Asian countries have so far used supply-side measures, such as water harvesting technologies and renovation of irrigation facilities, and demand-side measures, including promotion of efficient use of water resources and better water management practices to combat the water shortage. Integrated water management is needed to capture multiple benefits, including flood prevention, efficient use of water supply, and clean power generation. To cope with floods and storm surges, flood control facilities have been installed and communities have been trained in some countries to cope with floods. In the face of increasing water stress due to climate change, it is very important for communities in the region to share their experience and lessons with one another.

Agricultural productivity in several regions of Southeast Asia has declined, largely due to heat and water stress as well as climate variability, threatening food security in the region. Temperature and rainfall are the key factors affecting agricultural production in Southeast Asia. The production potential of major crops such as rice and maize has declined in many parts of the region due to the increase in heat stress and water stress. In a study by the International Rice Research Institute, Peng *et al.* (2004) found that rice yield decreased by ten percent for each degree of increase in the minimum temperature during the growing season in the period from 1991 to 2003. In Thailand, it is reported that increasing temperature has led to a reduction in crop yield, particularly in non-irrigated rice. This has been attributed to the effect of drought at critical stages of growth, such as the flowering period.

The most commonly used adaptation techniques in the region are changes in cropping patterns, which includes diversification into less water-intensive but low yield crops such as coarse cereals, pulses and millets (to reduce the risk of crop failure) and the crop calendar (sowing and harvesting schedule), and improved farm management. Farm-level adaptation practices are helpful in coping with climate change, but their effectiveness is limited in the absence of institutional and policy support from the government. Governments have a major role to play in enhancing the individual's adaptive capacity by providing public goods and services, such as reliable weather information forecasts and development of early warning systems. Innovative risk-sharing instruments need to be developed with active participation of the private sector to complement public sector efforts.

Southeast Asia has the highest technical mitigation potential to reduce GHG emissions from agriculture than any other region in the world (ADB 2009). Southeast Asia's vast area of croplands could be an important channel to sequester carbon in soils. As a major world rice producer, it can also contribute to reduction in methane emissions and food security. A variety of options exist for mitigation of GHG emissions in the agriculture sector. These include (i) reducing fertilizer-related emissions; (ii) reducing methane emissions from rice paddies; (iii) reducing emissions from land use change; (iv) sequestering carbon in agro-ecosystems; and (v) producing fossil fuel substitutes (for details see ADB,2009,p.142).

Many governments in the region have developed climate change plans and designated key agencies to implement them. As Non-Annex I parties to the United Nations Framework Convention on Climate Change (UNFCCC), Southeast Asian countries have no obligation to set quantitative targets for GHGs, yet most countries have developed policies, programs, and measures for adaptation and mitigation. Indonesia released its National Climate Change Action Plan in 2007, which calls for greater integration between mitigation, adaptation, and national development goals through better coordination between energy, transportation, forestry and agriculture. It also called for incorporating climate-related funding decisions into all development plans, with the most promising signs of institutional coordination in medium- and short-term development plans. The Philippines has initiated many adaptation measures in agriculture, water resources, and coastal areas that also aim to enhance food security, water security, and coastal security. Thailand has adopted adaptation measures in several sectors, including agriculture, water resource management, and forests. In Viet Nam, there is vast scope for addressing adaptation to climate change in policies on agriculture and water. On mitigation, Viet Nam introduced the Energy Law in 2005, aiming at improved energy efficiency and promotion of renewable sources of energy.

International financial and technology transfers are essential for the success of adaptation and mitigation efforts in Southeast Asia. Many climate change issues can be better addressed through regional cooperation. Given that climate change is an issue that cuts across all parts and levels of the government, there is a need for strong inter-governmental coordination. Addressing climate change requires leadership at the highest level of government. More research is needed to understand climate change challenges better and devise cost effective solutions at the local levels and fill knowledge gaps.

3 Existing rice policy framework in Asian countries

Climate change adaptation and mitigation policies in the context of rice production need to be compatible with the broader set of agricultural policies. To facilitate a better understanding of the existing policies, we undertake a review in this section of the policy matrix in each of the major countries. In particular, we discuss the countries' policies in the wake of the world rice crisis in 2008, which marked a major watershed in international rice markets story.

The world rice markets witnessed a major crisis in 2008 when world rice prices (of Thai 100 percent B, FOB Bangkok) registered a phenomenal increase from USD 385/ton in January 2008 to USD 854/ton by May 2008. Two of the world's major exporters, India and Viet Nam, had banned rice exports – India in late 2007 and Viet Nam in 2008. Amid the resulting tightening supply in the international market, world prices rose to unprecedented levels. This crisis sparked a major debate about the role of Asian exporters' policies. In the following sub-sections, we review the long-term policies of major countries with special focus on policies since the 2008 food crisis.

Bangladesh

Bangladesh has made impressive progress in increasing rice production despite an extreme scarcity of land resources. Land use in Bangladesh reached its frontier in the 1960s. There is a continuous decline in arable land by one percent per year and the population is growing by about two million every year, mainly because of the large base. As per some estimates, the country needs to increase rice production by 0.5 million tonnes/year to meet growing demand. Production nearly tripled from 1971–1972 to 2007–2008 despite a minor increase in area. This progress has been particularly impressive since the late 1980s when the government introduced a policy of gradual deregulation of markets and trade liberalization of agricultural machinery and inputs. More impressive is the fact that over ¾ of the growth in production came from increases in yield.

Despite the favourable trends in domestic production, Bangladesh has not been self-sufficient in cereal grains for a long time.[4] The average level of per capita rice consumption in Bangladesh is one of the highest in Asia – about 477 g/person/day in rural areas and 389 g/person/day in urban areas (Hossain and Deb, 2010). Commercial imports of rice were undertaken to meet the deficit in domestic production. Until the mid-1990s, Bangladesh imported mostly from Thailand, Pakistan, the United States of America and Viet Nam but since 1995 India has emerged as its main trading partner. Imports from India increased because of its proximity, road connectivity and exports of parboiled rice by India, which is a preferred type in Bangladesh (Deb *et al*., 2009). Rice imports increase substantially in years following poor harvests from floods and droughts. Bangladesh imported over 3.0 million tonnes of rice and wheat during 1987–1988, 1998–1999 and 2004–2005, all years that witnessed devastating floods. Rice imports got a major boost from a change in policy in 1993 when the government removed the ban on import of rice and wheat by the private sector. The availability and access to food grains have improved substantially over the past two decades due to this policy change.

Monsoon in Bangladesh has become more erratic in recent years due to climate change, exposing the crop to both droughts and submergence from heavy rains, which in turn resulted in substantial yield losses. Due to the high risks of cultivation, subsistence farmers are discouraged from adopting the input-intensive improved varieties and they use inputs in suboptimal amounts, which further lower the yields. The major impediments to subsistence farmers are availability and affordability of suitable varieties and transaction costs of acquiring inputs and credit. Development and diffusion of monsoon varieties tolerant to submergence, drought and soil salinity will be needed for further increases in rice production in the main rice-growing (aman) season. Increased research and development (R&D) and investments in rural infrastructure (both polices that fall measures under WTO's Green Box) could facilitate yield growth.

[4] This seems to be changing recently due to a policy emphasis on domestic production. Attaining self-sufficiency *per se* without accompanying improvements in productivity could prove to be expensive since this involves large devolution of subsidies.

Policy responses to the 2008 food crisis

Bangladesh undertook a series of policy measures to tackle the huge price rise during the world food crisis in 2008. Existing safety net programs were expanded, government participation in food grain markets was increased and incentives for increasing rice production were vastly improved.

Government intervention in food grain markets has been a regular feature in Bangladesh. The government declares a procurement price for rice, at which grains are procured from the market. Rice procurement has been less than four per cent of total production over the last two decades. Such low volumes enable procurement for safety net programs without influencing market prices in a major way. Government also imports rice from world markets to build stocks and operate the public food grain distribution system. Over time, however, the government has scaled down these operations by eliminating the rationing system, reducing the size of the public works programs and transferring responsibility of commercial grain imports to the private sector. With these measures food stocks reduced from about 1.5 million tonnes in the 1980s to 0.6 million tonnes by the time of the 2008 world food crisis. The government still maintains several safety net and social protection programs, and participates in open-market sales during emergencies. During the 2008 world food crisis, the government's main strategy was to increase the allocation of rice and wheat under the Public Food Grain Distribution System (PFDS). The government's proactive policy to boost agricultural production, which includes provision of inputs such as credit, irrigation and fertilizer, was more effective than the safety net programs (Hossain and Deb, 2010).

Climate-resilient agriculture in Bangladesh

Paddy cultivation is the largest contributor to agricultural GHG emissions in Bangladesh. In an effort to reduce these emissions, farmers are increasingly adopting the AWD method of irrigation, using deep placed urea, moving to non-rice crops and incorporating straw stubbles in to rice paddies instead of burning crop residues (IFPRI 2017).Adoption of AWD decreases irrigation costs and may result in an additional profit for farmers ranging between USD 100/ha and USD 400/ha and a reduction in emissions by about 0.8 to 4t$CO_2{}^e$/ha (Basak, 2016).

In addition to GHG emissions, saline intrusion (up to 8 km by 2030) resulting from sea level rise and tropical storms is especially critical in Bangladesh where many smallholders occupy low-lying, flood prone deltas. Some of the critical interventions to adapt are the traditional practices like the Sorjan system. This system involves raising tall beds for vegetables and crop production alternately with furrows for rice and fish production. Strengthening climate information services and reliable early warning systems is extremely important. Microcredit needs to be supplemented with credit for macro innovations on conservation and adaptation machinery andlow riskinterventions such astankreclamation and ghers[5]–paddy and aquaculture ponds with tall dikes for vegetable production.

The People's Republic of China

The People's Republic of China is the world's largest agricultural producer and consumer of major staple foods. It has become an extremely important player in the global food market since its entry into the WTO in 2001. China needs to play an important role in regional and global cooperation to deal with recurring regional/global food crises.

[5] Gher farming is a traditional agriculture system in Bangladesh. A pond is dug into a rice field to use for fish farming, and the removed soil used to create dykes around the pond for growing vegetables.

China has been a regular exporter of rice and importer of wheat until the mid-1980s. One explanation for this is the effort to minimize the foreign exchange cost of attaining a target consumption level measured in calories since the relative price of rice to wheat is two while the relative calorie content is one (IFPRI 1983). Even at the turn of the century China's imports to consumption ratio was quite low, at 1%, while the actual imports were less than 1 million tonnes. However, imports surged since 2012, crossing 2.5 million tonnes and reaching almost 5 million tonnes in 2016. The imports-to-consumption ratio has jumped to almost 8% in recent years and the country has emerged as one of the major importers of rice, along with Bangladesh, Indonesia, the Philippines and Japan. Of these, Bangladesh and Indonesia have increased domestic production and Philippines, reduced imports substantially after the world food crisis in 2008. The only country which has increased its imports substantially is China. As has already been seen Section 1.2, the large increase in imports, falling consumption-to-production ratio and falling exports, lead to the conclusion that China is importing rice mainly to augment the stocks. Therefore, any adverse impact on Chinese rice production due to climate change or otherwise, is unlikely to impact the world market in a direct way. There can be indirect impacts though. However, the stocks held by China are largely inaccessible to the world market. Because of this, any leftward movement of the supply curve (decrease in supply) or the rightward movement of the demand curve (increase in demand) in rest-of–the-world can have pronounced effects on world market.

Comprehensive land reforms after the 1949 revolution, supplemented by large scale public investment in irrigation and very tightly executed agricultural policies, led to rapid growth in both agricultural production and productivity until 1956 (Sicular, 1988). However reduced incentives for private enterprise under the *Great Leap Forward* and the commune system, further aggravated by droughts and floods in many parts of the country, led to the Great Famine of 1959-61 in which an estimated 30 million people perished (Lin, 1990; Becker, 1996; Lin and Yang, 2000). After a brief relaxation in policies, strict state control was reinstated during the Cultural Revolution (1966-1976) leading to severe deceleration in agricultural production and virtually no growth in total factor productivity (Fan, Zhang and Zhang, 2002 and 2004; Chow 2002).

The reform period: 1978 to present

The Chinese agricultural reforms can be broadly divided into four phases. The first phase spanned from 1978 to 1984 and was mainly aimed at improving production incentives, which included major institutional and pricing reforms. The institutional reforms included the end of collective farming and decentralizing the rural agricultural production through a new land tenure system called the Household Responsibility System (HRS). There were also increases in the procurement prices. The second phase lasted from 1985 to 1993 and was characterized by major grain marketing reforms. The third phase spanned from 1994 to 2001 which was marked by broad-based trade liberalization as China made serious efforts to enter the WTO. China's entry into WTO in 2001 marked the beginning of the fourth stage with a series of domestic institutional, marketing, and trade reforms in the agrarian and rural sectors.

The impact of these reforms, particularly the HRS, was impressive in terms of agricultural performance and poverty reduction. The change in farming institutions from collectives to households perhaps played the largest role in the growth process of Chinese agriculture. The remarkable feature of this phase of reforms is that it showed the biggest fall in poverty of all of China's reform stages. On the flip side, this was also accompanied by a considerable increase in inequality due to decollectivization and the erosion of the egalitarian land redistribution of the commune system.

Policies after world food price crisis

In spite of a large increase in the role of markets in the Chinese agricultural economy, the role of the government still remains very significant. The government places food self-sufficiency as top national priority. This is reflected in the policy emphasis on objectives such as food production (especially rice, wheat and maize[6]), stabilization of prices, a secure urban food supply and higher farm incomes. When the world rice crisis struck in 2007-2008, the Chinese government intervened effectively, increased grain production and stabilized domestic grain prices. These interventions can be grouped broadly into three main categories (Fang, 2010 in Dawe, 2010). First, policies to support grain production and farmers' income, including higher procurement prices for rice and wheat, increased subsidies (direct payments, seeds, farm machinery, fuel and fertilizers). Second, grain stock and marketing interventions, including an increase in state-controlled grain reserves through temporary procurement of rice and maize. And finally, tightened grain export policies. These policies stabilized domestic grain prices and increased grain availability in The People's Republic of China. However, these measures were costly and distorted world markets.

The crucial factor that helped China to navigate the world food crisis was its long-term policy support to grain production. China significantly increased support to grain production and achieved a fifth consecutive year-on-year increase in grain production in 2008. Strong export controls on grains and fertilizers were another key factor during the world food crisis. World grain prices would not have increased as much if China had participated more in world grain trade during the crisis, especially given China's large grain stocks relative to domestic utilization. But this could easily have an opposite effect if the country faced large supply shocks in the absence of adequate stocks. The larger a country is, the greater is the destabilizing effect of its domestic price stabilization policy on international markets, if the country is actively engaged in trade (Sekhar, 2008). An early warning system and market information will be extremely important for China (and other countries) to take timely remedial measures. Safety net programs targeting people vulnerable to food insecurity are urgently needed. Enhanced regional and international cooperation are critical in addressing the problem of world food crises of the type witnessed in 2008 (Brahmbhatt and Christiaensen, 2008).

The effects of climate change in China

Climate change effects are already being felt in China, where extreme weather events appear to be increasing in frequency, duration and intensity (ADB, 2015). These effects could reduce food production substantially (WHO, 2016). Climate change will probably have substantial impacts on water resources – e.g. changes in rainfall patterns and increases in the frequencies of droughts and floods. In the medium to long term the impacts of climate change on food availability are likely to grow.

China has 22 percent of the world's population but only seven percent of the world's arable land. China is importing grain to meet its food needs and these imports are likely to increase as climate change impacts increase in intensity and/or frequency. The Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) indicated that climate change is already having a negative impact on agriculture and food production by adversely affecting major crops, livestock production and fisheries. Mean near-surface air temperatures across China rose by 0.5–0.8°C during the 20th century and there is evidence that this process is

[6] China has since liberalized its maize policy due to the large buildup of government stocks.

accelerating. Over the last 50 years in eastern China the frequency and intensity of extreme heat events have increased. Droughts in northern and north-eastern China have become more severe, and flooding in the middle and lower reaches of the Yangtze River and south-eastern China has intensified.

ADB's projections (2015) are also on similar lines. ADB's projections show that temperatures are expected to increase by up to 4.5°C in the north and west and by up to around 3°C in the southeast by 2100 as compared to 1960–1990 averages. Precipitation is projected to increase up to 20 percent in the northeast, with the southeast receiving minimal or no increase. Consensus among different models used in the study is extremely high for temperature but projections vary widely for precipitation throughout the country. In the medium term, annual mean temperature is likely to increase by 1.5°C–2.4°C from 2031 to 2040, and by 2.3°C–3.0°C from 2051 to 2060. These findings are comparable to those by the IPCC'sAR5. The impact of climate change is likely to vary with the type of crop involved (WHO 2016) and also by the extent of irrigation (Wang *et al*., 2009). Wang *et al*. (2009) show that global warming is likely to be harmful to rainfed farms but beneficial to irrigated farms. The net impacts will be only mildly harmful at first, with the damages growing over time.
Some studies show that climate change will affect not only agricultural production, but also agricultural prices, trade and food self-sufficiency. Wang *et al*. (2010) project the impacts of climate change on China's agricultural sector under the A2 scenario of the IPCC. The A2 scenario assumes a heterogeneous world with continuous population growth and regionally-oriented economic growth. The results of the study indicate that rice yield, without CO_2 fertilization, for rainfed regions in China is projected to decline by 13 percent in 2020, 14 percent in 2050 and 29 percent in 2080s. The corresponding impacts for irrigated regions are 9 percent in 2020, 12 percent in 2050 and 17 percent in 2080s (Xiong *et al*., 2008). Wang *et al*. (2009) project rice production to decline by 5 percent without CO_2 fertilization effect and 0.3 percent with CO_2 fertilization effect. The corresponding impact on rice price is 18 percent and -2 percent respectively. On the trade front, the exports are projected to decline by 116 and 127 thousand tonnes respectively under the two scenarios of without CO_2 and with CO_2 fertilization. The fall in exports under the second scenario is mainly because of a decline in domestic price, which in turn, will result in higher domestic consumption leading to larger decline in exports. The increase in imports is 59 thousand tonnes in the first scenario. There is no impact on imports in the second scenario. Impact on self-sufficiency of rice is negligible in both scenarios.

Trade can and should be used to help China mitigate the impacts of climate change; the overall impact on China's grain self-sufficiency is moderate because the changes in trade account for only a small share of its total demand.

Efforts have been made to increase public investment in climate change research, and special funding has been allocated to adaptation issues. Insurance policies[7] and increased public investment in research are just two examples of climate adaptation measures. Beyond government initiatives, farmers have implemented their own adaptation strategies, such as changing cropping patterns, increasing investment in irrigation infrastructure, using water saving technologies and planting new crop varieties to increase resistance to climatic shocks.

[7] China's agricultural insurance program in the second largest in the world.

India

India is a major player in the world market for rice and any policy changes introduced by the Indian government to ensure price stability and food security within the nation are bound to have significant implications for the international market. Rice is the most important food crop in India with a share of 42 percent in the total food grain production in 2015-16. The yield of rice (not paddy) increased from 1901kg/ha in 2000–2001 to 2400 kg per hectare in 2015-16.This is below the world average yield of about 3000 kg/ha and much lower than other major countries such as China and Viet Nam, which recorded a yield of about 4555 kg/ha and 3838 kg/ha respectively in 2014. India's lower yield is likely due to inadequate irrigation, so vital for rice crop, in many regions of the country that are rainfed.

Food policy and public distribution system in India

There is strict monitoring and regulation of production, trade and price in India at various levels. India's present food policy owes its origins to the large food deficits faced during the mid-1960s. As a result of the crises, self-sufficiency came to occupy center stage of planning. A price support system for farmers (MSP); subsidized input provision; restrictions on imports and exports; investments in R&D and promotion of technology adoption were some of the policies adopted during this period. Also, to ensure food availability to the poor population, provision of subsidized grain was started through the public distribution system (PDS). The institutional frameworks necessary to implement this policy matrix were also created. This system, with marginal changes, continues to this day.

The Food Corporation of the Republic of India (FCI), a parastatal organization, is the institution responsible for procuring grain at MSP, stocking and distributing through the public distribution system (PDS). The grain procured using the MSP is used by FCI, mainly to provide subsidized grain to the poor and maintain emergency food reserves. In addition, the stocked grain is also used for welfare schemes of the government, market price stabilization, and sometimes exports by the government as well as private sector.

India's grain trade policy

Republic of India had a restrictive grain trade policy until 2000. Since 1947, India virtually banned imports of most agricultural products. Cereals and vegetable oils were subject to quantitative restrictions administered through a state trading monopoly until the mid-Nineties. After 2000, there was a shift in the country's overall trade policy as well as trade policy with respect to food grains.

Import dependence of rice was very low right from the beginning. Imports, as a percentage of domestic availability, were never in excess of three per cent even in the early 1960 s, at the peak of India's import dependence for food grains. Since then imports have tapered off to negligible quantities. India has been a long-term exporter of fine (basmati) rice. Concerns over food security made the government hesitant to allow exports of other varieties of rice. Non-basmati rice was finally freed from export restrictions in 1995 and exports rose to the level of almost five million tonnes, or six per cent of domestic production. In subsequent years annual exports of rice have remained in the range of 2-5 million tonnes. At present exports of rice (basmati and non-basmati) account for about 17 percent of India's total agricultural exports. Rice accounts for the bulk of cereal exports with a share of more than 93 per cent in recent years (*Agricultural Statistics at a Glance, 2016*). Exports of non-basmati rice, constitute only 6 percent of the production.

Exports of non-basmati rice from India have exhibited a continuous increase from 2005–2006, to 2010-11(except for the policy-induced reductions during the period 2008-09). Since 2007, India's trade policy began to be guided mainly by the domestic market situation and the world price movements. India restricted trade during this period through a combination of minimum export price (MEP), export quotas and outright export bans. India's exports fell to less than 1% of the production in 2008-09 and did not recover until three years after the food crisis. This was mainly because of the export ban imposed when the first signs of the crisis were visible and the ban was lifted only in 2011-12. Rice exports started rising immediately and have been consistently above 6 percent since 2012-13. India is currently the largest exporter of rice in the world. India exported 6.5 million tonnes of rice in 2015–2016 (*Agricultural Statistics at a Glance, 2016*). Although the export performance of the two varieties of rice, namely Basmati and non-Basmati, differed widely in the initial years of the millennium, they appear to converge to a rising trend lately, with India emerging as the leading exporter of non-basmati rice as well. India competes with Thailand for non-basmati rice and Pakistan, who produces a similar variety of Basmati, in world markets.

Climate change and rice production in India

Climate change has added a new dimension of uncertainty to India's rice production. According to a very comprehensive assessment of climate change impacts in the country by Wassmann *et al.* (2009), different regions of India are likely to be affected to varying degrees by climate change and the corresponding adaptation/mitigation strategies needed are different. Some of these adverse effects include, in Punjab and Haryana, high temperature-induced sterility in rice, abrupt temperature rise in rabi[8] season, declining soil organic matter, rising salinity, increased pests and diseases and shortage of irrigation water. In Uttar Pradesh and Western Bihar there is likely to be the additional problem of rain during maturity of rice. In Eastern Bihar and West Bengal, widespread flooding, frequent droughts in some pockets, rain and storms during maturity of rice, increased pests and diseases and, shortage of irrigation water are the likely effects of climate change. India's current expenditure on fertilizer, power and irrigation subsidies led to decline in public investment in agriculture. Some of these policies, particularly on fertilizer and power, have led to excessive fertilizer use that resulted in loss of soil fertility and excessive withdrawal of groundwater. This natural resource degradation, combined with climate uncertainty, has made farming in India largely uneconomic for small farmers.

The most important adaptation and mitigation strategies suggested for India include developing reliable weather forecasts and crop insurance models, extending irrigation facilities to rainfed regions and developing and promoting rice cultivars suitable for varying climatic conditions. Some of the other strategies needed are adjusting sowing and planting dates, improving water management through laser land levelling, direct seeded rice, and no-till practices.

Indonesia

Indonesia is the world's third largest producer of rice, after China and India. However, Indonesia remained the largest importing country for a long time because of much higher consumption vis-à-vis production. Rice sector in the country is promoted through a variety of measures relating to production, processing, trade and infrastructure provision. Food security

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[8] Rabi crops are crops sown in winter (around mid-November) and harvested in the spring (April/May) in the Indian subcontinent.

in Indonesia has improved significantly since the early 2000s. The latest FAO estimates show that the prevalence of undernourishment, at 8.7 percent of the population in 2012-14, is half of what it was only a decade ago (OECD, 2015).The decline in undernourishment owes, among other things, mainly to an increase in rice production and access. A significant focus of the food security programs in the country is on rice, which are implemented through self-sufficiency targets, price stabilization, and a "rice for the poor" (RASKIN) programme under which rice is provided at subsidized prices to poor or near-poor households. Fertilizer and other input subsidies are also provided to stimulate domestic production.

Approximately 60 percent of household's expenditure is on food among the lower income deciles in the country, of which almost 20 percent is on rice (12 percent overall). Also rice constitutes about four percent of the consumer price index. Thus, changes in rice prices influence the inflation rate and overall wellbeing of the poor. As is often the case, the rural poor are the most vulnerable to rice price instability.

Indonesia follows a government-managed food security system that involves domestic procurement through a government purchase price (GPP), government stocks and distribution (to poor households) as the main policy instruments. From the 1960s to the mid-1990s, BULOG (Badan Urusan Logistik, or the Indonesian Bureau of Logistics) implemented the GPP for producers and provided a subsidized price for consumers through open-ended procurement; monopoly control over international trade and through infrastructure provision (including storage and distribution facilities).

Although this elaborate system involved a high degree of state intervention, such an intervention was necessary in the late 1960s and 1970s. An econometric assessment of the 25-year period from 1970 to 1995 concluded that the Bulog's stabilization efforts paid very high dividends in fostering faster economic growth during Repelita I and II (the first two five-year plans, from 1969 to 1979) and political stability (BAPPENNAS, 2002;Timmer, 2004). The policy of high and stable prices created increased incentives for rice cultivation. Although such a bias was desirable at the time of adoption of new rice technology, it has outlived its utility by the mid-1990s. Diminishing marginal returns began to appear and the price stabilization program became very expensive as huge subsidies were needed to maintain stocks, subsidize exports and imports. Corruption of public agencies further aggravated the situation. Thus, there was a clear need for a more market-oriented price policy.

Indonesia experienced a sharp increase in rice prices in 1998 due to its worst drought in recent history caused by a severe El Nino. Responding to this, several key initiatives were implemented such as subsidized rice distribution to poor families (the RASKIN program), increased market operation and an open import policy. These measures restored stability of rice prices in the domestic market. The secular decline in the world prices and greater stability in world prices during the 1990s allowed Indonesia to follow this free import policy. The continuous decline in world prices led many analysts to argue in favour of greater reliance on imports in lieu of domestic production to meet country's requirements (Timmer, 2004). This situation changed in 2002-03 and more decisively in 2007-08, which prompted a reassessment of the policies.

The first instance of the domestic price shock occurred in 2002–2004 due to an import surge, which was in turn, due to allowing free imports by the private sector. The surge in imports continued to keep domestic rice prices weak until 2004 (Saifulla, 2010). While the import surge affected the GPP, prices were still remunerative enough for the importers. To reduce the negative impact (of imports) on producer prices, the government reformulated the import policy in 2004. Under this new policy rice imports were aligned with the seasonal cycle and only BULOG was allowed to undertake imports. Imports by the private sector were limited to special rice varieties, which accounted for less than one per cent of domestic consumption.

The second supply shock occurred in 2007. Due to delayed paddy planting, there was a consequent reduction in rice distribution by BULOG to poor families in the 2006–2007 lean season (November to February). The resultant increases in price saw several new initiatives to ensure price stabilization during the 2007–2008 lean season. These included: increasing rice reserves in 2008 from 204,000 tonnes to 352,000 tonnes; increasing the duration of rice distribution to poor families by a month; doubling the rice allocation to poor families; allowing free imports at any time by BULOG and efficient distribution to all regions; direct cash transfers to poor families; reduction in import tariffs in February 2008; restricting rice exports by BULOG and allowing exports only if domestic supply was adequate; improvement in rice trade monitoring at the borders to deter smuggling; moderating increases in GPP; delaying a fuel price increase until after the main harvest season.

Indonesia also has a major stockpiling program. The rice reserves in Indonesia were about 300,000 tonnes as of 2011-12, which are used for price stabilisation and natural disaster response. These reserves are in addition to the RASKIN reserves. There are about 56,000 tonnes of rice reserves for natural disasters under the direct control of the central government. Additionally, BULOG maintains contingency stocks of 200 tonnes per province and 100 tonnes per district. These stocks can only be activated during an emergency. There are a number of concerns surrounding Indonesia's rice stockpiling policy. On the one hand there are arguments that the current policies are inefficient and need to be reviewed. For example, the two separate initiatives to maintain stockpiles by BULOG and local level stockpiling, though allow stocks to be managed at the central and local levels, also result in duplication of stockholding efforts and increase costs in maintaining and operating the stocks. There are also arguments that the stockpiling policies do not go far enough and should be strengthened further. Some analysts argue that the reserve size is very low and the ideal stock level should be closer to one million tonnes, given the size of country's population. On the whole, it may be prudent to hold moderate buffer stocks along with free play of market forces to equilibrate supply and demand through trade.

One recent policy initiative is the introduction of a new Food Law in 2012. The law aims to strengthen food security by prioritizing domestic production and promoting the principle of food sovereignty.[9]Self-sufficiency has been defined as at least meeting 90 percent of consumption through domestic production and meeting the remaining deficit through imports by BULOG. Self-sufficiency targets have been set for five main staples — rice, maize, soybeans, sugar and beef. The timeframe for achieving self-sufficiency in rice has been revised to 2017. To attain self-sufficiency, Indonesia provides significant market price support and fertilizer subsidies to producers.

There are limitations to implementation of these policies. There are no clear criteria to determine the quantum, timing or sourcing of rice imports. There are multiple authorities making rice import decisions leading to lack of coordination. Also, domestic private trade is isolated with no direct link to international rice market and imports are only canalized through BULOG. The current rice policy has resulted in more stable but much higher rice prices than the international markets. One important limitation of the policy is that at the time of the lowest

[9] Food sovereignty is broadly defined as the right of people to healthy and culturally relevant food, produced through ecologically sound and sustainable methods.

stock (November-January), the domestic market is vulnerable because of delay in decision making by public authorities.

Climate change impact and policies in Indonesia

Naylor *et al.* (2007), in a comprehensive study, show that El Nino events typically lead to delayed rainfall and decreased rice planting in Indonesia's main rice-growing regions. The study uses a risk assessment framework to examine the potential impact of El Nino events and natural variability on rice in 2050 under conditions of climate change, with a focus on two main rice-producing areas - Java and Bali. The study uses a 30-day delay in monsoon onset as a threshold beyond which significant impact on the country's rice economy is likely to occur. Using the IPCC AR4 climate models, the results show a marked increase in the probability of a 30-day delay in monsoon onset in 2050, as a result of changes in the mean climate, from 9–18 percent today (depending on the region) to 30–40% at the upper tail of the distribution. Predictions of the annual cycle of precipitation suggest an increase in precipitation later in the crop year (April–June) of ten percent but a substantial decrease, of up to 75 percent at the tail, in precipitation later in the dry season (July–September).These results indicate that there is an urgent need for adaptation strategies in Indonesian rice agriculture that include increased investments in water storage, early warning systems, crop diversification and drought-tolerant crops.

Under climate change, Indonesia is predicted to experience temperature increases of approximately 0.8°C by 2030. Moreover, rainfall patterns are predicted to change, with the rainy season ending earlier and the length of the rainy season becoming shorter. Oktaviani *et al.* (2011) assess the climate change impacts on Indonesian agriculture using a computable general equilibrium (CGE) model. The results show largest adverse impact for soybeans, rice, and paddy (unmilled rice). Decreasing output of paddy and rice is likely to affect the country's food security adversely. Domestic prices for paddy and rice increase significantly, pushing up the consumer price index. International food price shocks are likely to aggravate these negative impacts. The study recommends addressing constraints to agricultural productivity growth through increased public agricultural research investments and enhancing awareness of both government agencies and farmers to counteract adverse impacts of climate change.

Japan

Rice consumption per capita in Japan has been decreasing since the 1960s. The possible reasons for this are diversified diet with economic growth and very little use of rice for processed foods, feed or biofuel (Ito and Kuwabara, 2007). The total consumption of rice has declined from 11.5 million tonnes (milled rice) in the early 1960s to 7.5 million tonnes in 2008 – a decrease of more than 30 percent despite an increase in population. Although consumption has increased slightly, to over 8 million tonnes since 2012, the decline over the years has been quite steep. Given this decline in consumption and Japan's policy of keeping domestic prices high which discourages exports, a decline in production became inevitable. In 2007-08, when the world food crisis hit, Japan's food self-sufficiency rate was only 40 percent (in calorie terms), which was the lowest among developed countries.

In 1995 a minimum access rice imports policy was introduced under a WTO agreement, requiring Japan to import a certain amount of rice every year. While rice farmers were required to cut production, rice imports have reached around 0.767 million tonnes (brown-rice basis) per year (about 10 percent of total consumption). Japan's low level of food self-sufficiency is considered a serious policy issue (Ito, 2010).[10] One of the first proposals for increasing self-sufficiency is to bring the abandoned farmland back into to production. The cost of rice production in Japan is very high – estimated to be more than USD3000/ton in 2007(Ito, 2010). Although this figure has declined slowly over the last few years, efforts to increase the self-sufficiency rate in Japan would be costly. Mechanization is not an economically viable option, unlike in the United States of America or Western Europe, due to the small farm sizes and relatively expensive farm equipment.[11] Many Japanese farmers, therefore, derive income from off-farm employment.

The other alternative is to leverage the international markets to mitigate supply shocks, which requires a reliable research and monitoring system of the global food supply and demand conditions. Japan's own research efforts in this area have not been strong, with Japan obtaining much of its information from the USDA and other international organizations. The government of Japan planned to strengthen the global monitoring system after the world food crisis through projects such as 'Survey for food supply and demand in the world'. In order to increase global supply of rice, the government of Japan has started funding projects to double rice production in Africa by 2018. Budgets for 'Support for lowland rice production in Africa' and 'Support for South-to-South aid for production enhancement' have also been increased.

Japan's role in global rice market

Japan can contribute substantially to a more stable global rice market. The Japanese rice market was closed until the WTO Uruguay Round of Negotiations in 1995. Under the WTO's Minimum Market Access (MMA) agreement, Japan was required to import about 0.4 million tonnes (brown-rice basis) in 1995, increasing to 0.767 million tonnes in 2000 and remaining at that level thereafter. As a result of these imports global japonica rice prices soared relative to those of indica rice and the domestic rice prices in Japan fell substantially. Since Japan began MMA imports in 1995, mostly of japonica varieties, the prices of japonica rice have been consistently higher than those of indica rice.[12]

Japan imported 0.68 million tonnes of milled rice every year since 2000. The result of Japan's MMA imports is to push the world price higher at the expense of needier countries reliant on imports as happened during the 2008 food crisis. There is considerable debate during and after the food crisis over the desirability of Japan importing the MMA quotas when the world supplies are extremely tight.[13] The broad consensus among analysts within and outside Japan is that the quota must be honoured under normal conditions. However, under conditions of tight supply and demand Japan may instead defer these commitments to later years.

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[10] The Minister of Agriculture suggested that the food self-sufficiency rate should be increased to around 50 percent.

[11] In Japan, by law all farmland must be cultivated directly by the owners. This is one reason why the farms are so small. According to official statistics, the average size of a farm in Japan was just 1.9 hectares, or 4.7 acres, in 2009, compared with 198 hectares (490 acres) in the United States of America and 3400 hectares in Australia. Only 1.7 percent of farmers in Japan cultivate more than 12.5 acres of land. Machinery can't work in Japan because Japanese farms are broken up and divided by terraces, ditches and embankments. Many parts of Japanese farm have to be worked by hand. Machinery, for example, can't reach the corners of plots so those areas need to be tended manually.

[12] Before 1995, prices of US indica rice (Arkansas) and US japonica rice (California) were similar in the American rice markets. Since Japan began MA imports in 1995, mostly of japonica varieties, the prices of California japonica rice have been consistently more expensive than those of Arkansas indica rice (for details see Ito, 2010).

[13] Japan uses the imported rice under MMA mainly to build up stocks and provide to the feed industry (Dawe, 2010, pp. 339, note 30). This rice is rarely used for domestic human consumption. Hence the question on desirability of imports when world supplies are tight.

Climate change and rice production in Japan

Japan's climate is undergoing major changes. The report on regional climate change and prospects in Japan, based on IPCC AR4, projected that the mean surface temperature in Japan has increased by1.15°C over the past century, and is expected to rise by 2.1 to 4.0°C within the next 100 years (Government of Japan, 2009). These values are slightly higher than those estimated for the world overall, which is about 0.8°C in the next 100 years. The report also illustrated that though notable changes in precipitation have not occurred during the 20th century, the patterns of rainfall have become more erratic. There has been an increase in extreme weather events such as droughts, floods, storms as well as an increase in their intensities. The recent climate trends in Japan indicate a drastic increase in hot days exceeding 30°C during summer. These climate changes will make difficult to plan rice farming. The reproductive phase of rice is very sensitive to high temperature, and hotter conditions lead to increasing sterility. In the summer of 2010, Japan experienced an extremely hot summer, with the quality of rice grain being adversely affected (Hasegawa *et al*., 2013). Japonica rice is usually cooked as intact white rice, and Japanese consumers prefer soft and glutinous texture of rice, making grain quality extremely important to consumers. Adaptation to avoid these risks requires genetically modified (GM) crops[14] that introduce a new heat-tolerant trait in the rice plant. Research indicates that the combination of advanced transplanting and the adoption of later-maturing cultivars may help to exploit the advantage of elevated CO_2 although this greatly depends on local conditions in the prefectures (Nakagawa *et al*., 2003).

Philippines

Rice is the basic staple food and a principal source of livelihood in Philippines. Total demand for rice, based on the Food Balance Sheets of FAO, has risen steadily over time due to the continuous high rate of population growth (about 2 percent/year) and increasing level of per capita intake, especially since 2000. Rice production growth lagged behind demand growth, necessitating increasingly larger imports. Historical consumption patterns in Asia and elsewhere suggest that as income rises, food intake becomes more diversified, usually away from basic staples. However, there is little evidence of this happening in the Philippines.

Two factors account for this contrary trend. One is the continued low level of per capita income. Although real per capita GDP increased by about 25 percent between the early 1990s and mid-2000s, average per capita income (USD 2956, in PPP) is still low compared with that of Thailand (USD 7061) or Malaysia (USD 11678), where noticeable shifts in food consumption patterns, including a reduction in per capita rice consumption, have taken place. A downturn in per capita rice intake is also evident in the Republic of Korea and China, where significant increases in per capita income have been sustained over many years. The other factor is the relatively high inequality of income and wealth in the Philippines.

[14] Abiotic stress tolerance has been facilitated by improvements in phenotyping and molecular genetics. Submergence-tolerant varieties, developed through incorporation of the *SUB1* gene are now being disseminated in flood-prone areas of tropical Asia. The identification of major quantitative trait loci (QTLs) such as *Saltol* should enable the development of salt-tolerant mega-varieties as with the *SUB1* case. Existing salt-tolerant varieties have been very successful in the inland saline areas of eastern India as well as the dry-season coastal regions of India and Bangladesh. Improved drought-tolerant breeding varieties have yields on a par with or above those of existing farmers' HYVs and yield 1–2 t/ha, while the HYV varieties collapse completely under drought stress. This active area of research is expected to result in major gains in rice production in rainfed areas over the next decade. For more details see Mackill *et al*. 2010.

Most people in the Philippines are net buyers of rice. Although this is true of most rice-consuming nations, this is particularly important for Philippines. This is because, unlike other countries, productivity in Philippines has not increased as desired or needed. An estimated 84 percent of the total population and 100 percent of the bottom two deciles of the population are net buyers of rice (World Bank, 2001, 2009; Balisacan, 2000). Productivity growth in the Philippines has discernibly declined from the level achieved during the Green Revolution era. Substantial policy changes were put in place since the mid-1980s to reinvigorate the agricultural sector. In spite of this, land and labour productivity showed only slight growth over time. Estimates show that technological change has been limited since the 1980s and growth in total factor productivity (TFP) is much slower than in other countries in the region. This is due to a lack of investment in appropriate technologies. Investments in agricultural research and related activities have remained at a low level of 0.1 percent of the gross value added (GVA) in agriculture over the last ten years. This is far below the one percent level recommended for developing countries and much lower than the two to three percent observed in many countries. Investments in rural infrastructure and other services have declined from 0.24 percent of GVA in 1995–1999 to a mere 0.07 percent in the next decade. This is particularly true of irrigation, which contributes about 25 percent of rice production increases. Average gaps in rice yield across the country currently range from about five tonnes per hectare in the wet season to about six tonnes per hectare in the dry season. Overcoming these constraints could increase yield by as much as 150 percent. Households are not adequately protected from adverse shocks to food consumption. The households that experienced adverse effects of increased prices and reduced earnings due to the El Niño and the Asian financial crisis in the late 1990s belonged mostly to the bottom deciles of the income distribution (Balisacan, 2001).

Government response to the food crisis in 2008

In response to the world food crisis in 2008, the Philippine government adopted mainly two sets of measures, namely rice production enhancement programs and increasing rice imports. Implementation did not yield the desired results, mainly due to the lack of inter-agency co-ordination of imports.

One of the key programs launched to increase rice production and attain self-sufficiency was the FIELDS program. The acronym stands for fertilizer, infrastructure and irrigation, extension and education, loans, drying and other post-harvest facilities, and seeds. FIELDS is one of the most important government programs for attaining self-sufficiency in rice. The specific components of the FIELDS program include provision of subsidized fertilizer and micronutrients, rehabilitation and restoration of irrigation facilities, provision of roads and other rural infrastructure, extension, education and training, research and development, improved access to agricultural credit, post-harvest facilities, and hybrid and certified seed production and subsidy. The program aims to provide farmers the needed support in an integrated manner to increase production growth. In this process the government has also enlisted the support of the local government units. However, rice imports continue to be important to meet supply deficit and stabilize prices.

Climate change and rice production in the Philippines

Climate change has added a new dimension to the uncertainty in rice production worldwide and in particular rice importing countries. By 2050 climate change and variability is estimated to cost the Philippine economy approximately PHP 26 billion/year (Dikitanan *et al.*, 2017). To this end, the Philippines needs to enhance investment in long-term sources of productivity growth, with special focus on development of rice technologies appropriate for local conditions and stress-tolerant varieties suitable for areas prone to droughts and floods. Investing in irrigation development with focus on restoration of traditional systems, and promotion of privately owned shallow tube wells, overhauling the top-down rice extension programs, increasing incentives for human resource development, improving research facilities, involvement of private sector and civil society organizations are some of the essential policy initiatives needed.

The government has taken some initiatives to address climate change vulnerability. Research shows that a maximum of 60 percent of the rice area of the Philippines is climatically suited to AWD, reaching more than 90 percent in the dry and 34 percent in the wet season. Adopting AWD methods of production could lead to a reduction of up 265,000tonnes of CH_4 emissions per year from lowland rice in the Philippines, or around 15 percent of the country's annual emissions from the agriculture sector (Sander *et al*., 2017).

There is also some encouraging evidence of adoption of climate-resilient practices by small farmers through mangrove restoration, integrated farming systems, use of stress-tolerant varieties of rice and integrated crop management, among others. However, adoption of these practices is still low throughout the country and limited by poor availability and access to improved seed, insufficient financial resources for investment and the limited extension services.

Small emergency reserves may be needed for the country, given the increase in weather-related and climate change uncertainty. The National Food Authority struggled in the 1970s and 1980s, to maintain its buffer stocks even for a month because of inadequate domestic production, and insufficient and unreliable rice imports. The present situation is better but still not very comfortable. Food policy in the country is governed by multiple agencies, which often leads to lack of coordination. The estimated losses due to inefficiency in its buffer stock policy have been estimated around PHP 170 billion (approximately SGD 5 billion) as of 2012-2013 (Anthony *et al.*, 2016).

Thailand

Agricultural policy in Thailand underwent a major turnaround in 1986 when a pro-consumer policy was replaced with a pro-producer policy (Siamwalla and Poapongsakorn, 1995; Poapongsakorn and Isvilanond, 2008). The government provided support to farmers through agricultural subsidies, the paddy pledging program being the most important support program. The export taxes and restrictions were eliminated to remove disincentives to export, although some import-competing crops such as palm oil retained some protection.[15] The government has also attempted an export cooperation policy with major rice-exporting countries. A rice export cooperation strategy was introduced in October 2002, inviting ministers from four major rice-exporting countries (Viet Nam, India, Pakistan and China) to a meeting and established a Council on Rice Trade Cooperation. Except for occasional information exchange deeper cooperation never materialized, mainly due the challenges related to governments' ability to influence rice supply, and the high price elasticity of global rice demand (Poapongsakorn, 2010).

[15] In the past, the Ministry of Commerce believed that rice exporters adopted a price-cutting strategy, resulting in low export prices. To avoid this the Chamber of Commerce Subcommittee on Rice would fix the export price every Wednesday. Exporters who failed to sell at this price were not eligible to receive an export license. Although all exporters quoted the MoC-fxed price for their exports, they provided rebates on the sly to their buyers. Therefore, the measure was totally ineffective (See Poapongsakorn, 2010).

Paddy pledging program

The paddy pledging policy was first introduced in the 1981–1982 cropping season. Its main objective was to provide soft loans to farmers. The program allows farmers to withhold sale of their crop to obtain a soft loan from the banks by using their paddy (unmilled rice) as collateral. The target (pledging) price is usually set as the prevailing market price during the harvest period. Farmers can choose to either redeem or forfeit their collateral, depending on whether the market price is higher or lower than the pledging price. Farmers can keep the pledged paddy in their own storage facilities or in the central warehouses. The program not only benefited farmers who did not have storage facilities but also the rice mills with warehouses. The program was further extended in 2001 to cover dry-season paddy, benefiting both the well-off farmers and the rice millers in the irrigated areas. The program, therefore, has transformed into a *de facto* price support program. This resulted in large sales to the government. Consequently, the government's rice stock jumped markedly, and the government became the country's largest rice trader.[16] These accumulated stocks did help Thailand during the outbreak of world food crisis in 2008. Because of the spike in world rice prices in early 2008 and export restrictions by Thailand's two major competitors (India and Viet Nam), Thailand was able to export over ten million tonnes in 2008, mainly due to the liquidation of stocks. Thailand was also able to export a large amount of parboiled rice because of India's export ban. However, Thailand could have exported several million tonnes more if the Thai government had decided to release some of its existing large stock of 2.1 million tonnes for export by early 2008, and if the pledging price for the dry-season rice crop had not been set at a high level of THB 14000/ton. Nevertheless, Thailand is one major rice-exporting country that was able to export and meet world demand partially during the 2008 crisis.

Climate change and agriculture in Thailand

Climate change is considered a serious threat and challenge to the development of agriculture in Thailand, especially rice production (Phuong, 2016). Thailand is a low-lying country, making the country extremely vulnerable to the changing climate. Analyses suggest that western, upper part of central, and the left part of northern regions of the country will be better off in terms of farmland values (Attawanich, 2013), while the southern and eastern regions, the lower part of central, and right part of northern regions are projected to be worse off. Most of these regions are rice-growing regions.

For the past five decades temperature has increased in Thailand, ranging from 0.10–0.18°C per decade. The annual mean temperature in Thailand rose by approximately 1°C from 1981 to 2007. Temperature increased while rainfall remained below normal, leading to serious droughts over the years. Current rice production systems rely on ample water supply and are therefore vulnerable to drought stress. Drought is the most important limiting factor in rice production and is increasingly becoming a severe problem.

Climate change affects the balance of fresh water ecosystems. Saline seawater intrusion has already contaminated some underground water sources. Other major production constraints are rainfall variability and drought. Climate vagaries and lack of irrigation, frequently combined

[16] The pledging program proved to be quite expensive to the government (Poapongsakorn, 2010). A Special Committee on the Study of the Paddy Pledging Program in 2007 (Department of Internal Trade) estimated that the monetary cost of the 2005–2006 program was of approximately THB 935.4/ton of paddy, and the loss from rice sale was THB 5663.7 million, for a total monetary cost to the taxpayers of THB 10565.44 million. These estimates did not include the cost of milling, paid in-kind and amounting to THB 1310.54 million, and the interest cost of the government's outstanding debt.

with coarse-textured sandy and unevenly distributed saline soils, result in low crop yields and endemic poverty in Northeast Thailand. Thailand, together with Viet Nam and Indonesia, will experience the largest effect of climate change in Asia. These countries are projected to experience a potential fall of about 50 percent in rice yield, assuming that there will be no adaptation and no technical improvement in 2100. The rice yield decline would range from 34 percent in Indonesia to 75 percent in the Philippines (ADB, 2009).

Viet Nam

Rice is the most important food staple in Viet Nam, with domestic and international rice price movements being closely monitored by the government. A variety of input subsidies for fertilizer and pesticides are used to promote domestic production. The Ministry of Agriculture and Rural Development, the Ministry of Industry and Trade, and the Viet Nam Food Association (VFA) play key roles in the rice economy of the country. Domestic rice marketing is mainly controlled by two state-owned enterprises - the Northern Food Corporation (Vinafood 1) and the Southern Food Corporation (Vinafood 2).

Since the beginning of reforms in 1986, food security policies in Viet Nam can be broadly categorized into two phases. In the first phase, emphasis was on ensuring sufficient food supplies at the national level. In the second phase, efforts were made to promote exports after ensuring adequate domestic production. Expansion of land area, increasing yields through greater use of inputs and mechanization, multi-cropping and higher cropping intensity, investment in infrastructure for irrigation and rural transportation are some of the important policies adopted during this phase. Enactment of the 1993 land law was a major policy initiative that made important changes in the administration of land use by assigning clear responsibilities to various authorities. As a result of these policies, rice production increased quite rapidly in the country.

Changes in rice area in Viet Nam from 1976 to 2007 can be divided into three phases. In the first phase from 1976–1989, both area and production of paddy remained at a low but stable level. The second phase, also known as *DoiMoi* (Renovation), spanned from 1990 to 1999. During this phase area under paddy production grew dramatically to a record high from 6 million hectares in 1990 to 7.66 million hectares in 1999. In the third phase from 2000 to 2007 paddy area generally declined but productivity increased, and production hovered around 36 million tonnes from 2004 to 2007.Although farmers' net profit from rice has improved to VND8–10 million/ha/year on an average, paddy is still relatively less profitable compared to many other crops because of low yields of the third rice crop of the year (*Mua*).Because of this farmers in the Mekong river delta have adopted crop rotations on paddy soil. Several crops or fish are grown in rotation with rice. These rotations, which help to break the monoculture of rice planting, reduce pests and diseases in the field and have achieved high economic returns of VND15–70 million/ha/year.

There is an established set of policies currently in place to promote rice economy in the country. Some of the important policies include to dedicate an area of nearly four million hectares for rice, to allow free domestic trade and establish distribution systems for rice nationwide, to monitor the domestic supply and demand and world market conditions in order to assess the potential for rice exports and set annual export targets, to restrict or if necessary ban rice exports, to ensure food security, granting rice import–export rights to domestic private traders during domestic supply shocks. A number of governmental agencies direct and manage rice trading in Viet Nam. VINAFOOD 1 in Hanoi manages the supply and availability of rice for the

Northern regions of Viet Nam and VINAFOOD 2 in Ho Chi Minh City manages rice production in the Mekong Delta (Southern regions). Through these organizations, Viet Nam has been able to export six to seven million tonnes of rice annually. To minimize sudden drop in domestic prices and decline in farmers' incomes, the government often holds rice stocks through the private firms. Rice export volumes are set and other related policies are determined every quarter and interventions sought to be made in response to developments in international markets, but these play a limited role in international trade of rice in Viet Nam.

The VFA is the leading agency for rice exports but the emphasis is mainly on large contracts of the government-to-government type. Export volumes and prices are planned from the beginning of the year. This makes it difficult to react to sudden changes in market conditions. Exporters' attention is limited to meeting their annual export quotas to fulfil the export contracts signed by the government, and not to in-depth market analyses and forecasts.

Climate change in Viet Nam: The impact of the 2014 drought

There has been increased competition in Viet Namfor land and water between rice and industrial crops on the one hand, and agriculture and industrial/urban development on the other. Between 2001and 2007, more than 500000ha of farmland were converted into industrial parks. In 2008 alone, more than 125000ha of rice fields were lost. There is a strong association between climate conditions in Viet Nam and the global effects of El Niño and La Niña that occur normally every two to seven years. The Central Highlands is one of the regions most sensitive to El Niño effect, which often leads to serious drought during the dry season. Since 2014, the drought associated with the El Niño phenomenon has been strongly affecting Viet Nam.

In this region, rice is one of the most sensitive crops to drought. The drought impact was found affect local conditions, such as availability of surface and groundwater, land use systems, capital availability and social specificities. Effects of the drought are more evident in sloping lands and remote areas than in lowland and peri-urban areas.

Specific actions to adapt to climate change in Viet Nam

The typical monoculture farming of rice in the Central Highlands could be replaced with diversified cropping systems, which involves both crop cultivation and livestock. This will help diversify income sources of households and increase their resilience to effects of climate change. Available drought-tolerant crop varieties may be deployed during the dry season (winter-spring and spring-summer cropping) and incorporating drought-tolerant traits in all rice varieties planted during the drought-prone periods is extremely important. Other important initiatives include specific interventions such as localized storage, food distribution and employment programs, promoting private sector involvement, evolving appropriate insurance mechanisms, developing disaggregate water availability maps, formulating guidelines for rainwater harvesting and building check dams in sloping areas. In addition to these short-medium term measures, few long-term measures are also needed that include developing early warning systems; developing geographical information system (GIS) for analysing climate risks at a more disaggregated level; and conducting cost-benefit analyses of existing CSA options.

The current rice policy framework across the Asian countries is summarized in Table6. Annex A provides the scientific projections of climate change impacts on the rice sector. A summary of the impacts of climate change on rice in major countries and the needed interventions are presented in Table7. It can be seen that the climate change impacts are broadly of two types – gradual impacts such as declines in yield due to higher temperature and water stress and sudden extreme events such as storm surges and floods. The adaptation and mitigation strategies needed for the former type of impacts are more long-term in nature such as varietal development and transfer of technology whereas the latter type requires more immediate and short-term measures including imports and stocks. Since trade and stock policies are linked to the current production surpluses and consumption patterns, we turn to reviewing the current production, consumption and trade patterns across major countries in the next section.

Table 6: Rice policy matrix in the major Asian countries

Country	Support price or other measures	Input subsidies	Public stocking	Subsidized food distribution	Canalization of trade or State trading entities	Free exports	Free imports	Latest applied tariff[17]
Bangladesh	√	√	×	√	×	×	√	0
China	√	√	√	√	√	×	×	65
India	√	√	√	√	√	√	√	70
Indonesia	√	√	√	√	√	×	×	N.R.
Japan	√	×	√	×	×	√	√	0
Philippines	×	√	√	√	×	×	√	50
Thailand	√	√	√	√	√	√	√	52
Viet Nam	√	√	√	√	√	×	√	40

[17] Varies by country from 2015 to 2017. Source: Integrated Database notifications and Consolidated Tariff Schedules database (WTO, 2017), available athttp://tariffdata.wto.org/ accessed on 13 October 2017.

Table 7: Summary of climate risks and adaptation and mitigation measures required in Asian countries

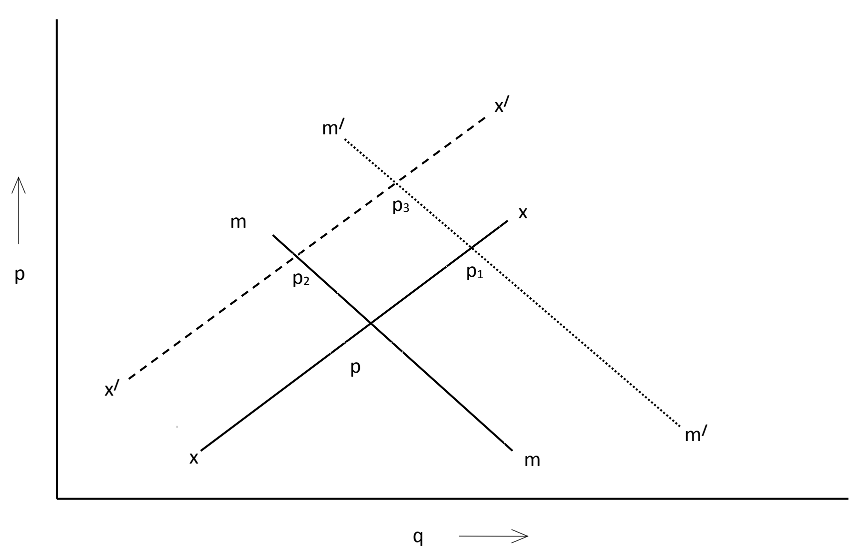
Country	Climate risk for rice	Type of adaptation/mitigation measures needed
Bangladesh	Tropical storms and saline intrusion (up to 8 km by 2030) resulting from sea level rise Imports increased substantially in years following poor harvests from floods and droughts (1987–1988, 1998–1999 and 2004–2005)	Strengthening climate information services and early warning systems, adopting traditional practices like the Sorjan system that involves raising tall beds for vegetables alternately with furrows for rice and fish production.
China	Changes in rainfall patterns and increases in the frequencies of droughts and floods; sea level rise, storm surges, glacial and/or permanent frost melt; and heat waves Crop yield without CO_2 fertilization for rainfed and irrigated regions to decline by 13 percent and 9 percent respectively in 2020	Insurance policies and increased public investment in research; changing cropping patterns; increasing investment in irrigation infrastructure; using water saving technologies
India	Punjab and Haryana: High temperature-induced sterility; abrupt temperature rise in rabi season; declining soil organic matter; rising salinity; increased pests and diseases and, shortage of irrigation water Excess rain during maturity of rice in Uttar Pradesh and Western Bihar Eastern Bihar and West Bengal: widespread flooding; frequent droughts in some pockets; rain and storms during maturity of rice; increased pests and diseases and shortage of irrigation water	Developing reliable weather forecasts and crop insurance models; irrigation facilities; developing heat-tolerant, flood-resistant, salt and alkali-tolerant rice cultivars; water-saving technologies such as laser land levelling, direct seeded rice, no-till rice cultivation; improved pest management techniques; crop diversification and harnessing the indigenous technical knowledge of farmers..
Indonesia	Increase in the probability of a 30-day delay in monsoon onset in 2050; a substantial decrease in precipitation up to 75 percent in the dry season (July–September); adverse effect on food security; rise in domestic prices for paddy and rice; food inflation	Increased investments in water storage, early warning systems, crop diversification and drought-tolerant crops; increased public agricultural research investments and enhancing awareness of both government agencies and farmers
Japan	Increase in extreme weather events such as droughts, floods, storms as well as increase in their intensities; drastic increase in hot days exceeding 30°C during summer; increasing sterility and adverse effect on quality of the grain	Genetically modified (GM) crops that introduce a new heat-tolerant trait; advanced transplanting and the adoption of later-maturing cultivars may help to exploit advantage of elevated CO_2
Philippines	Climate change estimated to cost the Philippine economy approximately PHP 26 billion/ year by 2050,	Development of rice technologies appropriate for local conditions and stress and drought tolerant varieties; irrigation development with focus on restoration of traditional systems rather than constructing new large-scale irrigation systems, and promotion of privately owned shallow tube wells; redesigning and overhauling of the top-down rice extension programs to a more decentralized system; alternate wetting and drying' (AWD) technology
Thailand	Temperature increase, rainfall below normal and serious droughts over the years; Saline intrusion from the sea.	Development of drought and salinity tolerant varieties of rice; early warning systems
Viet Nam	Strong association between climate conditions in Viet Nam and El Niño and La Niña occurring every two to seven years; 63 provinces continue to be affected by El Niño-induced drought since 2014	Monoculture farming of rice in Central Highlands could be replaced with diversified cropping systems; drought-tolerant varieties; early warning systems; geographical information system (GIS) for analysing climate risks at a more disaggregated level

4 Role of trade in adaptation and mitigation

Trade policies of major countries have a crucial bearing on the world market as was witnessed during the food crisis in 2008. Domestic price stabilization policies can have a major destabilizing effect on international market. The world food crisis in 2008 emanated due to different reasons and manifested in different ways in wheat and rice markets. Wheat prices started rising from 2006 mainly because of adverse weather shocks in Australia. Fuel and corn prices also increased in world markets(the latter due to sizeable diversion of corn for biofuel production). Rice prices started firming up gradually from 2003 because of the long-run supply-demand imbalance. However, this process accelerated greatly after the wheat prices started rising. This increase in prices - wheat from 2006 and rice in 2008 - are the first round effects.

The subsequent policy actions by exporting countries gave rise to the second round effects in the two markets. As concerns grew in 2007 that world food supplies were limited and prices of wheat, corn and vegetable oils were rising, several Asian countries started rethinking on their domestic policies. India imposed export controls in September 2007 followed by Viet Nam shortly thereafter (Table 8). Thailand also hinted at export restrictions. Importing countries searched for suppliers. The Philippines, in particular, tried to build up their domestic stocks to protect against shortages. Aggressive buying by the Philippines was followed by Malaysia, who announced a plan to triple the size of their national buffer stock despite extremely high prices in the international market. Indonesia also set a target to triple its level of buffer stocks from one million tonnes to three million tonnes. Thus, rice exporting countries withheld their exports reducing the supply in world market while importing countries scrambled to build their stocks at the same time (Table 8 and Table 9). These simultaneous shifts – leftward shift of the export supply curve and the rightward shift of the import demand curve – led to a huge increase in rice prices.

Figure 2: Shifts in export supply and import demand schedules



Suppose xx and mm are the export supply and import demand schedules and the equilibrium price is p. In case of a demand or a supply shock alone, the equilibrium price would rise to p_1 or p_2 respectively. This is the case of wheat - exporting countries did not withhold export supplies, which helped moderate the price rise. The emerging supply-demand gap, reflected in inventory levels, was equilibrated through a gradual increase in exports by the exporting countries. Absence of panic buying and hoarding by importing countries helped in controlling the price spike to a much lower level in case of wheat. As a result, the second round effects are not so prominent in case of wheat.

In rice, the scenario was different, which is in keeping with traditional trade policy of rice exporting countries. The major exporting countries slapped export controls and importing countries resorted to panic buying. This led to the shift in supply and demand schedules as denoted by x'x' and m'm'. The resulting price p_3 is higher than either p_1 or p_2 and very much higher than p. Empirical evidence suggests that over the last six decades, most of the major exporters in international rice market tried to insulate their domestic markets from international volatility (IFPRI, 1983; Sekhar 2011). The key role in domestic price stabilization in these countries was played by storage. The policies pursued and the conduct of major players suggests that there was a tendency to overstock rather than export (IFPRI, 1983). This was so even when the stock levels were already high. This was mainly because of the precautionary motives of major countries, particularly after the 1970's food crisis. This behaviour is consistent across rice producing countries. This was due to a persistent scepticism of countries about international market as a reliable source of supply in the event of production shocks in the future, if stocks are exhausted in the current period. This precautionary behaviour resurfaced and became more prominent after the 2008 crisis.

Table 8: Annual changes in rice exports and real price in the last decade ('000 mt)

Year	China	India	Pakistan	Thailand	Viet Nam	USA	Major Exporting Countries	World	Real World Price – Wheat ($/ton)	Real World Price-Rice ($/ton)
2004	-224	1469	933	-2863	879	186	380	833	1	31
2005	560	119	863	102	-469	164	1339	1474	-11	47
2006	124	1052	-825	2181	-183	-737	1612	1708	40	13
2007	32	-1086	143	454	127	413	83	35	54	3
2008	-625	-2564	-72	-1441	1301	-304	-3705	-2520	50	290
2009	-97	-8	1090	477	784	484	2730	-743	-85	-57
2010	-150	692	-615	1600	266	-1	1792	4714	-9	-86
2011	-59	7602	71	-3702	717	-316	4313	2664	67	10
2012	-100	524	44	-245	-917	201	-493	611	1	25
2013	9	-900	-100	1800	700	-179	1330	1910	3	-47

Table 9: Annual changes in rice stocks of various countries and real price ('000 mt)

Year	China	India	Pakistan	Thailand	Viet Nam	USA	Major Exporting Countries	World	Real World Price – Wheat ($/ton)	Real World Price-Rice ($/ton)
2004	-19396	-200	385	-1596	-143	-68	-21018	-21389	1	31
2005	-4984	-2300	-326	606	267	450	-6287	-7545	-11	47
2006	-2148	2020	-13	1282	25	159	1325	2685	40	13
2007	-868	910	404	-1084	75	-104	-667	-1260	54	3
2008	1847	1570	0	197	626	-331	3909	5428	50	290
2009	784	6000	500	2080	-57	42	9349	11517	-85	-57
2010	1988	1500	-100	1313	-491	207	4417	2443	-9	-86
2011	2040	3000	-800	-485	471	330	4556	3793	67	10
2012	2449	1600	250	3715	-115	-211	7688	5771	1	25
2013	1759	0	-150	3500	500	-147	5462	2438	3	-47

Source: PS & D database, Economic Research Service, United States Department of Agriculture (ERS-USDA)

5 Role of stocks in adaptation and mitigation

Public stockholding of rice is not a recent phenomenon in the Asia Pacific region. Almost all the countries in the region have a long history of public stockholding and therefore, it appears that such stocking of rice is likely to continue, if not expand, in the foreseeable future. Also, there is increasing evidence of a mistrust of international markets in most countries after the of the 2007-2008 global food price crisis and governments have started laying renewed emphasis on domestic production and stockholding.

A number of countries are reviewing the institutional arrangements for procurement and stocking to reduce inefficiencies. There are also attempts to devise different organisational structures to improve efficiency and cost-effectiveness. All these efforts indicate increase in countries' policy emphasis on increasing domestic stockholding. Stockholding programs by countries like the Philippines and Indonesia are also related to the increasing frequency of natural disasters and emergencies due to climate change as these countries are prone to major natural catastrophes. Also maintaining food reserves and ensuring economic access to food are being seen as the major obligations of the welfare state. Republic of India's National Food Security Act, Indonesia's RASKIN programme, and Philippines' NFA-run subsidized food programmes are all examples of this commitment.

Public stockholding of rice is therefore likely to remain an important part of food policy of many countries in Asia Pacific. However, given the implications of domestic stockholding policies on the international market, the growing and large national/public reserves need to be factored into analyses of Asia's food security and trade. Regional reserves may need to be evolved to preclude need for large, and often unused, national food stocks. One model that can be improved and adopted is APTERR, which is discussed in more detail below.

APTERR and regional rice reserve mechanisms

The *ASEAN Food Security Information System* (AFSIS) and the *ASEAN plus Three Emergency Rice Reserve* (APTERR) are two major initiatives at the regional level to promote food security. AFSIS was started in 2003 with the aim of developing an information repository for five commodities in the ASEAN region - rice, maize, soybeans, sugar, and cassava. AFSIS monitors and analyses production, import, export, stocks, prices, food security ratio and self-sufficiency ratios for these commodities.

The ASEAN Emergency Rice Reserve (AERR) was established in 1979 with voluntary contributions (in the form of pledges) of 87,000 tonnes by the member states. A rice reserve for East Asia was conceived in 2001, which led to the start of the East Asian Emergency Rice Reserve (EAERR). After the 2007-2008 world food crisis, the AERR and EAERR were merged to form the ASEAN Plus Three Emergency Rice Reserve (APTERR) in 2009. A formal agreement was signed by the ASEAN +3 states (China, Japan, and South Korea) in October 2011.

The main objective of APTERR and AFSIS is to monitor food security at the regional level in order to minimize the need for national public stockpiling. However these initiatives have not been fully effective because of difficulties at various levels – absence of requisite physical stocks leading to delays in distribution to regions affected by natural calamities; rigid rules and procedures for release of stocks from APTERR; and difficulty in collecting data in a timely manner.

Regional stockholding needs a renewed attention since, if all the importing and exporting countries adopt stockpiling policies, price rise in international market will be much sharper even for small supply shocks. Widespread adoption of stockpiling practices could have an opposite effect to their intended outcomes, and aggravate volatility in food supply and price. Therefore, the following initiatives are needed to stabilize global rice supply - close coordination of stockpiling policies by the countries in the region; establishment of regional reserves with minimum physical stocks; establishment of a reliable regional public stockpiling database and timely updating of data; establishing clear norms for procurement, storage, release mechanisms in the context of the goals and objectives of the stockpiling program; greater private sector involvement in stockpiling for greater efficiency. Part of the inefficiencies in managing public stocks arises due to unscientific management of stocks such as lack of adequate and protected storage space (GoI, 2015). The other part is due to the policy mismanagement of holding excessive stocks and non-release in a timely manner. Involvement of the private sector can help address the first issue of stock management. The quantum and release of stocks are public policy issues though, which may not be amenable to private sector participation.

Agricultural market information system (AMIS)

The Agricultural Market Information System (AMIS) was created in 2011 after two consecutive price hikes occurred in 2007/08 and 2010. AMIS was created to address excessive food price volatility and to strengthen global food security in periods of heightened insecurity in international food markets. The main aim was to enhance international policy coordination in times of crisis. It was established under the auspices of the Group of Twenty (G20) in 2011. AMIS includes the main producing and consuming countries of major food crops - wheat, maize, rice and soybeans.

Its main objectives of AMIS are i) improving agricultural market information, analysis and short-term supply and demand forecasts at both national and international levels ii) to collect and analyse policy information affecting global commodity markets, and promote international policy dialogue and coordination iii) report on critical conditions of international food markets, including structural weaknesses, and strengthen global early warning capacity on these movements iv) build data collection capacity in participating countries by promoting best practices and improved methodologies, providing training to national stakeholders and facilitating the exchange of lessons learned among participating countries. The AMIS mechanism is mainly aimed at addressing the data and information exchange. There is little scope of ensuring trade policy coordination under the present terms of the initiative.

6 Conclusions

Climate change impacts manifest in gradual yield declines (long-term) and sudden floods and storms (short-term). A two-pronged strategy is needed to cope with this new reality.

i. Gradual yield declines
- Investment in R&D
- Development of rice varieties tolerant to heat-stress, drought, flood and salinity
- Knowledge sharing among countries
- Irrigation development;
- Adoption of alternate wetting and drying' (AWD) technology
- Improved GIS systems for analysing climate risks at a more disaggregated level

ii. Extreme events

Stocks and trade can play an important role in such exigencies. However, trade policy distortions in rice markets need to be addressed too.

The food crises of the 1973-74 and 2008 are reminders that supply in the world rice markets is not elastic at all times. Important rice-consuming countries in Asia adopted excessively precautionary policies of stockholding and restrictive trade after the 1970s crisis. Such behaviour is not altogether misplaced for two reasons. First is the large rice consuming populations in these countries, particularly China and India. The second reason is the high levels of poverty and the resultant low levels of absolute consumption in many of these countries. As a result, these countries withdrew from the international market when the first signs of trouble were visible. In the past this often led to situations of high stock levels in some of the exporting countries and high prices in the world markets at the same time (IFPRI 1983; Sekhar 2008; 2011). Such inward-oriented policies have again come to the fore after the food crisis of 2008. However, it needs to be emphasized that the outward-orientation of major wheat exporters played an important role in dampening price surges in world wheat market. Also we have seen (in section 4) the adverse impacts on rice market of simultaneous trade restrictions by exporting countries.

The international community would gain from exploring the possibility of a small regional reserve system, combined with trade liberalization. The reserves need not be physical in form but can be a combination of physical and virtual reserves (IFPRI, 2008).[18] Such an arrangement could address the food security concerns of rice-consuming countries and encourage these countries to integrate with world markets. The United States of America, as the only major exporter where rice does not constitute the national main food staple, could play a major role in this process. Reserves would need to be supplemented with freer trade of rice. Export controls, particularly as imposed by some exporting countries in 2008, should be few and far between. An alternate approach is where large countries such as China and India build their own stocks, with other countries developing a smaller reserve system. This approach merits some attention, given the destabilizing potential on world markets of these two countries' consumption (Sekhar, 2008).

[18] Previous challenges to such attempts should be taken into consideration (Sanderson, 1977; Gilmore and Huddleston, 1983).

The following broad strategy may be useful to address sudden extreme events:

- Reliable early warning systems and information sharing

- Judicious mix of the stocks-trade-import financing instruments on the following lines
    - Regional physical and virtual reserves with contributions from major countries, particularly the United States of America(along the lines of APTERR and G20);
    - Encourage countries to reduce export restrictions and import barriers;
    - Create a facility to finance commercial grain imports;
    - Release grains from reserves after the country has exhausted the options of drawing down its own stocks and making use of the financing facility for commercial imports; and
    - Emergency release during humanitarian crisis.

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Annex A: Projections of impact of climate change on rice production

Mathews et al. (1997) and Nelson et al. (2009) are two sets of reliable estimates of impact of climate change on rice production in important countries. Mathews et al. (1997) used two crop simulation models of rice growth, ORYZAl (Kropffet al., 1994) and SIMRIW (Horie, 1987). These models, in combination with three General Circulation Models (GCM s), namely, Geophysical Fluid Dynamics Laboratory (GFDL), Goddard Institute for Space Studies (GISS) and United Kingdom Meteorological Office (UKMO), were used to simulate the effect of climate change on rice production in various countries. For details see Mathews et al. (1997). Following tables summarize the average estimated production of rice (and changes) by the year 2100, under various climate change scenarios.

Estimated Changes in Total Rice Production Predicted by the ORYZA1 Model

Country	AEZ	Current Production in '000 tons	GFDL		GISS		UKMO	
			Change (%)	000 tons	Change (%)	000 tons	Change (%)	000 tons
Bangladesh	3	27691	14.2	31621	-5.0	26298	-2.8	26919
	5	8854	-7.4	8201	0.3	8881	-25.2	6619
	6	79872	0.8	80484	-21.7	62514	-19.5	64334
	7	91928	5.8	97196	5.8	97135	3.1	94695
	8	2361	-6.4	2209	-14.2	2026	-27.6	1710
India	1	32807	4.6	34305	-10.8	29272	-5.5	31017
	2	49949	1.8	50849	-2.9	48493	-7.9	46002
	5	227	-7.4	210	0.3	228	-25.2	170
	6	26628	5.4	28069	3.2	27480	-1.3	26287
	8	1011	-6.4	946	-14.2	867	-27.6	732
Indonesia	3	44726	23.3	55155	9.0	48748	5.9	47387
Japan	8	12005	-6.4	11231	-14.2	10300	-27.6	8696
Malaysia	3	1744	24.6	2173	17.6	2050	26.8	2211
Myanmar	2	13807	21.5	16776	-10.5	12356	1.2	13974
Philippines	3	9459	14.1	10797	-11.8	8340	-4.7	9018
Republic of Korea	6	8192	-13.6	7078	-5.3	7775	-21.9	6401
Taiwan	7	2798	11.8	3128	12.8	3156	28	3583
Thailand	2	20177	9.3	22044	-4.7	19230	-0.9	19989
Total		**434136**		**462472**		**415129**		**409743**
Change (%)				**6.5**		**-4.4**		**-5.6**

Source: Mathews et al. (1997)

Estimated Changes in Total Rice Production Predicted by the SIMRIW Model

Country	AEZ	Current Production in '000 tons	GFDL		GISS		UKMO	
			Change (%)	000 tons	Change (%)	000 tons	Change (%)	000 tons
Bangladesh	3	27691	8.0	29914	-10.2	24869	-9	25200
	5	8854	-1.7	8700	7.3	9501	-1.4	8730
	6	79872	9.7	87596	-30.7	55332	-17.2	66162
	7	91928	1.0	92768	-10.0	82600	-8.4	84158
	8	2361	-10.0	2125	9.7	2590	-5.8	2223
India	1	32807	-8.2	30104	-19.5	26417	-14.8	27964
	2	49949	9.1	54473	10.5	55192	-3.2	48366
	5	227	-1.7	223	7.3	244	-1.4	224
	6	26628	-19.9	21339	-36.9	16804	-92.4	2011
	8	1011	-10.0	910	9.7	1109	-5.8	952
Indonesia	3	44726	17.5	52543	9.8	49093	6.9	47816
Japan	8	12005	-10.0	10804	9.7	13172	-5.8	11303
Malaysia	3	1744	12.0	1953	1.7	1774	14.7	2001
Myanmar	2	13807	15.6	15961	-13.8	11896	-4.9	13134
Philippines	3	9459	9.4	10345	-13.7	8163	-5.4	8944
Republic of Korea	6	8192	1.6	8323	13.8	9323	-8.8	7468
Taiwan	7	2798	2.4	2866	5.1	2941	20.7	3378
Thailand	2	20177	6.4	21461	-11.6	17842	-7.3	18696
Total		**434136**		**452409**		**388860**		**378730**
Change (%)				**4.2**		**-10.4**		**-12.8**

Source: Mathews et al. (1997)

Nelson et al. (2009) used the IFPRI's IMPACT Model to project the impact on rice production of climate change. Because climate-change simulations are inherently uncertain, two climate models have been used to simulate future climate, using the A2 scenario of the IPCC's Fourth Assessment Report: the National Center for Atmospheric Research, US (NCAR) model and the Commonwealth Scientific and Industrial Research Organization, Australia (CSIRO) model. Climate change will have a direct impact on water availability for irrigated crops. Internal renewable water (IRW) is the water available from precipitation. Both the climate scenarios result in more precipitation over land than would occur with no climate change. Under the NCAR scenario, all regions experience increased IRW. Under the CSIRO scenario, the average IRW increase is less than occurs with NCAR, and the Middle East and North Africa and Sub-Saharan Africa regions both experience reductions of about 4 percent.

In addition to precipitation changes, climate change-induced higher temperatures increase the water requirements of crops. The ratio of water consumption to requirements is called irrigation water supply reliability (IWSR). The smaller is the ratio, the greater the water stress on irrigated crop yields. Across the group of developing countries, IWSR improves under the NCAR scenario and worsens under the CSIRO scenario. However, regional differentiation of climate-change effects is important. IWSR improves slightly for the Latin America and Caribbean region and for the Middle East and North Africa, but worsens slightly for Sub-Saharan Africa under both scenarios. For East Asia and the Pacific and for South Asia, reliability increases under the NCAR scenario but declines under the CSIRO scenario. Yield reductions of irrigated crops due to water stress are directly estimated in the hydrology portion of IMPACT, taking into account the growing demand for water outside agriculture as well as agricultural demands.

Climate Change induced yield effects by crop and management system

(% change from yield with 2000 climate to yield with 2050 climate)

Crop	Region	CSIRO, No Carbon Fertilization	NCAR, No Carbon Fertilization	CSIRO, with Carbon Fertilization	NCAR, with Carbon Fertilization
Rice, irrigated					
	Developing countries	-14.4	-18.5	2.4	-0.5
	Developed countries	-3.5	-5.5	10.5	9.0
Rice, rainfed					
	Developing countries	-1.3	-1.4	6.5	6.4
	Developed countries	17.3	10.3	23.4	17.8

Source: Nelson et al. (2009), Table 1

Note: For each crop and management system, this table reports the area weighted average change in yield for a crop grown with 2050 climate instead of 2000 climate.

Climate-change effects on rice production, no CO_2 fertilization

Prodution	South Asia	East Asia and the Pacific	Europe and Central Asia	Latin America and the Caribbean	Middle East and North Africa	Sub-Saharan Africa	Developed Countries	Developing Countries	World
2000 (mmt)	119.8	221.7	1.1	14.8	5.5	7.4	20.4	370.3	390.7
2050 No climate Change (mmt)	168.9	217.0	2.6	17.8	10.3	18.3	20.3	434.9	455.2
2050 No climate Change (% change)	41.0	-2.1	144.4	19.8	87.4	146.0	-0.3	17.4	16.5
CSIRO (% change)	-14.3	-8.1	-0.2	-21.7	-32.9	-14.5	-11.8	-11.9	-11.9
NCAR (% change)	-14.5	-11.3	-0.8	-19.2	-39.7	-15.2	-10.6	-13.6	-13.5

Source: Nelson et al. (2009), Table 3

Note: The rows labeled “2050 No CC (% change)” indicate the percent change between production in 2000 and 2050 with no climate change. The rows labeled “CSIRO (% change)” and “NCAR (% change)” indicate the additional percent change in production in 2050 due to climate change relative to 2050 with no climate change. For example, South Asia rice production was 119.8 mmt in 2000. With no climate change, South Asia rice production is predicted to increase to 168.9 mmt in 2050, an increase of 41 percent. With the CSIRO scenario, South Asia rice production in 2050 is 14.3 percent lower than the 168.9 mmt, the production with no climate change in 2050 ;

mmt = million metric tons.

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