Expert Group Meeting on the Impact of Climate Change on ASEAN Food Security in Manila, the Philippines

6–7 JUNE 2013

Special Policy Report

Organised by the RSIS Centre for Non-Traditional Security (NTS) Studies

Centre For Non-Traditional Security Studies

Ponder the Improbable

EXPERT GROUP MEETING ON THE IMPACT OF CLIMATE CHANGE ON ASEAN FOOD SECURITY IN SOUTHEAST ASIA

SPECIAL POLICY REPORT

ORGANISED BY
THE RSIS CENTRE FOR NON-TRADITIONAL SECURITY (NTS) STUDIES

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PHILIPPINES

THE RSIS CENTRE FOR NON-TRADITIONAL SECURITY (NTS) STUDIES
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Preface

It was not by chance that the RSIS Centre for Non-Traditional Security (NTS) Studies and Economic Research Institute for ASEAN and East Asia (ERIA) came together to begin exploring climate change and its impacts on food security for Southeast Asia. Both institutions have a history of looking into these issues and their potential implications. It was thus only natural for the two institutions to examine, share, brainstorm and think of Southeast Asia's food future under a changing climate scenario together.

Numerous global and regional climate impact studies and research, including a number of assessment reports (ARs) from the Intergovernmental Panel on Climate Change (IPCC), have repeatedly identified Southeast Asia as one of the most vulnerable regions to climate change. While these changes are expected to affect many facets of life in the region, it has been stressed that impact on agriculture and food will be of critical importance. This is largely because a majority of people in the region still heavily depend on the food and agriculture sector for their daily food requirements and income. Any impact on this sector will therefore have major consequences for not only the livelihoods of millions of people but also the health of most economies in the region.

The latest IPCC assessment report (AR5), which came out in April 2014, after work on this report had already begun, has once again mentioned the lack of concrete data and information coming from the region. It is thus both the NTS Centre and ERIA's hope that this report will help to fill some of that gap. We also hope it will increase awareness on the issue as well as highlight some of the established information and knowledge regarding climate change impacts on food and agriculture for the region. We also trust that this collection of papers will go some way in broadening the discussion on 'food security and climate change' from a narrow production-centric focus to one that includes the dimensions of supply chains, value chains, international trade, health and nutrition, and its direct correlation with socioeconomic development, by and large.

Lastly, we would like to once again thank all authors who presented their papers during the Expert Group Meeting held in Manila in June 2013, out of which this report was born; the authors who have contributed to this report; the invaluable support of editors; and, everyone else who has had a role in successfully putting this in front of you today. We hope you will find this report useful and informative, and will share it with others who might appreciate it as well.

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Introduction: Asian Food Security under +2°C to +4°C Climate Change

Jonatan A. Lassa

The 10th session of Contribution of Working Group II to the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) in March 2014 provided a broad analysis on climate change impacts, adaptation and vulnerability. Chapter 7, titled 'Food systems and food security', of IPCC 2014 suggests that, if countries adopt adaptive crop management measures, they can avoid losses in the range of 15–18 per cent of current yields. However, even when effective adaptation can be made, local food system is still likely to experience both positive and negative yields as a result of increases in local temperature at about 2°C above pre-industrial revolution levels. In addition, local warming of about 4°C or higher above pre-industrial levels may create very significant risks and challenges to food security.

The IPCC AR5 presents levels of confidence based on evidence and scientists' agreements in three categories – high confidence, medium confidence and low confidence. Some of the high-confidence evidences are listed below:

- The effects of climate change on crop and food production are evident in several regions of the world. In addition, the negative impacts of climate change have outweighed its positive impacts.

- High latitude regions enjoy more positive trends while, in the low latitude regions (including the tropics), food systems are more likely to experience negative impacts of climate change.

- Neither the food security aspect nor dimension can escape from the impacts of climate change as all food systems are potentially affected, including food production, access, utilisation and price stability.

The AR5 also discusses the potential impact of climate change in Asia in general. However, the chapter suggests that there is very limited empirical work on climate change impact on food security in Southeast Asia. There are at least three key reasons for this. First, the AR5 only refers to existing peer-reviewed publications while most of the academic work on climate change and food security in the region is as grey literature. Second, there is lack of systematic study concerning climate impacts on food security from the region. Third, there is little representation of Southeast Asian scientists in the IPCC authorship, as countries such as Indonesia did not nominate any national representation to the IPCC Fourth Assessment Report (AR4) 2007.

This report, entitled 'Climate change impact on food security in Southeast Asia', is therefore timely, as it is based on expert knowledge that exhibits understanding of the climate change-food security nexus in Southeast Asia in brief. It is based on presentations from the Expert Group Meeting on the Impact of Climate Change on ASEAN Food Security, which was held on 6–7 June 2013 in Manila, the Philippines, and was facilitated by the Centre for Non-Traditional Security (NTS) Studies, S. Rajaratnam School of International Studies (RSIS), Nanyang Technological University, Singapore, with support from the Economic Research Institute for ASEAN and East Asia (ERIA), Jakarta, Indonesia. The meeting brought together leading experts in the region on climate change, agriculture and food security from the private sector, non-governmental organisations, academe and think tanks.

This report is by no means a comprehensive collection. There are six selected brief papers in this report. The topics include rice's biological vulnerability to climate change (section 3); food and nutrition security and climate linkages (section 4); intra-ASEAN agricultural trade under climate change (section 5); the effects of climate change on intra-ASEAN agricultural trade (section 6); coastal vulnerability of ASEAN food security (section 7); and, a brief observation and projection of climate change impact on food security in the Southeast Asian region (section 8).

R. Wassmann and S. V. K. Jagadish (section 3) briefly view rice adaptation measures as anticipatory action to multiple stressors that arise from abiotic stresses, such as heat, drought, submergence and salinity, where breeding has typically been pursued individually. They suggest that breeding technology is the key to improve adaptation in the rice sector. Wassmann and Jagadish also discuss a novel stress combination matrix to illustrate combined abiotic stress (such as heat and drought, and heat and salinity) and its negative effects on crop production.

Robert J. Holmer (section 4) argues that climate change may affect food and nutritional security, and therefore policies and supports must be in place to avoid unnecessary child deaths and lower cognitive outcomes in children, and lower adult productivity. Holmer has the merit of mentioning existing regional cooperation in ASEAN, where the leaders have demonstrated their commitment through different mechanisms, such as the ASEAN Integrated Food Security (AIFS) Framework and the Strategic Plan of Action on Food Security for the ASEAN Region (SPA-FS).

Venkatachalam Anbumozhi (section 5) provides a brief analysis of intra-ASEAN agricultural trade under a changing climate. He argues that climate extremes may create cascading effects on inter-regional supply chains, where failure in one food production centre may transmit the asymmetry in food demands, leading to food price adjustments throughout the supply chain network. One of his suggestions is that countries can cooperate and create flexibility of fishing agreements to cope with declining fishing stocks, as well as integration of fisheries into other national policies on climate change, food security and trade. In addition, adaptation measures are also suggested followed by a set of food policy mix with proposed short- and medium-term targets.

Rolando T. Dy (section 6) argues that climate change affects food production and processing, and food safety and access through extreme events, such as flooding, typhoons, droughts, higher temperature and sea level rise. However, he notes that it is strategically important that the magnitudes of the impact, while difficult to quantify, be monitored. He proposes advancement in adaptation measures, such as more research into drought-tolerant and flood-resistant crops and emergency rice buffer stocks.

Laura David (section 7) briefly highlights climate change impact on coastal vulnerability by referring to IPCC AR4. She argues that climate change phenomena, such as sea surface temperature (SST), anomalous water budget, sea level rise, more intense storms and ocean acidification, will have predominantly negative impacts on coastal agriculture and fisheries in Southeast Asia. David suggests that adaptation actions should include experimenting with drought/flood/salt-tolerant agriculture staples and temperature-tolerant mariculture species. She notes that food security under climate adaptation will entail coastal habitat protection since coastal vulnerability and degradation will have far-reaching consequences for food security.

Rizaldi Boer and Kiki Kartikasari (section 8) briefly discuss direct and indirect impacts of climate change on food security in ASEAN. Identified indirect impacts on production include change of severity of pests and diseases, damage of irrigation infrastructure, etc. Indirect impacts on food consumption include financial losses that eventually influence calorie intake and consumption adjustment. Direct impacts are mainly on crop production and distribution systems, which have been catagorised as continuous, discontinuous and permanent impacts.

Rice and Climate Change: Biological Vulnerability to Climate Change and Adaptation Options

R. Wassmann and S. V. K. Jagadish

Abstract

This paper reviews major challenges for rice production that stem from climate change (namely, high temperature, flood, salinity and drought) and also considers multiple stresses and regional differentiations in impacts. Climate-related stresses are discussed in terms of severity as well as possible adaptation strategies. Rice production is a complex cropping system requiring frequent decision-making by farmers on a variety of management options. In turn, this feature allows many entry points for adaptation, such as cultivar selection and modifications in the water regime. While climate change threats for rice production are evident, recent research in plant breeding and natural resource management has opened up a range of promising adaptation pathways.

Keywords: Adaptation option, biological vulnerability, climate change, rice, submergence

Introduction

Rice, with its wide geographic distribution extending from 50°N to 35°S, is expected to be the most vulnerable cultivated crop to future changing climates. Rice is sensitive to different abiotic stresses that will exacerbate with more climate extremes under climate change.[1] Plant breeding has a proven track record in improving tolerance to these abiotic stresses, in particular, as new molecular tools, such as marker-assisted backcrossing, are now available to speed up the introgressing of tolerance genes. At present, selected high-yielding rice varieties have been further developed to cope with individual stresses – a process that is likely to be continued in order to cover the major megavarieties that are affected by individual stresses. However, these climate-induced extremes often appear in combination, that is, salinity is frequently accompanied by submergence in coastal rice systems. A major bottleneck for combined tolerance to different stresses is the lack of thorough understanding of the complex genotype x environment (GxE) interactions that may adversely affect reciprocal development of traits.

High Temperatures

Temperatures beyond critical thresholds reduce the growth duration of the rice crop, increase spikelet sterility, reduce grain-filling duration and enhance respiratory losses, resulting in lower yields and lower-quality rice grains.[2] Rice is relatively more tolerant to high temperatures during the vegetative phase but highly susceptible during the reproductive phase, and particularly so at the flowering stage.[3] Unlike other abiotic stresses, heat stress occurring either during the day or night has differential impacts on rice growth and production. Recently, high night temperatures have been documented to have a greater negative effect on rice yield, with 1°C above critical temperature (> 24°C) leading to 10 per cent reduction in both grain yield and biomass.[4] With rapid increase in the minimum

1 S. V. K. Jagadish et al., 'Genetic advances in adapting rice to a rapidly changing climate', *Journal of Agronomy and Crop Science* 198, no. 5 (2012): 360–73.

2 S. V. K. Jagadish et al., 'Physiological and proteomic approaches to address heat tolerance during anthesis in rice (*Oryza sativa* L.)', *Journal of Experimental Botany* 61, no. 1 (2010): 143–56; Wanju Shi et al., 'Source-sink dynamics and proteomic reprogramming under elevated night temperature and their impact on rice yield and grain quality', New Phytologist 197, no. 3 (2013): 825–37.

3 S. V. K. Jagadish, P. Q. Craufurd and T. R. Wheeler, 'High temperature stress and spikelet fertility in rice (*Oryza sativa* L.)', *Journal of Experimental Botany* 58, no. 7 (2007): 1,627–35.

4 Shaobing Peng et al., 'Rice yields decline with higher night temperature from global warming', *Proceedings of the National Academy of Sciences of the United States of America* 101, no. 27 (2004): 9,971−5.

(nighttime) temperature during the last 2–3 decades compared to the maximum (daytime) temperature, and predictions that this trend will continue, impacts that, for now, are being identified in select vulnerable regions will be felt on a global scale.[5]

Recent research points to significant interaction between high temperatures and relative humidity, with higher humidity levels accompanied by moderate-to-high temperatures having a more pronounced negative impact when compared to conditions with lower relative humidity.[6] On the basis of the above-stated interaction, rice cultivation regions in the tropics and subtropics can be classified into hot/dry or hot/humid regions. It can be confidently assumed that rice cultivation in hot/dry regions, where temperatures may exceed 40°C (for e.g., Pakistan, Iran and India), has been facilitated through unintentional selection for efficient transpiration cooling (an avoidance mechanism) under sufficient supply of water. With erratic rainfall patterns and increasing pressure on irrigation water, this adaptive trait would become less functional, hence drastically increasing the vulnerability of rice in most productive regions, such as Egypt, Australia, etc. For this reason, developing rice varieties that can withstand both high day and night temperatures under varying levels of humidity and water supply will be vitally important.

Floods

Floods are a significant problem for rice farming, especially in the lowlands of South and Southeast Asia. Since there were no alternatives, subsistence farmers in these areas have depended on rice, which – in contrast to other crops – thrives under shallow flooding.[7] However, yield losses are attributed to unpredictable flood events, which can be grouped into three damage mechanisms:

- Complete submergence (often referred to as flash flooding), causing plant mortality after a few days.
- Partial submergence over longer time spans (often referred to as stagnant flooding), triggering substantial yield losses.
- Water logging in direct-seeded rice, creating anaerobic conditions that impair germination.

Complete or partial submergence is an important abiotic stress that affects about 10–15 million hectares (ha) of rice fields in South and Southeast Asia, causing annual yield losses estimated at USD 1 billion. This number is anticipated to increase considerably in the future given the increase in sea water level as well as increases in the frequency and intensity of flooding caused by extreme weather events.[8]

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5 Jarrod R. Welch et al., 'Rice yields in tropical/subtropical Asia exhibit large but opposing sensitivities to minimum and maximum temperatures', *Proceedings of the National Academy of Sciences of the United States of America* 107, no. 33 (2010): 14,562−7.

6 R. Wassmann et al., 'Regional vulnerability of rice production in Asia to climate change impacts and scope for adaptation', *Advances in Agronomy* 102 (2009): 91–133.

7 Endang M. Septiningsih et al., 'Development of submergence-tolerant rice cultivars: the *Sub1* locus and beyond', *Annals of Botany* 103, no. 2 (2009): 151–60.

8 Intergovernmental Panel on Climate Change (IPCC), 'Summary for policymakers', in *Climate Change 2013: The physical science basis*, Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, eds Thomas F. Stocker et al. (New York: Cambridge University Press, 2013), http://www.climatechange2013.org/images/uploads/WGIAR5-SPM_Approved27Sep2013.pdfwww.climatechange2013.org/images/report/WG1AR5_SPM_FINAL.pdf.

Although a semiaquatic plant, rice is generally intolerant to complete submergence and plants die within a few days when completely submerged. Traditionally, flood-prone areas along the big rivers of South and Southeast Asia have been growing deepwater rice. This type of rice plant escapes complete submergence by rapid internode elongation that pushes the plants above the water surface, where it has access to oxygen and light to resume the mitochondrial oxidative pathway and photosynthesis. However, low yield potential and long maturity duration have led to the replacement of deepwater rice by short-maturity varieties grown in the seasons before and after peak flooding. While conventionally bred varieties were characterised by poor grain quality and poor agronomic traits, new molecular approaches have yielded high-yielding varieties with the *Sub1* gene that is responsible for conveying flood tolerance.[9]

The most common problem in flood-prone areas is flash flooding. It can completely submerge rice fields for up to two weeks at any time during the season and often occurs more than once. Another type of flooding stress is stagnant flooding, which is characterised by prolonged partial flooding without submerging the plants completely. In contrast to the tolerance mechanism of Sub1, stagnant flooding requires plants to have facultative elongation ability to keep up with the constant rise of water levels. Improved breeding lines that are tolerant of submergence followed by stagnant flooding have been developed by the International Rice Research Institute (IRRI) and are expected to be adopted in large areas of rainfed lowlands where these two types of flooding coexist.[10]

Salinity

Rice can be categorised as a moderately salt-sensitive crop, but growing rice is the only option for crop production in most salt-affected soils. The reason for this counter-intuitive advantage of the rice crop in saline areas lies in the fact that rice thrives well in standing water, which, on the other hand, helps leach salts from the root zone to lower layers. Similar to drought tolerance, salt stress response in rice is complex and varies with the stage of development. Rice is relatively more tolerant during germination, active tillering and toward maturity, but sensitive during the early vegetative and reproductive stages.[11] Salinity tolerance seems to involve numerous traits, some of which are more or less independent. Most salt-tolerant landraces are low yielding and with many undesirable traits. Hence, a precision marker-assisted breeding approach is employed to rapidly transfer tolerance genes from the traditional varieties into high-yielding breeding lines.

The increasing threat of salinity has become an essential issue linked to the consequences of climate change. As an indirect effect of increased temperature on sea level rise, flooding and salinity may affect much larger areas of coastal wetlands in the coming 50–100 years. Sea level rise will increase salinity encroachment in the coastal and deltaic areas that have previously been favourable for rice production.[12] Furthermore, over half (or, 55 per cent) of total groundwater is naturally saline. Secondary salinisation, specifically due to the injudicious use of water and fertilisers in irrigated agriculture, could increase the percentage of brackish groundwater. The groundwater table, if it

9 Septiningsih et al., 'Development of submergence-tolerant rice cultivars', op. cit.

10 Jagadish et al., 'Genetic advances in adapting rice to a rapidly changing climate', op. cit.

11 Folkard Asch and Marco C. S. Wopereis, 'Responses of field-grown irrigated rice cultivars to varying levels of floodwater salinity in a semi-arid environment', *Field Crops Research* 70, no. 2 (2001): 127–37.

12 Wassmann et al., 'Regional vulnerability of rice production in Asia to climate change impacts and scope for adaptation', op. cit.

rises and is brackish in nature, would be ruinous for most vegetation. Higher temperature aggravates this situation by excessively depositing salt on the surface via capillary action, which is extremely difficult to leach below the rooting zone.

Drought

Drought stress is the largest constraint to rice production in rainfed systems, affecting 10 million ha of upland rice and over 13 million ha of rainfed lowland rice in Asia alone. The 2002 drought in India could be described as a catastrophic event, as it affected 55 per cent of the country's area and 300 million people.[13] Rice production declined by 20 per cent from the inter-annual baseline trend. Similarly, the 2004 drought in Thailand affected over 8 million people in almost all its provinces. Severe droughts generally result in starvation and impoverishment of the affected population, causing production losses during the years of complete crop failure, with dramatic socioeconomic consequences on human populations. Production losses due to drought of milder intensity, although not as alarming, can still be substantial. For instance, the average rice yield in rainfed eastern India during 'normal' years still varies in the range of 2.0–2.5 tonnes/ha, far below achievable yield potentials. Chronic dry spells of relatively short duration can often result in substantial yield losses, especially if they occur around the flowering stage. In addition, drought risk reduces productivity even during favourable years in drought-prone areas because farmers avoid investing in inputs when they fear crop loss. Inherent drought is associated with the increasing problem of water scarcity, even in traditionally irrigated areas, due to rising demand and competition for water. This is, for instance, the case in China, where the increasing shortage of water for rice production is a major concern although rice production is mostly irrigated.

In Asia, more than 80 per cent of developed freshwater resources are used for irrigation purposes, mostly for rice production. Thus, even small savings of water due to a change in current practices will have a significant bearing on reducing the total consumption of freshwater for rice farming. By 2025, 15–20 million ha of irrigated rice will experience some degree of water scarcity. Many rainfed areas are already drought prone under present climatic conditions and these are likely to experience more intense and more frequent drought events in the future.

Thus, water-saving techniques are absolutely essential for sustaining – and, possibly, increasing – future rice production under climate change. The period of land preparation encompasses various options for saving water, such as lining of field channels, land levelling, improved tillage and bund preparation. Similarly, crop establishment can be optimised under water scarcity by direct seeding, which reduces turnaround time between crops and may tap rainfall. Finally, the crop growth period essentially offers three alternative management practices to save irrigation water – saturated soil culture (SSC), alternate wetting and drying (AWD), and aerobic rice.

Multiple Stresses

Abiotic stresses, such as heat, drought, submergence and salinity, are the major factors responsible for significant annual rice yield losses. However, these often occur in combination in the fields, causing incremental crop losses. For example, successive flood/drought exposures within one season were seen in Luzon in the Philippines in 2006. During the wet season crop, seasonal rainfall exceeded 1,000 mm, including a major typhoon (named Xangsane) that brought with it around 320 mm of rainfall in a single day. Yet, a short dry spell that coincided with

13 Sushil Pandey et al., 'Coping with drought in rice farming in Asia: Insights from a cross-country comparative study', *Agricultural Economics* 37, no. s1 (2007): 213–24.

the flowering stage resulted in a dramatic decrease of grain yield and harvest index when compared to irrigated control fields.

Breeding for abiotic stresses have typically been pursued individually. In a novel stress combination matrix, illustrating the interactions between different abiotic stresses (such as heat and drought, and heat and salinity), Mittler showed that combined stress increased negative effects on crop production.[14] For example, in response to heat stress, plants open their stomata to maintain a cooler canopy microclimate through transpiration, but under combined heat and drought stress, the sensitive stomata are closed to prevent loss of water, which then further increases the canopy/tissue temperatures.[15] A similar phenomenon occurs under combined heat and salinity stress. It was concluded that the study of abiotic stress combinations involves a 'new state of abiotic stress' rather than just a sum of two different stresses. Therefore, the need to develop crop plants with high levels of tolerance for a combination of stresses is advocated. In support of this hypothesis, recent research has highlighted physiological, biochemical and molecular connections between heat and drought stress.

Regional Differentiation of Impact

Given the geographic heterogeneity of the major rice-growing regions, climate change impacts will occur in differentiated regional hotspots. South, East and Southeast Asia contain several mega-deltas that are highly susceptible to sea level rise and storm surges. Rice production in these mega-deltas forms the backbone of the agricultural sector in many Asian countries and is responsible for a large share of the rice that is internationally marketed.[16] Therefore, any shortfall in rice production in these areas due to climate change would not only affect national economies and food security in the delta countries but also have repercussions on the international rice market.

Similarly, increasing temperatures will have very different significance depending on the baseline temperature regimes of a given rice-growing region. While archipelagos, such as Indonesia and the Philippines, are to some extent shielded from extreme heat events, effectively all continental countries in South, East and Southeast Asia experience pronounced heat waves even under current climate. Assuming temperature increase, the decisive question will be the timing of these heat waves within the ontogenetic development of the rice plant or, in other words, whether the high temperatures will coincide with the sensitive flowering period of the rice plant.

Drought impacts on rice production are often associated with El Niño years, and thus also show a strong geographic differentiation.[17] Drought impacts will be more immediate in rainfed rice production, as opposed to irrigated production, because reservoirs, river diversion and groundwater pumping can to some extent buffer short-term shortages in rainfall. Strong El Niño years, however, will surpass the buffering capacity of irrigation in regions with a strong ENSO (El Niño southern oscillation) signal, as was apparent in Indonesia and the Southern Philippines during the 1997/1998 ENSO event. Recent developments in the application of seasonal climate forecasts to the agricultural sector suggest that there is large potential for enhancing agricultural risk management, thus enabling farmers to tailor the management of decisions on the cropping season.[18]

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14 Ron Mittler, 'Abiotic stress, the field environment and stress combination', *Trends in Plant Science* 11, no. 1 (2006): 15–19.

15 Krishna S. V. Jagadish et al., 'Does susceptibility to heat stress confound screening for drought tolerance in rice?', *Functional Plant Biology* 38, no. 4 (2011): 261–9.

16 Wassmann et al., 'Regional vulnerability of rice production in Asia to climate change impacts and scope for adaptation', op. cit.

17 R. Wassmann et al., 'Rice and global climate change', in *Rice in the global economy: Strategic research and policy issues for food security*, eds Sushil Pandey et al. (Los Baños: International Rice Research Institute, 2010), 411–32.

18 Holger Meinke et al., 'Actionable climate knowledge: From analysis to synthesis', *Climate Research* 33, no. 1 (2006): 101–10.

Ensuring Food and Nutrition Security in Southeast Asia in the Face of a Changing Climate

Robert J. Holmer

Abstract

Despite rapid economic growth in many Southeast Asian countries, the socioeconomic costs of malnutrition remain high in the region, resulting in unnecessary child deaths, lower cognitive outcomes in children and lower adult productivity. This situation is exacerbated by climate change, with Southeast Asia being one of the world's most vulnerable regions to this global phenomenon. Increased availability, affordability and consumption of nutrient-dense fruits and vegetables are promising strategies to substantially reverse malnutrition. However, corresponding policies and support mechanisms must be put in place to realise this vision.

Keywords: Balanced diet, fruits, malnutrition, vegetables

Introduction

Ensuring adequate, safe and nutritious food for all its citizens is a high priority and longstanding agenda in the framework of ASEAN community building. In this aspect, however, it is important to distinguish between having sufficient food and having adequate nutrition. The Committee on World Food Security has come up with a definition for the term 'food and nutrition security', as that which

> …exists when all people at all times have physical, social and economic access to food, which is safe and consumed in sufficient quantity and quality to meet their dietary needs and food preferences, and is supported by an environment of adequate sanitation, health services and care, allowing for a healthy and active life.[19]

Hence, food, nutrition, sanitation and hygiene issues are intrinsically linked and negative health impacts can be minimised by reducing environmental health risks while, at the same time, improving nutrition. The UN has supported the Scaling Up Nutrition (SUN) movement, which promotes for action and investment to improve maternal and child nutrition, recognises malnutrition as one of the world's most serious, but least addressed, health problems with enormous human and economic costs. For instance, the World Bank estimates that the effects of malnutrition can cost up to 9 per cent of a country's gross domestic product.[20]

Significant progress has been achieved over the past 30 years in reducing the proportion of malnourished children in Southeast Asia. However, malnutrition persists, affecting large numbers of children. While the region continues to deal with the problems of infectious diseases and undernutrition, it is, at the same time, experiencing an upsurge in non-communicable disease risk factors, such as overweight and obesity, particularly in the rapidly increasing urban settings, with urbanisation as a

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[19] Committee on World Food Security, 'Coming to terms with terminology: Food security, nutrition security, food security and nutrition, food and nutrition security', accessed 12 May 2013, http://www.fao.org/fsnforum/sites/default/files/file/Terminology/MD776(CFS___Coming_to_terms_with_Terminology).pdf.

[20] World Bank, *Repositioning nutrition as central to development: A strategy for large-scale action* (Washington, D.C.: International Bank for Reconstruction and Development/World Bank, 2006), 246.

factor contributing to obesity.[21] It is not uncommon to find undernutrition and obesity existing side-by-side within the same community and even the same household, a phenomenon that is dubbed as 'double burden of disease'.[22]

Worldwide, about 1.1 billion people are considered overweight due to excessive intake of calories, among whom an estimated 17.6 million are children. In low-income countries, obesity is still rare, but its prevalence among children in many middle-income countries is similar to that in the US.[23] Drewnowski and Specter noted the lack of opportunities for children to engage in physical activity in the cities, coupled with the availability of high-fat, high-sugar, high-salt, energy-dense, micronutrient-poor foods that tend to be lower in cost, but are perceived to be tastier, and are often more accessible than healthier food choices, as contributing factors.[24] Low-income groups often consume unhealthier diets than other sections of the population[25], as fresh fruits and vegetables are often not affordable, thus discouraging their consumption.[26] These dietary patterns, in conjunction with low levels of physical activity, result in sharp increases in obesity while undernutrition issues remain unsolved.[27]

Overweight children have a strongly increased risk of being overweight as adults.[28] Similar to the effects of undernutrition, obesity is also associated with underperformance in education. There is recent evidence that a poor diet, with high fat, sugar and processed food content, in early childhood may be associated with small reductions in intelligence quotient (IQ) in later childhood while a healthy diet, with a high intake of nutrient-rich foods at about the time of IQ assessment may be associated with small increases in IQ.[29] Belot and James in the UK also reported significant educational improvements of pupils in the subjects of English and the Sciences in primary schools that were part of the 'Feed Me Better' campaign (led by chef Jamie Oliver), which shifted school meals away from low-budget processed foods toward healthier options with more fruits and vegetables.[30]

An increase in the availability, affordability and consumption of nutrient-dense fruits, vegetables and pulses is one way malnutrition may be substantially reversed, as these foods are important sources of vitamins and micronutrients that the human body requires for good health. Vitamins protect vision, boost immunity, protect from harmful free radicals and aid in absorption of other nutrients. Minerals serve as electrolytes, affect the body's water balance, act as cofactors for enzyme function, and are components of bones and teeth, membrane function, thyroid hormone and haemoglobin, and a part of nucleic acids. Micronutrients, which are vital for the health and development of children as also the health and well being of adults – particularly for pregnant and nursing mothers, and those with

21 Lopez R., 'Urban sprawl and risk for being overweight or obese', *American Journal of Public Health* 94, no. 9 (2004): 1,574–9.

22 Dele O. Abegunde et al., 'The burden and costs of chronic diseases in low-income and middle-income countries', *The Lancet* 370, no. 9603 (2007): 1,929–38; Derek Yach et al., 'The global burden of chronic diseases: Overcoming impediments to prevention and control', *JAMA* 291, no. 21 (2004): 2,616–22.

23 Donald A. P. Bundy et al., 'School-based health and nutrition programs', in *Disease control priorities in developing countries*, eds Dean T. Jamison et al., 2nd ed. (Washington, D.C.: International Bank for Reconstruction and Development/World Bank, 2006), 1,091–108.

24 Adam Drewnowski and S. E. Specter, 'Poverty and obesity: The role of energy density and energy costs', *American Journal of Clinical Nutrition* 79 (2004): 6–16.

25 Nicole Darmon and Adam Drewnowski, 'Does social class predict diet quality?', *American Journal of Clinical Nutrition* 87, no. 5 (2008): 1,107–17

26 Mayuree Rao et al., 'Do healthier foods and diet patterns cost more than less healthy options? A systematic review and meta-analysis', *BMJ Open* 3, no. 12 (2013); doi:10.1136/bmjopen-2013-004277.

27 Gemma P. Yuchingtat et al., 'Physical activity of high school students in the city of Manila' (Pasig City: Philippine Association for the Study of Overweight and Obesity [PASOO]), accessed 12 May 2013, http://www.obesity.org.ph/files/research/pa_highschool.pdf.

28 Power C. and Parsons T., 'Nutritional and other influences in childhood as predictors of adult obesity', *Proceedings of the Nutrition Society* 59, no. 2 (2000): 267–72.

29 Kate Northstone et al., 'Are dietary patterns in childhood associated with IQ at 8 years of age? A population-based cohort study', *Journal of Epidemiology & Community Health* 66, no. 7 (2012): 624–8; doi:10.1136/jech.2010.111955.

30 Michèle Belot and Jonathan James, 'Healthy school meals and educational outcomes' (ISER Working Paper Series No. 2009–01, Colchester, UK: Institute for Social & Economic Research [ISER], 2009).

chronic diseases – are most easily obtained from foods, such as fruits and vegetables. The World Health Organization and the Food and Agriculture Organization of the United Nations (FAO) recommend a minimum intake of at least 400 g of fruits and vegetables per person a day[31] to achieve nutrition targets. Consumption at levels far below this value is common in most ASEAN countries.[32]

Climate Impact on Fruits and Vegetables

In response to the food crisis in 2007/2008 and for preserving food security in the region, ASEAN leaders demonstrated their commitment to food security enhancement through the announcement of the Statement on Food Security in the ASEAN region during the 14th ASEAN Summit in Thailand in 2009. During the summit, leaders committed to adopt the ASEAN Integrated Food Security (AIFS) Framework and the Strategic Plan of Action on Food Security for the ASEAN Region (SPA-FS) that provides scope and joint pragmatic approaches for cooperation among ASEAN member states for addressing food security in the region. In spite of the implementation of the AIFS Framework being gradual, significant achievements in accessibility and availability have already been realised. Considering the equal importance of a balanced diet in addressing the double burden of malnutrition (i.e., undernourishment and obesity) and the role of agriculture as a vehicle, the need to integrate and mainstream nutrition aspects into agricultural production systems is important. Moreover, as the issue is crosscutting in nature, the need is for multisectoral, multidisciplinary and multistakeholder approaches and collaboration. The urgent need to integrate nutrition into the AIFS Framework was emphasised at a high-level consultation, titled 'Integrating nutrition into ASEAN Integrated Food Security Framework and its Strategic Plan of Action for Food Security', which was jointly organised by the FAO and the ASEAN Secretariat in January 2013 in Bangkok, Thailand. Corresponding recommendations were endorsed at a subsequent joint session of the ASEAN Ministerial Meeting on Agriculture and Forestry (AMAF) and Health Development (HD).

Asian Development Bank describes Southeast Asia as one of the world's most vulnerable regions to climate change due to its long coastlines, high concentration of population and economic activity in coastal areas, as well as its heavy reliance on agriculture, natural resources and forestry.[33] Climate change poses a major risk for Southeast Asia that will complicate and compound existing development problems, such as population growth, rapid urbanisation, increasing competition for natural resources, environmental degradation, and, most importantly, food and nutrition insecurity, thus seriously hindering the region's efforts toward sustainable development and poverty reduction. Already, over the last 50 years, the region has experienced a range of observed climate changes, including declining precipitation, increasing water scarcity, rising average temperatures and growing frequency of extreme weather events in the form of storms and floods.[34] These changes pose a real and undeniable threat to the agro-ecosystems and natural resources that underpin the region's agriculture sector, the livelihoods of its rural communities, and, by extension, food and nutrition security. In the ASEAN context, potential shifts in agro-ecological zones, droughts, desertification, variations in hydrological cycles, rising sea levels and saline water intrusion could radically alter existing cropping patterns and threaten in situ agricultural biodiversity. According to the Intergovernmental Panel on Climate Change (IPCC)[35], the poorest segments of societies are most vulnerable to climate change, with poverty determining vulnerability via

31 For more information, see http://www.fao.org/ag/magazine/fao-who-fv.pdf.

32 Keatinge J. D. H. et al., 'The importance of vegetables in ensuring both food and nutritional security in attainment of the Millennium Development Goals', *Food Security* 3, no. 4 (2011): 491–501.

33 Asian Development Bank (ADB), *The economics of climate change in Southeast Asia: A regional review* (Manila: ADB, 2009), 224.

34 Ibid.

35 Intergovernmental Panel on Climate Change (IPCC), *Climate change 2007: Impacts, adaptation and vulnerability*, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, eds Martin Parry et al. (Cambridge, UK, and New York: Cambridge University Press, 2007).

several mechanisms, principally in relation to access to resources to allow coping with extreme weather events and through marginalisation from decision-making and social security.[36] The distribution of vulnerability to climate change can be observed clearly in the pattern of vulnerability to natural disasters, with the poor being more vulnerable to these events. Since poor farmers in the region rely on small-scale rainfed farming systems as their main source of food and income, climate change is increasingly and simultaneously eroding their livelihood assets and access to natural resources and services while, at the same time, eroding their capacity to cope with climate-related crises and adopt sustainable solutions to climate change.

During a recent Expert Consultation on Vegetable Research and Development Priorities in Southeast Asia, organised by the ASEAN-AVRDC (Asian Vegetable Research and Development Center) Network on Vegetable Research and Development (AARNET)[37], climate change was mentioned as a major challenge. The need for innovative, climate-smart agricultural technologies that have the potential to strengthen resilience, improve productivity and reduce emissions of agricultural production systems and value chains to sustainably feed and nourish the region's growing population in the face of a changing climate was emphasised by regional experts. In vegetables, similar to other crops, photoperiod-temperature responses are usually highly heritable and thus air temperature can safely be assumed to be a vital measure for establishing breeding and agronomic programme targets. However, issues negatively associated with increasing temperature, such as a relatively greater proportion of maleness in flowers, fungal infections and greater insect pressure exposing crops to viruses, are also likely challenges that will have to be addressed. A further option, in the face of increasing temperatures, that is always available to the vegetable production community is to switch from a crop with less heat tolerance to one that is already adapted to higher temperatures. Thus, the availability of varieties that are tolerant or resistant to abiotic and biotic stress factors but correspond to market demands and also combine appropriate technologies (such as cultivation on raised beds, microirrigation and grafting) to allow production during periods of intermittent drought and/or water logging is indispensable. Further, integrated crop management strategies that minimise contamination from pesticides and other pollutants as well as improved storage technologies and better post-harvest management must be available and accessible to ensure year-round accessibility and affordability of safe and nutritious vegetables for consumers and to increase profits for vegetable growers and other players along the value chain.

Closing Remarks

AVRDC - The World Vegetable Center and its partners are ready to contribute to the ASEAN Multi-Sectoral Framework on Climate Change: Agriculture and Forestry towards Food Security (AFCC) to strengthen and enhance food and nutrition security in the region through sustainable, efficient and effective use of land, water and aquatic resources by minimising the risks to and impacts of their contributions to climate change.

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36 Kelly P. M. and Adger W. N., 'Theory and practice in assessing vulnerability to climate change and facilitating adaptation', *Climatic Change* 47, no. 4 (2000): 325–52.

37 ASEAN-AVRDC Regional Network for Vegetable Research and Development (AARNET), 'Expert consultation on vegetable research and development priorities in Southeast Asia', Bangkok, Thailand, 21 March 2013, http://avrdc.org/aarnet/?wpfb_dl=2.

Climate Change and Intra-ASEAN Trade in Agricultural Products

Venkatachalam Anbumozhi

Abstract

This paper addresses the new competition for food that has arisen due to changing climate conditions and its implications for agricultural production systems. It argues that ASEAN needs more open trade agreements at the regional level and enabling infrastructure, both soft and hard, at national levels to tackle climate risks and attain food security. It also suggests that governments take into consideration the vulnerabilities of small-scale producers when designing new climate resilient value chains.

Keywords: Food logistics, food policy response, intra-ASEAN trade, supply chain

Climate Change and Agricultural Production

The general consensus among the research community is that agriculture is highly vulnerable to the increased frequency, severity and unpredictability of extreme weather-related events caused by climate change (for e.g., cyclones, droughts, floods, rising sea levels, etc.). On a global scale, various models predict the impact of climate change on different time scales. Though positive opportunities may arise for increased production in temperate countries due to carbon fertilisation effects, past and current research indicate that, in the tropical ASEAN countries, the net effect will be negative.[38] For Asia, biophysical crop model results show yield reductions under a changed climate when compared to a no-climate change scenario. By 2050, the expected reduction in crop yields is in the range of 14–20 per cent for irrigated paddy, 32–44 per cent for irrigated wheat, 2–5 per cent for irrigated corn and 9–18 per cent for irrigated soybean.[39] Within ASEAN, differences may occur locally, and it is very difficult to make exact predictions, as available data at the sub-national levels and for other food and cash crops, such as cashew nut, are scarce.

Effect of Climate Change on Fisheries

Many inland fisheries of ASEAN will be threatened by alterations to water regimes, reduced precipitation and greater evaporation, and indirect effects, when more water is used for irrigation to offset reduced precipitation. Threats to aquaculture arise from increases in temperature, pH, biochemical oxygen demand, increased frequency of diseases, sea level rise and salt-water intrusions, as well as an uncertain future supply of fishmeal and oils from capture fisheries.[40]

Some data also suggest a general decline in tilapia production with rising temperatures.[41] However, countries such as Indonesia, the Philippines, Thailand and Vietnam are projected to witness aquaculture growth under the influence of climate change. For these countries, in recent years, net export of fish has generated more foreign exchange earnings than other agricultural products, such as rice, coffee and sugar. At the policy level, there is

38 Asian Development Bank (ADB), *The economics of climate change in Southeast Asia: A regional review* (Manila: ADB, 2009); Food and Agriculture Organization of the United Nations (FAO), *The state of world fisheries and aquaculture, 2008* (Rome: FAO, 2009); Intergovernmental Panel on Climate Change (IPCC), *Climate change 2007: Impacts, adaptation and vulnerability*, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, eds Martin Parry et al. (Cambridge, UK, and New York: Cambridge University Press, 2007); C. L. Walthall et al., 'Climate change and agriculture in the United States: Effects and adaptation' (USDA Technical Bulletin 1935, Washington, D.C.: U.S. Department of Agriculture [USDA], 2012); M. L. Parry et al., 'Effects of climate change on global food production under SRES emissions and socio-economic scenarios', *Global Environmental Change* 14, no. 1 (2004): 53–67; Thomas V., 'Disasters, climate, and growth' (IEG Working Paper 2011, Washington, D.C.: Independent Evaluation Group [IEG], 2008).

39 Asian Development Bank (ADB), *Food for all: Investing in food security in Asia and the Pacific–Issues, innovations, and practices* (Manila: ADB, 2011).

40 Food and Agriculture Organization of the United Nations, *The state of world fisheries and aquaculture, 2008,* op. cit.

41 Junning Cai, PingSun Leung and Nathanael Hishamunda, 'Assessment of comparative advantage in aquaculture: Framework and application on selected species in developing countries' (FAO Fisheries and Aquaculture Technical Paper 528, Rome: Food and Agriculture Organization of the United Nations [FAO], 2009), http://www.fao.org/docrep/012/i1214e/i1214e.pdf.

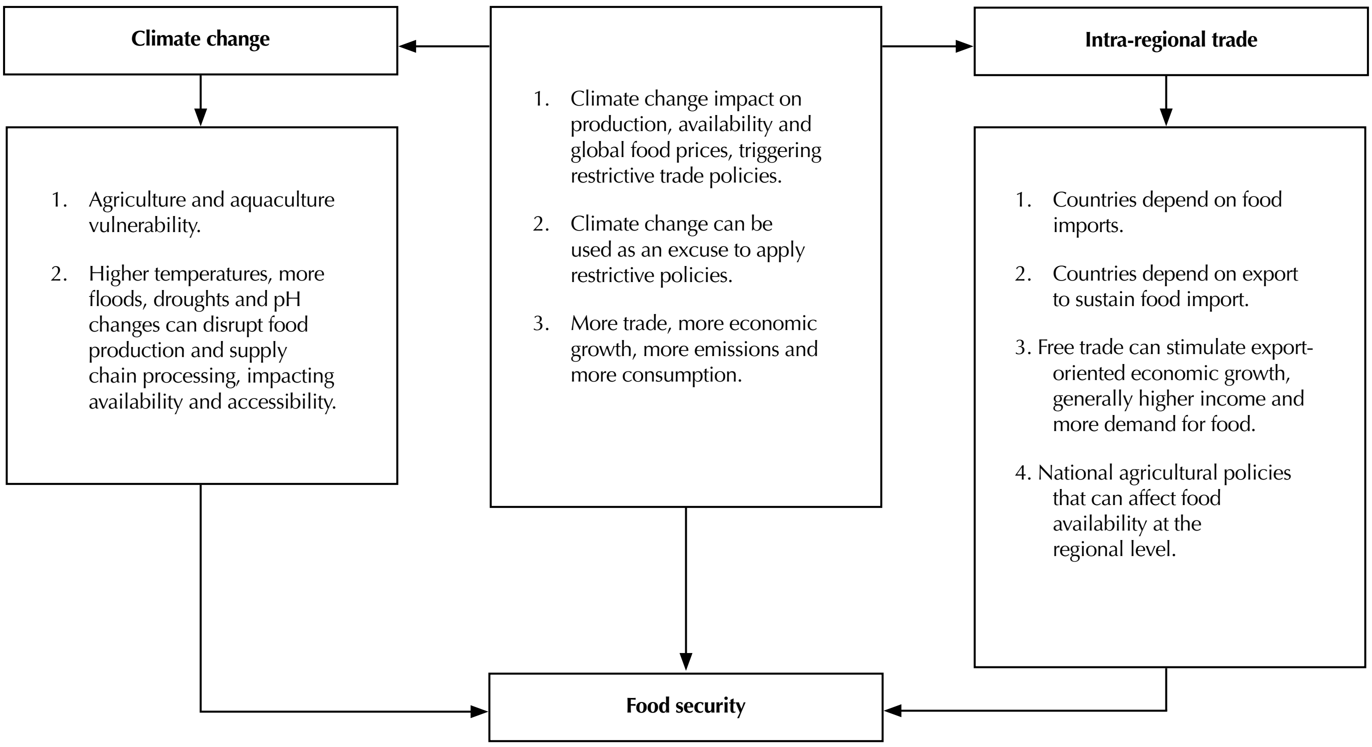
need for increased cooperation and flexibility of fishing agreements to cope with declining fishing stocks, as well as the integration of fisheries into other national policies on climate change, food security and trade.

Climate Change and Intra-Regional Trade in Food Products

Climate change is having direct impacts on intra-regional trade. The total food supply of any country depends on production capacity, imports and exports – all of which generate income and foreign exchange with which to buy food. In this context, changes in food availability (due to climate change and other factors) in China and India (with markets sizing nearly 2.8 billion) will affect world prices, generating more or less capacity for any ASEAN country to obtain food on the global markets. The biophysical impacts of climate change discussed in section 1 when integrated into the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) show that food prices are set to increase sharply for key crops. In 2050, prices are projected to be higher by 29–37 per cent for rice, 81–102 per cent for wheat, 58–97 per cent for corn and 14–49 per cent for soybean when compared to no-climate change prices.[42]

ASEAN houses the world's major rice and shrimp exporting countries (namely, Thailand and Vietnam), its major rice importers (namely, Singapore, Indonesia and the Philippines,) as well as still-agrarian countries (namely, Laos, Myanmar and Cambodia). In the event of sharp increase in world prices, large exporting countries, such as Thailand and Vietnam, could impose export bans to bring stability and security to the domestic market. Indeed, they invoked the Agreement on Agriculture (AoA) within the World Trade Organization framework when the food crisis erupted in 2008. Nevertheless, it remains unclear how free trade restrictive measures can be reasonably implemented, if the needs of neighbouring ASEAN countries that rely heavily on trade to ensure food stability under varying climate conditions are taken into consideration. These linkages are illustrated in Figure 1.

Figure 1: Climate change, trade and food security linkages.



42 Asian Development Bank (ADB), *Building climate resilience in the agriculture sector of Asia and the Pacific* (Manila: ADB, 2009).

Some studies even suggest that, as temperatures in Southeast Asia go up, crop and livestock production will increase at first and then decline as the heat stress continues (Table 1).

Table 1: Temperature and agricultural production in Southeast Asia.

Mean increase in global temperatures °C	Crop production change %	Livestock production change %
1.0	0.82	-0.12
1.3	0.0	-0.28
1.8	-0.82	-1.39
2.8	-1.58	-1.17
4.0	-2.62	-1.83
4.2	-2.78	-2.04
5.2	-4.78	-3.15

Source: Roy Darwin, 'Climate change and food security' (Agriculture Information Bulletin No. 765-8, Washington, D.C.: U.S. Department of Agriculture, Economic Research Service, 2001), http://www.ers.usda.gov/media/303959/aib765-8_1_.pdf.

The risks associated with climate change will be further aggravated when accompanied by other crisis, such as food and economic crises. During the last food crisis in 2008, for instance, several countries in Southeast Asia introduced export restrictions, stock piling and price control (Table 2), which eventually affected intra-regional trade equilibrium. This, in turn, affected the volatility of staple agricultural products, such as rice, and consequently the ability of poor people to buy food grains. In order to avoid such volatilities in the future, ASEAN introduced an emergency rice reserve, purely on voluntary basis. The current status of this virtual reserve is illustrated in Table 3.

Table 2: Policy responses of selected ASEAN countries to the 2008 global food crisis.

Policy response	Cambodia	Indonesia	Malaysia	Myanmar	The Philippines	Singapore	Thailand	Vietnam
Reduce import duties		X						
Increase supplies using reserves	X	X					X	
Build up reserves/stockpiles	X		X		X	X	X	X
Increase imports/relax restrictions		X			X		X	X
Increase export duties								
Impose export restrictions	X							X
Price controls/consumer subsidies	X	X	X		X		X	
Minimum support prices					X			X
Minimum export prices								
Subsidies to farmers					X			

Note: Cambodia, Thailand and Vietnam are considered to be net exporting countries whereas Indonesia, Malaysia, Myanmar, the Philippines and Singapore are net importing countries.
Source: Asian Development Bank (ADB), *Food for all: Investing in food security in Asia and the Pacific–Issues, innovations, and practices* (Manila: ADB, 2011).

Table 3: Quantities earmarked for the ASEAN Emergency Rice Reserve.

Country	**Earmarked quantity** Tonnes
Brunei Darussalam	3,000
Cambodia	3,000
Indonesia	12,000
Laos	3,000
Malaysia	6,000
Myanmar	14,000
The Philippines	5,000
Singapore	5,000
Thailand	15,000
Vietnam	14,000

Source: ASEAN Food Security Information System [AFSIS], http://www.afsisnc.org/.

Other trade and rice balance data of ASEAN countries are presented in Tables 4 and 5, respectively. Data indicate that the share of intra-ASEAN trade was less than 30 per cent on average when compared to extra-regional trade and the production potential of staple crops, such as paddy rice, varied widely across the region.

Table 4: Intra- and extra-ASEAN trade in 2010.

Country	**Intra-ASEAN trade**		**Extra-ASEAN trade**		**Total trade** USD million
	Value USD million	**Share of total trade** %	**Value** USD million	**Share of total trade** %	
Brunei Darussalam	3,544.3	29.9	8,315.9	70.1	11,860.2
Cambodia	1,909.9	21.8	6,865.6	78.2	8,775.5
Indonesia	68,162.5	25.6	198,055.2	74.4	266,217.7
Laos	2,215.3	84.2	415.6	15.8	2,630.9
Malaysia	85,076.7	25.1	253,718.0	74.9	338,794.7
Myanmar	5,581.6	53.6	4,833.9	46.4	10,415.5
The Philippines	21,398.4	20.3	84,272.6	79.7	105,671.0
Singapore	171,355.4	36.3	300,809.6	63.7	472,165.0
Thailand	69,375.3	19.7	283,158.9	80.3	352,534.2
Vietnam	29,494.6	20.9	111,862.5	79.1	141,357.1
ASEAN	458,114.0	26.8	1,252,307.8	73.2	1,710,421.8

Source: ASEAN Secretariat, 'ASEAN trade statistics 2011'.

Table 5: ASEAN Rice Balance Sheet in 2010 (tonnes).

Country	Initial stock	Production	Domestic utilisation	Import	Export
Brunei Darussalam	15,505	869	33,797	32,294	0
Cambodia	128,000	4,590,000	2,927,000	0	1,471,000
Indonesia	1,172,435	40,346,922	38,433,251	186,438	2,897
Laos	30,169	1,820,750	1,764,642	NA	NA
Malaysia	275,899	1,585,708	2,531,159	1,094,419	NA
Myanmar	4,345,208	20,196,456	19,157,000	0	667,000
The Philippines	2,638,287	10,737,201	13,163,706	1,638,314	159
Singapore	55,000	NA	262,000	280,000	33,000
Thailand	6,251,800	20,899,417	11,267,000	0	8,500,000
Vietnam	5,680,101	25,282,075	18,327,996	0	5,950,000
ASEAN	20,592,404	125,449,397	107,867,551	3,231,465	16,624,056

NA = not available
Source: ASEAN Food Security Information System [AFSIS], http://www.afsisnc.org/.

This suggests that, for ASEAN, there is potential for further increase in trade at the regional level, given the production opportunities and consumption limitations of some countries.

ASEAN Food Security under Changing Climate and Trade: Policy Implications

A changing climate is already affecting food production and livelihoods of vulnerable, small-scale producers in the ASEAN region, and this provides an indication of challenges that lie ahead.[43] Although the relationship between trade and food security is complex to understand, available adaptation options (Table 6) are easy to grasp.

[43] Ibid.

Table 6: Examples of climate change adaptation measures and policy options.

Adaptation measure	Policy option
Near-term actions (5–10 years)	
Crop insurance for risk coverage	Improved access to information, risk management, revised pricing incentives
Crop/livestock diversification to increase productivity and protect against diseases	Availability of extension services, financial support, etc.
Adjust timing of farm operations to reduce risks of crop damage	Extension services, pricing policies, etc.
Changes in cropping patterns, tillage practices	Extension services to support activities, policy adjustments
Modernisation of irrigation structures	Promote water-saving technologies
Efficient water use	Water pricing reforms, clearly defined property rights
Risk diversification to withstand climate shocks	Employment opportunities in non-form sectors
Food buffers for temporary relief	Food policy reforms
Redefining land use and tenure rights for investments	Legal reforms and enforcements
Medium-term targets (by 2030)	
Development of crop and livestock technology adapted to climate stress: drought and heat tolerance, etc.	Agriculture research (cultivar, fish and live stock trait development)
Develop market efficiency	Invest in rural infrastructure, remove market barriers, property rights, etc.
Irrigation and water resources consolidation	Investment by public and private sectors
Promoting regional trade in stable commodities	Pricing and exchange rate policies
Improving early warning/forecasting mechanisms	Information and policy coordination across sectors
Capacity building and institutional strengthening	Targeted reforms of existing institutions on agriculture and skills development

Source: Adapted from Venkatachalam Anbumozhi and Asian Development Bank Institute (ADBI), 'Climate change in the Asia-Pacific: How countries can adapt?' (presented at the Workshop on Agricultural Adaptations to Climate Change, Bangkok, Thailand, 19–23 November 2012, Tokyo: ADBI, 2012).

However, the above policy options should be seen in light of the fact that trade and climate change factors will continue to have implications for food security at the national and regional levels for ASEAN countries. As a consequence, policymakers need to increase their awareness on these issues.[44]

[44] Ulrich Hoffmann, 'Assuring food security in developing countries under the challenges of climate change: Key trade and development issues of a fundamental transformation of agriculture' (UNCTAD Discussion Papers No. 201, Geneva: United Nations Conference on Trade and Development [UNCTAD], 2011).

Specific policy recommendations for ASEAN shall include:

- A more precise assessment of local food production vulnerabilities to climate change vis-à-vis major agricultural trading crops and inland fish species.
- ASEAN economic integration or free trade efforts should be enhanced along with the recognition that food security and climate change are interlinked crosscutting issues.
- Buyers in importing countries should build longer term and more stable relationships with suppliers in food exporting countries to create the means to mitigate production volatility.
- National planning efforts should incorporate food security early warning systems taking into consideration factors, such as weather-related events, at the ASEAN level and potential external shocks coming from their major trading partners (ASEAN+5 countries).
- Long-term innovative financing plans should be developed to support adaptation actions that are taken at national levels.

Supply Chain and Associated Logistics

Adaptation at the farm level is necessary, but not sufficient, to tackle the wide array of problems that will arise along the (global) food supply chains. Technical expertise, market power and actionable knowledge of downstream actors, such as processor, wholesalers and retailers, will play a seminal role in facilitating the long-term coinvestment needed to thwart climate change impacts on food security. It may be feasible to scale up local-level adaptation to global supply chains assuming that other chains actors bring their capacities to the adaptation process. However, this will require structural changes in which adaptive measures are applied at critical spots of the food value chains. To bring about such changes will require a collective approach to assessing climate change impacts and adaptation options.

Because ASEAN food supply chains are complex and often informal, it is difficult and discouraging for decision-makers to take part in collective targeted interventions.[45] This also underlines the importance of more case study research analyses of specific food chains (such as rice, corn, shrimp, etc.) for providing actionable recommendations for collective adaptation. The key factors for any food supply chain in the ASEAN countries will include crop impacts, the vulnerability of small producers (in terms of income, housing, road and education), supply chain characteristics (such as logistics, technology and finance) and behaviours along with institutions (i.e., economic operators).

To help farmers/producers build their adaptive capacity and deliver more resilient supply chains, the private sector should take the following steps:

- Raise awareness and understanding of adaptation within suppliers/producers/retailers, drawing upon their market knowledge and technical capacity.
- Continuously ask producers/suppliers about current climate trends and impacts.
- Work through existing institutions, including governments, to spread the risks by diversifying procurement to more sites.

45 Venkatachalam Anbumozhi, Mari Kimura and Kumiko Isono, 'Leveraging environment and climate change initiatives for corporate excellence' (ADBI Working Paper Series No. 335, Tokyo: Asian Development Bank Institute [ADBI], 2011).

Meanwhile, governments should:

- Provide research support platforms to share knowledge about crops and site-specific impacts and adaptation strategies.

- Improve physical infrastructure for irrigation, transportation and marketing.

- Offer business operators and farmers easier and more equitable access to financial instruments, such as start-up investments and microfinancing, to implement collective adaptation measures.

Conclusion

This paper has attempted to provide insights into how climate change is affecting agricultural production and trade in the ASEAN region and the roles that governments and the private sector can play in strengthening the adaptive capacity of producers and, by doing so, making their value chains resilient. However, much more research is needed on how countries and companies can best invest in building adaptive capacity along the entire value chain of food importing countries in ASEAN, as they are often one step removed from primary production and therefore the focus of policy research. Furthermore, many small-scale producers do not form part of global supply chains. These subsistence farmers do have a small surplus to sell in the local markets. It is thus the primary role of individual governments to bring these small-scale producers to the core of addressing climate change and food security issues while ASEAN, as a community, must ensure that they have appropriate knowledge, technology and financial resources to increase their productivity and are connected to global markets. Governments and the private sector should take key steps to support these producers in their value chains rather than leaving them to bear disproportionately the cost of climate change.

Effects of Climate Change on Intra-ASEAN Trade of Agri Products

Rolando T. Dy

Abstract

ASEAN is an agri-food surplus region. Products that see significant intra-ASEAN trade include rice, sugar, vegetable oil, coffee, pepper and fish. Climate change affects the production, processing and food safety of these products as well as 'physical access'. Climate change impact occurs in various forms: (i) extreme rains and outbursts that result in severe flooding; (ii) increased frequency of extreme events (such as typhoons and droughts); (iii) higher temperature; and, (iv) rapid sea-level rise. It is strategically important that the magnitudes of these impacts, although difficult to quantify, are monitored. Areas of cooperation include: (i) climate change adaptation and mitigation; (ii) cost-effective design of climate-proofed infrastructure; (iii) design of disaster relief and crop insurance; (iv) research into drought-tolerant and flood-resistant crops; and, (v) emergency rice buffer stocks.

Keywords: Agri-products, exports, food trade balance, imports, inter-ASEAN trade

Introduction

ASEAN is a global player in agri-food products and an agri-food surplus region. Among the region's main exports are rice, palm oil, coconut oil, sugar, coffee, cocoa, banana, pineapple, pepper, cashew, rubber, fish, shrimps, tapioca starch, processed poultry meat, processed seafood and food preparations.

This paper will attempt to respond to the following questions:

- Given that ASEAN is a major producer of agriculture products, how will climate change scenarios affect the production, processing and food safety of these products?

- How will climate change affect the 'physical access' aspects of ASEAN-produced food products?

- What are the policy implications from the anticipated effects of climate change scenarios on ASEAN agri-food production and physical access?

Food safety issues are not dealt with in this paper.

Intra-ASEAN Trade

Products for which intra-ASEAN trade is significant are rice, sugar, vegetable oil, coffee, pepper and fish. Table 1 presents the global ranking of ASEAN countries for agri-food exports in 2012.

Table 1: Global ranking of ASEAN countries for agri-food exports, 2012.

Commodity	Ranking in world exports				
	Indonesia	Malaysia	The Philippines	Thailand	Vietnam
Rice	-	-	-	3	2
Sugar	-	-	-	2	-
Palm Oil	1	2	-	-	-
Coffee	3	-	-	-	2
Pineapple	3	4	2	1	-
Pepper	4	6	-		1
Memo item					
Coconut	2		1		
Rubber	2	3		1	

Source: Various sources, including FAO Statistics Online statistics (2012 figures).

Rice

Based on a U.S. Department of Agriculture report[46], top exporters of rice in 2011/2012 were India (10.38 million tonnes [mt]), Vietnam (7.72 mt), Thailand (6.94 mt), Pakistan (3.46 mt), US (3.20 mt), Myanmar (1.36 mt) and Cambodia (0.80 mt) [Table 2]. Meanwhile, ASEAN-4 (namely, Thailand, Vietnam, Myanmar and Cambodia) exported 16.82 mt or 42 per cent of the world's rice export. By contrast, top importers of rice in 2012 were Indonesia (1.96 mt), the Philippines (1.50 mt), Malaysia (1.01 mt), Thailand (0.60 mt) and Singapore (0.36 mt). There were small imports by Brunei Darussalam and Laos as well. The regional rice imports in 2012 totalled around 5.6 mt or only 33 per cent of the ASEAN export surplus. The region had three times coverage (export surplus/imports), which provided a safe margin for deficit ASEAN countries to be given first option in times of crisis. What is more, Myanmar and Cambodia have yet to reach their full production potentials.

Table 2: ASEAN rice trade balances, 2012 (million tonnes).

Country	Export	Import	Surplus (deficit)
Vietnam	7.72	0.10	7.62
Thailand	6.94	0.60	6.34
Myanmar	1.36	Nil	1.36
Cambodia	0.80	Nil	0.80
Indonesia	-	1.96	(1.96)
The Philippines	-	1.50	(1.5)
Malaysia	-	1.01	(1.01)
Singapore	-	0.36	(0.36)

Note: Trade for Brunei Darussalam and Laos were small.
Source: U.S. Department of Agriculture.

Sugar

In 2012, Thailand exported 7.9 mt of raw sugar (equivalent) while the Philippines exported 0.28 mt (Table 3). By contrast, most other ASEAN countries were net importers. For instance, Indonesia imported 3.03 mt, Malaysia 1.72 mt, Cambodia 0.41 mt, Singapore 0.42 mt and Vietnam 0.40 mt, or a total of 5.98 mt of raw sugar was imported by ASEAN member countries in 2012.[47] For sugar, while there was an overall regional surplus, the coverage was only 1.3 times.

Table 3: ASEAN sugar trade balances, 2012 (million tonnes).

Country	Export	Import	Surplus (deficit)
Vietnam	Nil	0.40	(0.40)
Thailand	7.90	0	7.90
Myanmar	Nil	0.03	(0.03)
Cambodia	0	0.41	(0.41)
Indonesia	0	3.03	(3.03)
The Philippines	0.28	Nil	0.28
Malaysia	0.31	1.72	(1.41)
Singapore	0	0.42	(0.42)

Note: Trade for Brunei Darussalam and Laos were small.
Source: U.S. Department of Agriculture.

[46] U.S. Department of Agriculture, 'World rice trade', 10 May 2013.

[47] For more information, see UN Trade Map, http://www.trademap.org/.

Vegetable oils (palm, palm kernel and coconut)

Among vegetable oils, palm oil dominates intra-ASEAN trade. In 2012, Indonesia (22.64 mt) was the top exporter of vegetable oil, followed by Malaysia (19.02 mt), the Philippines (1.14 mt) and Thailand (0.66 mt) [Table 4].[48] For palm oil, ASEAN controls 91 per cent of global exports. The region's palm oil importers were Myanmar (0.58 mt), Vietnam (0.58 mt) and the Philippines (0.30 mt). However, these were small amounts relative to ASEAN supply.

Table 4: ASEAN vegetable oil trade balances, 2012 (million tonnes).*

Country	Export	Import	Surplus (deficit)
Vietnam	Nil	0.58	(0.58)
Thailand	0.66	0.07	0.59
Myanmar	0	0.58	(0.58)
Cambodia	-	-	-
Indonesia	22.64	-	22.64
The Philippines	1.14	0.30	0.74
Malaysia	19.02	1.75	17.27
Singapore	0.18	0.69	(0.51)

Note: Trade for Brunei Darussalam and Laos were small.
*Total of palm, palm kernel and coconut oils.
Source: U.S. Department of Agriculture; author's estimates of Philippine imports.

Coffee

In 2012, Vietnam exported nearly 2.4 mt of mostly Robusta coffee beans, followed by Indonesia (approximately 0.30 mt) [Table 5]. Coffee beans were imported by Malaysia (68,000 tonnes), the Philippines (31,000 tonnes) and Thailand (25,000 tonnes). There is a large surplus of coffee beans in the region.[49] There is also vibrant trade in soluble coffee, mostly in single-serve packs (Table 6).

Table 5: ASEAN coffee beans trade balances, 2012 (thousand tonnes).

Country	Export	Import	Surplus (deficit)
Vietnam	2,395	12	2,387
Thailand	Nil	25	(25)
Myanmar	-	-	-
Cambodia	-	-	-
Indonesia	297	56	241
The Philippines	-	31	(31)
Malaysia	-	68	(68)
Singapore	-	-	-

Note: Trade for Brunei Darussalam and Laos were small.
Source: U.S. Department of Agriculture; author's estimates.

48 U.S. Department of Agriculture, 2012/2013.

49 International Coffee Organization, January–December 2011.

Table 6: ASEAN soluble coffee trade balances, 2012 (thousand tonnes).

Country	Export	Import	Surplus (deficit)
Vietnam	27	15	12
Thailand	44	35	9
Myanmar	-	-	-
Cambodia	-	-	-
Indonesia	150	28	122
The Philippines	0	136	(136)
Malaysia	117	0	117
Singapore	-	-	-

Note: Trade for Brunei Darussalam and Laos were small.
Source: U.S. Department of Agriculture; author's estimates.

Pepper

World production of pepper ranges from 300,000–330,000 tonnes per year. In 2012, Vietnam is estimated to have produced up to 133,000 tonnes of pepper while Indonesia and Malaysia produced 30,500 tonnes and 12,000 tonnes, respectively; these countries accounted for nearly 57 per cent of the global supply of pepper. Global export demand of pepper is around 200,000–225,000 tonnes per year.[50] ASEAN is a major supplier of pepper to the global market, principally to the US, Europe, Japan and Australia[51], and intra-ASEAN trade of pepper is small.

Fish

ASEAN is a major world player in fish exports and has vibrant intra-regional trade in fish products.

Fresh and chilled fish. In 2012, Indonesia and Myanmar were key exporters of fresh and chilled fish (Table 7). Malaysia and Singapore bought half of the exports of Indonesia and over 95 per cent of the exports of Thailand. Myanmar supplied nearly 85 per cent of Thailand's imports. Singapore was a significant buyer of Myanmar's exports in 2010.[52]

Table 7: ASEAN fish (chilled and fresh) trade balances, 2012 (thousand tonnes).

Country	Export	Import	Surplus (deficit)
Vietnam	-	-	-
Thailand	74	76	(2)
Myanmar	152	Nil	152
Cambodia	Nil	Nil	-
Indonesia	92	Nil	92
The Philippines	4	Nil	4
Malaysia	34	105	(71)
Singapore	3	44	(41)

Note: Trade for Brunei Darussalam and Laos were small.
*Myanmar data was for 2010.
Source: UN Trade Map (HS [Harmonized System] 302).

50 For more information, see 'Know pepper', *CommodityOnline.com*, http://www.commodityonline.com/commodities/spices/pepper.php.

51 Ibid.

52 UN Trade Map, op. cit.

Frozen whole fish. Thailand is a big buyer of whole fish for its global canned-tuna industry. In recent years, Thailand has imported nearly 1.3 mt of frozen whole fish annually (Table 8). The fishing fleets of Indonesia, US, Taiwan and Japan supplied nearly half of Thailand's imports of whole fish, with Indonesia alone accounting for nearly 15 per cent of its imports. Meanwhile, China, Japan, Taiwan and Papua New Guinea supplied tuna canneries in the Philippines. Similarly, China and Japan supplied 30 per cent of whole fish imports by Malaysian canneries while Vietnam, Thailand and Indonesia together contributed a total of 20 per cent of Malaysian imports.[53]

Table 8: ASEAN fish (frozen whole) trade balances, 2012 (thousand tonnes).

Country	Export	Import	Surplus (deficit)
Vietnam	70**	60**	10
Thailand	120**	1,330**	(1,210)**
Myanmar	-	-	-
Cambodia	Nil	Nil	-
Indonesia	431	139	292
The Philippines	25	199	(174)
Malaysia	47	115	(68)
Singapore	18	36	(18)

Note: Trade for Brunei Darussalam and Laos were small.
* Thailand's exports for 2012 were estimated.
** e-estimate.
Source: UN Trade Map (HS [Harmonized System] 303).

Frozen cuts and fillets. Vietnam is a global player in basa catfish. In 2012, Vietnam supplied frozen cuts and fillets to Malaysia (48 per cent of imports) and Indonesia (24 per cent of imports). The Philippines, meanwhile, imports close to 60 per cent of its fish from Vietnam. The trade patterns were also similar for Singapore and Thailand. For ASEAN fish trade balances for frozen cuts and fillets in 2012, see Table 9.

Table 9: ASEAN fish (frozen cuts and fillets) trade balances, 2012 (thousand tonnes).

Country	Export	Import	Surplus (deficit)
Vietnam	425*	12*	413
Thailand	80*	30	50*
Myanmar	-	-	-
Cambodia	Nil	Nil	-
Indonesia	91	4	87
The Philippines	11	25	(14)
Malaysia	13	28	(15)
Singapore	5	24	(19)

Note: Trade for Brunei Darussalam and Laos were small.
* e-estimate.
Source: UN Trade Map (HS [Harmonized System] 304).

Prepared fish. Thailand is the leading global player in prepared fish, especially canned tuna, ahead of China and Ecuador, with most of Thailand's prepared fish being exported to countries outside ASEAN. Similarly also for the Philippines, Indonesia and Vietnam, which are the eighth, ninth and 10th largest exporters of prepared fish, respectively. Table 10 presents the ASEAN fish trade balances for prepared fish in 2012.

53 Ibid.

Table 10: ASEAN fish (prepared fish) trade balances, 2012 (thousand tonnes).

Country	Export	Import	Surplus (deficit)
Vietnam	45*	Nil	45
Thailand	801	37	764
Myanmar	-	-	-
Cambodia	0	1	(1)
Indonesia	95	4	91
The Philippines	112	3	109
Malaysia	22	35	(13)
Singapore	9	36	(27)

Note: Trade for Brunei Darussalam and Laos were small.
* e-estimate.
Source: UN Trade Map (HS [Harmonized System] 1604).

Effects of Climate Change

Climate change impact occurs in various forms, such as extreme rains and outbursts resulting in severe flooding, increased frequency of extreme events (such as typhoons and droughts), higher temperature, and rapid sea-level rise. This paper dwells not on the technical aspects of these events but rather on their impact on specific crops.

Extreme events affect not only food supply but also food logistics and farm income. For example, the rare, but disastrous, Typhoon Bopha (local name Pablo) destroyed large areas of farms in Southern Philippines in December 2012. Some 15,000 hectares (ha) of export banana farms and thousands more areas of rubber, coconut and other tree crops were destroyed in the Davao region. Over and beyond that, roads and bridges, schools, hospitals and government buildings were devastated, with damage being estimated at around USD 1 billion. Relief operations were made difficult because of severe damage to the transport network as well.

Similarly, another extreme event (Typhoon Washi), also in the Philippines, that occurred in December 2011 flooded two cities: Cagayan de Oro and Iligan. Several thousand houses and lives were lost in its aftermath. More recently, Typhoon Haiyan, a Category 5 supertyphoon, devastated Central Philippines in November 2013, affecting about 14 million people, displacing some 4.5 million and killing at least 6,000.[54] It also destroyed 33 million coconut trees (or, nearly 330,000 ha of farms) and 30,000 fishing boats.[55]

Crops and temperature rise

According to Lacombe, Chu and Smakhtin,

> …almost all significant human-induced changes in precipitation are anticipated to occur over the sea, not the land. The exception is the increases in rainfall in central and northern Myanmar, which should benefit crop production, as this is the driest area in the region. Cambodia and southern Vietnam may experience small decreases in dry-season precipitation, with negligible consequences for agriculture. Increases in temperature, projected for the whole region in line with global patterns, may even increase crop yields – particularly in the mountains of Yunnan and the northern parts of Thailand, Laos and Myanmar, where short growing seasons currently limit agricultural production.[56]

54 Oxfam International, 'Philippines Typhoon Haiyan – Our response', http://www.oxfam.org/en/emergencies/philippines-typhoon-haiyan.

55 Mark Tran, 'Typhoon Haiyan sends coconut farming "back to year zero"', *The Guardian*, 6 February 2014, http://www.theguardian.com/global-development/2014/feb/06/typhoon-haiyan-coconut-farming-year-zero.

56 Guillaume Lacombe, Chu Thai Hoanh and Vladimir Smakhtin, 'Multi-year variability or unidirectional trends? Mapping long-term precipitation and temperature changes in continental Southeast Asia using PRECIS regional climate model', *Climatic Change* 113, no. 2 (2012): 285–99.

Crops and sea level rise

Sea level rise could have dramatic effects on key rice-producing areas. According to a study by the Center for International Earth Science Information Network (CIESIN) at Columbia University, a 1m sea level rise could displace over 7 million residents in the Mekong Delta while a 2m sea level rise could double that number. The delta, a rice-growing region that spans southern Vietnam, is home to 18 million people. More than half of Vietnam's rice is produced in the delta, as well as 60 per cent of its fish and shrimp.[57] It is very likely that the river deltas of Chao Phraya in Thailand, as well as Salween and Irrawaddy in Myanmar could be affected. It should be noted here that around 1 billion people live in cities and coastal areas that are at risk of sea level rise and coastal flooding, and these figures are expected to rise in the coming decades. Most of the high-risk areas are in Asia.[58]

Climate change and trans-national river conflicts

The Mekong River originates from the Tibetan Plateau and winds 5,000 km to China, Laos, Thailand, Cambodia and Vietnam. Therefore, events of glacier melting and dam building could affect rice supply in the region.

Climate change and food security

Reduction of farm production due to various climate change episodes will affect farm incomes and, in turn, food security. Strong typhoons and consequent flooding will affect rice and other crops in the Philippines and Vietnam, which will disrupt physical access to food supply, both for relief operations and farm input/output logistics. Meanwhile, extended drought and high temperatures could affect water salinity in fishponds, water supply in freshwater ponds and fish migration in the oceans.

The influential Intergovernmental Panel on Climate Change (IPCC), in a report released in April 2014, concluded that climate change is already damaging food production and increasing food prices. Climate change will have further impacts in the future.

Policy Implications

Climate change will certainly impact on food supply and trade in ASEAN. The magnitudes of these impacts, while difficult to quantify, are strategically important and should be monitored.

Some areas of cooperation that need to be pursued are:

- Exchanges in climate change adaptation and mitigation (such as training, and sharing of experiences and best practices).
- Cost-effective design of climate-proofed infrastructure.
- Design of disaster relief and crop insurance.
- Research into drought-tolerant and flood-resistant crops.
- Emergency rice buffer stocks.

57 'Vietnam: Sea-level rise could "displace millions"', *IRIN*, 20 May 2011, http://www.irinnews.org/Report/92763/VIETNAM-Sea-level-rise-could-displace-millions.

58 Suzanne Goldenberg, 'At-risk cities hold solutions to climate change: UN report', *The Guardian*, 11 April 2014, http://www.theguardian.com/environment/2014/apr/11/cities-solution-climate-change-ipcc.

Climate Change Vulnerability of Coastal Food Security

Laura David

Abstract

In Southeast Asia, 270 million people rely on the ocean for 20–40 per cent of their food protein. As a result, resources are heavily subscribed and, in many instances, stretched to the limit. Overfishing and destructive fishing have been identified as the heaviest persistent stressors burdening the ecosystem. Other identified stressors are sedimentation, coastal development and marine pollution.

On top of these existing issues, the oceans of Southeast Asia are now experiencing added pressure from climate change. The aim of this paper is to highlight potential impacts of climate and ocean changes on food security by making use of the different climate change scenarios, as given by the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. This paper focuses on coastal agriculture and fisheries.

Keywords: Climate change adaptation, coastal adaptation, sea level rise, vulnerability

Introduction

Coastal and marine environment climate and ocean changes include changes in intensity and pattern of sea surface temperature (SST), anomalous water budget, sea level, storms, and ocean acidification. Although specific values differ for each of the Special Report on Emissions Scenarios (SRES) in the Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change, all models project that, by 2100, the Western Equatorial Pacific region shall experience significant increases in SST (range, 1–4°C). Prolonged drought and intense episodic rainfall is also a likely scenario (with increase in variability as well). Models also agree that storms will become more intense although there is no consensus on changes in frequency or storm tracks. It needs to be noted that this climate of the region is strongly affected by ENSO (El Niño southern oscillation) and Pacific decadal oscillation (PDO) events, and the AR4 SRES models do not have a verdict on how patterns of ENSO and PDO events will change. The AR4 conservatively estimated global sea level rise at 30–60 cm, with the Western Equatorial Pacific region likely to experience higher than global estimates. Ocean pH is globally projected to increase 0.3–0.4 units by 2100. It is pertinent to note that, since the AR4 SRES are global simulations, consequent projection responses of ocean organisms are rendered robust only over long time periods (by 2050–2100) and broad areas (regional to global).

Coastal populations rely heavily on coastal agriculture and fisheries not only as food resource but also in terms of livelihood. Rice, corn and vegetables are staple lowland commodities while fish constitutes 25–45 per cent of dietary protein in these regions, which are all vulnerable to climate and ocean changes. Also, as artisanal fishers are typically seasonal farm hands and vice versa, the impact on the productivity of these commodities will have significant impact on coastal livelihoods too.

Coastal agriculture will experience significant impacts through changes in rainfall temporal pattern, storm events and sea level rise. Changes in rainfall directly affect agriculture due to access to irrigation water since, in most areas, there are currently no provisions for severe prolonged drought. Flooding may also affect agricultural produce in at least two different ways: (i) by destroying the harvestable goods; and, (ii) by restricting the transport of products from farm to market. Flooding may happen due to anomalous rainfall, storm events or sea level rise. Storm surge and sea level rise will have the additional consequence of making arable land salty, thus rendering it a hostile environment for agricultural crops. Additionally, where topography is low and there is high dependence on groundwater extraction, sea level rise can have long-term effects due to salt-water intrusion into groundwater. Mitigation of already contaminated groundwater, where possible, can, however, be very costly. Agricultural failure may thus lead to movement of farmers to coastal areas, creating additional pressure on coastal fisheries.

Impact on Fisheries and Marine Environment

Fisheries will be affected by changes in rising ocean temperatures and by extreme rainfall events. In addition, fishes will also be affected if their habitat health is compromised due to changes in rising ocean temperatures, storm events, sea level rise and ocean acidification.[59]

Specifically for the marine environment, slow but persistent change in temperature has been associated with consequences to distribution limits of certain flora or fauna[60] and linked to changes in the timing of spawning events[61]. Temperature-sensitive species will likely adapt to warming waters by migrating to higher latitudes or deeper waters where temperatures will still be conducive. For those that cannot migrate, predictions suggest that reproduction will be negatively affected and recruitment failures also be likely[62], resulting in decline of local fish populations. For species that cannot migrate or adapt to changes in temperature, local extinction is likely.

Pelagic fisheries are also not climate proof. Where upwelling is the main process driving the aggregation of target species, climate-related disturbance has been shown to have significant impact. This is the case, for example, for the sardine fisheries of Southern Philippines, where extreme rainfall limits surface manifestation of the upwelling near the coast and significantly reduces sardine fish catch.[63] Changes in fish distribution and availability can lead to decrease in catch per unit effort and consequently increased fish prices or choice of target species.

Extreme rainfall can also impact coastal habitat health due to nutrient input. High nutrient input could cause changes in water quality, triggering algal blooms, which can then contribute to water turbidity, anoxia and toxicity depending on the algal species. Anoxia and toxicity can cause massive fish kills.[64]

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59 Adel Heenan, Robert Pomeroy and Rusty Brainard, eds, *Incorporating climate and ocean change into an ecosystem approach to fisheries management (EAFM) plan* (Honolulu: The USAID Coral Triangle Support Partnership, 2013).

60 M. L. Cambridge, A. M. Breeman and C. van den Hoek, 'Temperature limits at the distribution boundaries of four tropical to temperate species of *Cladophora* (Cladophorales: Chlorophyta) in the North Atlantic ocean', *Aquatic Botany* 38, nos. 2–3 (1990): 135–51; Kevin J. Gaston, 'Global patterns in biodiversity', *Nature* 405 (2000): 220–7; Juan P. Carricart-Ganivet, 'Sea surface temperature and the growth of the West Atlantic reef-building coral *Montastraea annularis', Journal of Experimental Marine Biology and Ecology 302*, no. 2 (2004): 249–60.

61 J. R. Wilson and P. L. Harrison, 'Spawning patterns of scleractinian corals at the Solitary Islands – a high latitude coral community in eastern Australia', *Marine Ecology Progress Series* 260 (2003): 115–23.

62 Ned W. Pankhurst and Philip L. Munday, 'Effects of climate change on fish reproduction and early life history stages', *Marine and Freshwater Research* 62, no. 9 (2011): 1,015–26.

63 Olivia C. Cabrera et al., 'Barrier layer control of entrainment and upwelling in the Bohol Sea, Philippines', *Oceanography* 24, no. 1 (2011): 130–41; doi:10.5670/oceanog.2011.10.

64 Laura T. David et al., 'The saga of community learning: Mariculture and the Bolinao experience', *Aquatic Ecosystem Health & Management* 17, no. 2 (2014): 196–204; doi: 10.1080/14634988.2014.910488.

Mangrove forests, seagrass meadows and coral reefs are refuge for the adults and nursery grounds for the young. Coral reefs are highly susceptible to degradation from increases in ocean temperature (coral bleaching), physical damage from stronger storms and reduced calcification due to ocean acidification.[65] Loss of coral cover typically results in the decline of smaller-bodied coral-associated fishes that are dependent on the structure of the reef habitat for shelter.[66] Only the small generalist species and rubble-dwellers are expected to increase in abundance on degraded coral reefs.[67] These species are generally not utilised as food fish.

More intense storms and sea level rise are likely to impact seagrass meadows. Intense storms bring about increased nutrient and sedimentation from the watershed and increased energy of incoming waves. High nutrient input can be good for seagrass, as these meadows are known to be nutrient poor. However, increased sedimentation can bury seagrass meadows or, at the very least, leave the water murky for extended periods of time, which will compromise seagrass productivity. Intense storms, on the other hand, are likely to uproot shallow water seagrass meadows.[68] In addition, sea level rise is expected to lead to a loss of deep-water seagrass habitats present at the edge of their depth limits due to light availability.[69] The combined effect will lead to a thinning of the meadows and a decrease in seagrass species diversity. Where fisheries are concerned, seagrass-related fisheries, such as that of rabbit fish and prawns, will be impacted. It will also have a cascade effect on larger target fish since seagrass meadows provide food for these higher trophic levels.

Storms and associated storm surge were recently documented to defoliate and damage mangrove stands. Sea level rise is also likely to have the most significant impact on mangrove habitats. Old tall mangroves that are taller than the average tree line are the ones most likely to suffer from the passage of high winds. Seedlings may also become buried under storm-associated sedimentation. Seaward seedlings will suffer from lack of ample sunlight due to higher sea levels while adults that are only salinity tolerant for short periods of time (typically located more shoreward) will also suffer from prolonged exposure to seawater. However, over the longer term, the impacts of sea level rise need not necessarily be negative, provided shoreward migration is possible.[70] If not, similar to the impact on seagrasses, mangroves forests will thin out and loss of diversity is likely.

There are also particular economically important species that require the presence of all three coastal habitats to be sustainable, such as groupers.

As habitat health is degraded due to climate change, larger predators will also be affected. This can happen in two ways. First, both pelagic and demersal predators also use the mangroves, seagrass and corals as nursery grounds. Hence, their populations will also be compromised, as

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65 Philip L. Munday et al., 'Climate change and the future for coral reef fishes', *Fish and Fisheries* 9, no. 3 (2008): 261–85; Morgan S. Pratchett et al., 'Vulnerability of coastal fisheries in the tropical Pacific to climate change', in *Vulnerability of tropical Pacific fisheries and aquaculture to climate change*, eds Johann D. Bell, Johanna E. Johnson and Alistair J. Hobday (Noumea: Secretariat of the Pacific Community, 2011), 493–576; T. P. Hughes et al., 'Climate change, human impacts, and the resilience of coral reefs,' *Science* 301, no. 5635 (2003): 929–33; Ove Hoegh-Guldberg et al., 'Vulnerability of coral reefs in the tropical Pacific to climate change', in *Vulnerability of tropical Pacific fisheries and aquaculture to climate change*, op. cit., 251–96.

66 Nicholas A. J. Graham et al., 'Climate warming, marine protected areas and the ocean-scale integrity of coral reef ecosystems', *PLoS ONE* 3, no. 8 (2008): e3,039.

67 David R. Bellwood et al., 'Coral bleaching, reef fish community phase shifts and the resilience of coral reefs', *Global Change Biology* 12, no. 9 (2006): 1,587–94.

68 Frederick T. Short, 'Effects of sediment nutrients on seagrasses: Literature review and mesocosm experiment', *Aquatic Botany* 27, no. 1 (1987): 41–57.

69 Michelle Waycott et al., 'Vulnerability of mangroves, seagrasses and intertidal flats in the tropical Pacific to climate change', in *Vulnerability of tropical Pacific fisheries and aquaculture to climate change*, op. cit., 297–368.

70 Ibid.

the habitats get degraded. Second, as the smaller habitat-affiliated fishes are compromised, the predators may end up migrating to more bountiful, cooler and deeper areas. This will tax small-scale fishermen who have limited mobility.

Importance of Mariculture in Adaptation

An alternative food resource is mariculture, which is a more controlled environment. However, experience has shown that this is not climate-proof either. Anomalous warming of ocean water affects the oxygen content of the water and has historically resulted in massive fish kills within mariculture sites.[71] Increase in surface ocean temperatures might also abet the formation of algal blooms, which impact aquaculture either due to their toxic nature or by further reducing the water's oxygen content. Increase in the intensity of storms might also compromise the integrity of the mariculture structures themselves, with floods bringing debris-laden rushing waters. Lastly, ocean acidification is also likely to compromise large-scale commercial shellfish culture.

In summary, SST, anomalous water budget, sea level rise, more intense storms and ocean acidification will have predominantly negative impacts on coastal agriculture and fisheries in Southeast Asia. Appropriate adaptation to temperature will include experimenting with temperature-tolerant mariculture species and reviewing the location of mariculture areas. Anomalous water budget will require drought/flood/salt-tolerant agriculture staples and a review of the way groundwater is used, especially in agriculture. Most importantly, climate adaptation for food security will entail coastal habitat protection since degradation of these refuge and nursery grounds could prove to be a factor with far-reaching consequences for food security. This requires ecosystem-based management that extends from the watershed ridge to the edge of coral reefs. Specifically, there should be focus on addressing identified persistent stressors of the coastal systems of Southeast Asia, such as sedimentation, unregulated and inappropriate coastal development, marine pollution, and destructive fishing.

Adaptation to climate to address food security will be a resource-heavy endeavour. However, this has to be done in order to continue providing food for a population of over 270 million in Southeast Asia that relies on the ocean for 20–40 per cent of its food protein. It should be noted though that vulnerability of coastal areas to global environmental changes is site specific. It depends on the amount of exposure an area has, the resources available in the area and the ability of affected communities to cope with such changes. Therefore, any adaptation measure should be tailor fitted for the specific area, and no single recipe can be applied to the entire region.

[71] David et al., 'The saga of community learning', op. cit.

Climate Change Impact on Food Security in ASEAN

Rizaldi Boer and Kiki Kartikasari

Abstract

This paper highlights current research and studies on climate change, including natural hazard impacts, and discusses the different types of climate change impacts on food security in the Southeast Asian region. The authors propose three types of impacts: continued impacts, discontinued impacts and permanent impacts.

Keywords: ASEAN, climate change impacts, food demand, food security

Introduction: Observed and Projected Climate Change in Southeast Asia

Most ASEAN countries are located along the coastlines and a few of them are archipelagic. Due to geological and geographic factors, ASEAN is also one of the world's most vulnerable regions to a range of climatic and natural hazards, such as earthquakes, typhoons, sea level rise, volcanic eruptions, droughts, heat waves and tsunamis, that are becoming more frequent and severe. According to the Stern Review[72] and Intergovernmental Panel on Climate Change (IPCC)[73], Southeast Asia is one of the world's most vulnerable regions to climate change due to its long coastlines, high concentration of population and economic activity in coastal areas, and heavy reliance on agriculture, fisheries, forestry and other natural resources.

Historical data clearly shows that global temperatures have increased consistently despite the rate of increase being quite varied between regions. In all ASEAN countries, average temperature has increased between 0.1–0.3°C per decade over the last 50 years.[74] There is also some evidence that average temperature increase has become more pronounced in recent years when compared to the previous century.[75] Sea level rise was also observed in many ASEAN country stations. In Indonesia, the relative sea level rise has ranged from 1–10 mm/year.[76] In Vietnam, during the period 1960–2000, sea level rise at the Hon Dau station in northern Vietnam was around 1.9 mm/year.[77] In the Mekong Delta, based on data from the Vung Tau tide gauge, relative sea level rise was 6 mm/year.[78]

The frequency and intensity of extreme climate events (ECEs) have tended to increase in many parts of the world, including in Southeast Asian countries. In the Philippines, during the 1951–2008 period, the frequency of extreme daily rainfall showed an increasing trend in most parts of the country although this was not significant everywhere. Reports suggest that extreme weather events now occur in places where historically they did not. The most

72 Nicholas Stern, *The economics of climate change* (London: HM Treasury, Cabinet Office, 2006), http://www.hm-treasury.gov.uk/sternreview_index.htm.

73 Intergovernmental Panel on Climate Change (IPCC), 'Summary for policymakers', in *Climate Change 2007: The physical science basis*, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, eds Susan Solomon et al. (Cambridge, UK and New York: Cambridge University Press, 2007).

74 Ibid.

75 James Hansen et al., 'Global temperature change', *Proceedings of the National Academy of Sciences of the United States of America* 103, no. 39 (2006): 14,288–93.

76 Ministry of Environment (MoE), Republic of Indonesia, *Indonesia country report: Climate variability and climate change, and their implication* (Jakarta: MoE, Republic of Indonesia, 2007).

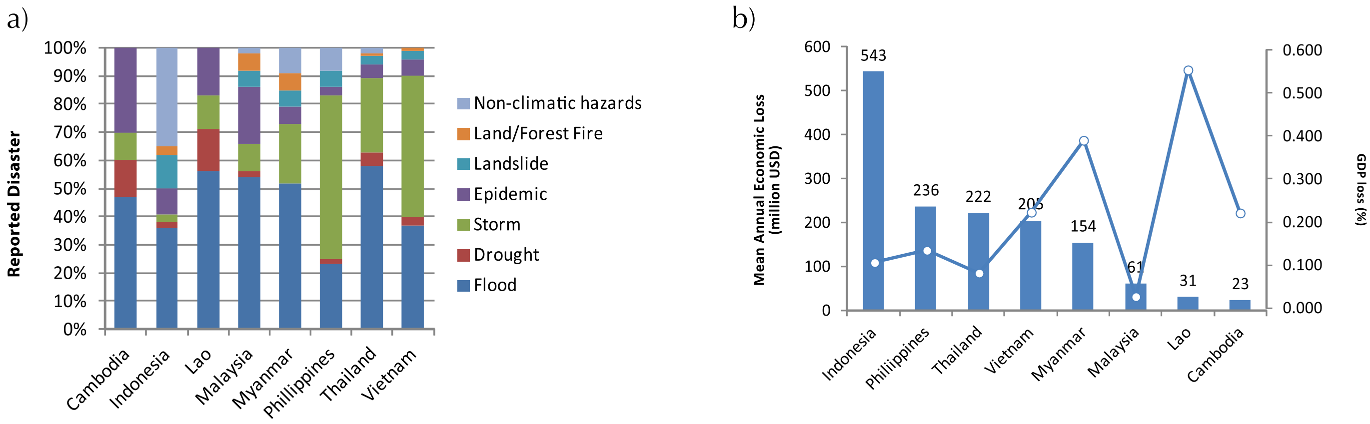
77 Pham Thi Thuy Hanh and Masahide Furukawa, 'Impact of sea level rise on coastal zone of Vietnam', *Bulletin of the Faculty of Science, University of the Ryukyus* 84 (2007): 45–59.

78 James Syvitski, 'Deltas at risk', *Sustainability Science* 3, no. 1 (2008): 23–32; James Syvitski et al., 'Sinking deltas due to human activities', *Nature Geoscience* 2, no. 10 (2009): 681–6.

prevalent ECEs vary across the ASEAN countries. Storms are the main ECE in the Philippines and Vietnam while floods are common in all countries (Figure 1a). Disaster data over 40 years (1970–2009 period) suggest that mean annual economic losses due to five climate hazards (namely, storm, flood, landslide, drought and fire) in ASEAN countries vary from USD 23–543 million, which is equivalent to gross domestic product (GDP) losses of between 0.02–0.50 per cent[79] (Figure 1b) in the form of crop failures and damage to infrastructure.

A number of studies have shown evidence of the shortening of the return periods for extreme rainfall events connected with global warming.[80] If an extreme event with return period of 40 years occurs once within the next 20 years, the economic loss would increase by 5.4 per cent (equivalent to about USD 10 million) from current levels.[81]

Figure 1: (a) Natural disasters and (b) mean annual economic and gross domestic product losses due to five climate related hazards (storm, flood, landslide, drought and fire) in eight ASEAN countries.



GDP = gross domestic product

Note: [sic: read Philippines, Laos, Land/forest fire].

79 S. Gupta, *Synthesis report on ten ASEAN countries disaster risks assessment: ASEAN Disaster Risk Management Initiative* (Bangkok: UNISDR and World Bank, 2010).

80 For example, see Peter Urich et al., 'Analysis of the January 2011 extreme precipitation event in the Brisbane River Basin' (CLIMsystems Technical Report, Hamilton: CLIMsystems Ltd, 2011); Asian Development Bank (ADB), 'Addressing climate change in Asia and the Pacific: Priorities for action' (Manila: ADB, 2010).

81 Based on Gupta, *Synthesis report on ten ASEAN countries disaster risks assessment*, op. cit.

Previous studies have estimated that global warming may increase the frequency and intensity of ECEs. Knutson et al. predicted that greenhouse warming would cause the globally averaged intensity of tropical cyclones to shift towards stronger storms, with intensity increases of 2–11 per cent by 2100.[82] However, at the same time, many modelling studies consistently project decreases in the globally averaged frequency of tropical cyclones in the range of 6–34 per cent, too. Thus, global warming would substantially increase the frequency of the most intense cyclones. It has been predicted that the precipitation rate within 100 km of a storm centre would increase to the order of 20 per cent from current levels. Changes in the intensity of tropical cyclones would have severe impacts on the Philippines, Vietnam, Laos, Myanmar and Thailand. The Philippines will be the most affected country.

ECEs associated with ENSO (El Niño southern oscillation) have also been predicted to increase due to global warming. Timmerman et al. suggest that greenhouse forcing and warmer conditions linked to it will result in 'more frequent El Niño-like conditions and stronger cold events (La Niña)'.[83] Hansen et al. found that, over recent years, El Niño events have become more frequent because global temperature anomalies associated with each El Niño have continued to increase.[84] In some ASEAN countries, extreme drought years are usually associated with the occurrence of El Niño while wet years are associated with La Niña. Although most ASEAN countries will be affected by ENSO events, Indonesia would be most severely affected by its increasing intensities. The future course of ENSO events, however, is yet uncertain, as climate models disagree on this aspect. While some suggest that ENSO cycles will become more intense, others state these are likely to become less so or even see little change.

Detailed studies on how global warming will change ECEs in ASEAN in the future are scarce. Among the few studies that are available, most are on long-term basis (up to 2100). As the warming atmosphere is the driver of climate change, increases in the global temperature within the timeframe of the present study (2010–2030 period) may not be high enough to cause drastic changes in extreme climate. Thus, we found that the occurrence of future ECEs within

82 Thomas R. Knutson et al., 'Tropical cyclones and climate change', *Nature Geoscience* 3 (2010): 157–63.

83 A. Timmerman et al., 'Increased El Niño frequency in a climate model forced by future greenhouse warming', *Nature* 398 (1999): 694–7.

84 Hansen et al., 'Global temperature change', op. cit.

the 2010–2030 timeframe is likely to be the same as current levels. Nevertheless, a number of studies have found evidence suggesting a shortening of return periods for extreme rainfall events connected with global warming,[85] and this would have big implications for planning and decision-making with regard to durable infrastructure and emergency services, as well as land use regulation and building codes.

Climate Change Impacts on Agriculture and Food Security in ASEAN

Among other traditional factors, a whole body of literature indicates that climate change is threatening agriculture and food security.[86] The impacts of climate change could be adverse or favourable. For example, the opportunity for cultivating new crops and varieties will emerge in several Northern hemisphere countries under a warmer climate.[87] To the contrary, adverse impacts, such as yield decrease, are also projected to occur in some countries, especially in those with little technological intervention in agriculture production. Given that ASEAN plays a significant role in world food supply as home to some of the important exporting countries of major food crops, such as rice and sugarcane[88], the threat of climate change to agriculture in the region has long been a priority.[89]

Climate change affects agriculture and food security directly and indirectly. Indirect impacts are mainly on the production component and include, for example, changes in the severity of pests and diseases, damage to irrigation infrastructure, etc. Indirect impacts on food consumption are also relevant in the sense that climate change (climate hazards) will reduce GDP, which will eventually influence the calorie intake and consumption behaviour of affected populations. Direct impacts are mainly on crop production and distribution systems. The direct impacts through which climate change will influence agriculture and food security can be categorised as continuous, discontinuous and permanent impacts.

85 For example, see Urich et al., 'Analysis of the January 2011 extreme precipitation event in the Brisbane River Basin', op. cit.; Asian Development Bank, 'Addressing climate change in Asia and the Pacific', op. cit.

86 William W. L. Cheung et al., 'Large-scale redistribution of maximum fisheries catch potential in the global ocean under climate change', *Global Change Biology* 16 (2010): 24–35; Domenico Ventrella et al., 'Agronomic adaptation strategies under climate change for winter durum wheat and tomato in southern Italy: Irrigation and nitrogen fertilization', *Regional Environmental Change* 12, no. 3 (2012): 407–19; M. L. Parry et al., 'Effects of climate change on global food production under SRES emissions and socio-economic scenarios', *Global Environmental Change* 14, no. 1 (2004): 53–67; Thomas W. Hertel, Marshall B. Burke and David B. Lobell, 'The poverty implications of climate-induced crop yield changes by 2030' (GTAP Working Paper No. 59, West Lafayette: GTAP [Global Trade Analysis Project], 2010); Gerald C. Nelson et al., 'Food security and climate change: Challenges to 2050 and beyond' (IFPRI Issue Brief 66, Washington, D.C.: International Food Policy Research Institute [IFPRI], 2010); Marco Bindi and Jørgen E. Olesen, 'The responses of agriculture in Europe to climate change', *Regional Environmental Change* 11, no. 1 suppl (2011): 151–8; Bipul Chatterjee and Manbar Khadka, eds, *Climate change and food security in South Asia* (Jaipur: CUTS International, 2011); Sir John Beddington et al., 'Achieving food security in the face of climate change: Final report from the Commission on Sustainable Agriculture and Climate Change' (Copenhagen: CGIAR Research Program on Climate Change, Agriculture and Food Security [CCAFS], 2012).

87 Reidsma P., 'Adaptation to climate change: European agriculture' (PhD dissertation, Wageningen: Wageningen University, 2007).

88 Food and Agriculture Organization of the United Nations (FAO), *FAO statistical yearbook 2012: World food and agriculture* (Rome: FAO, 2012), http://faostat.fao.org/default.aspx.

89 R. Wassmann et al., 'Climate change affecting rice production: The physiological and agronomic basis for possible adaptation strategies', *Advances in Agronomy* 101 (2009): 59–122; Suzanne K. Redfern, Nadine Azzu and Jesie S. Binamira, 'Rice in Southeast Asia: Facing risks and vulnerabilities to respond to climate change', in *Building resilience for adaptation to climate change in the agriculture sector*, Proceedings of a joint FAO/OECD workshop, eds Alexandre Meybeck et al. (Rome: Food and Agriculture Organization of the United Nations [FAO] and Organisation for Economic Co-operation and Development [OECD], 2012), http://www.fao.org/docrep/017/i3084e/i3084e.pdf.

Continuous impacts

Studies on the continuous impact of climate change on crop production are plenty and range from the global to local levels. Continuous impacts are mainly through changes in temperature, rainfall intensity, the onset and length of seasons, salt intrusion and increasing concentration of carbon dioxide (CO^2) in the atmosphere. Increasing temperatures will generally benefit crops that grow under optimum temperatures by causing them to grow faster. However, for several crops, such as cereals, faster growth will mean less time for the grain filling period, resulting in yield reduction.

Masutomi et al. found that changes in rice yield across ASEAN countries due to continuous impacts of climate change range from 1.5–2.3 per cent.[90] This estimate is not much different from some other studies.[91] With a slight temperature increase of around 0.5°C, rice yield would decrease by about 3.2 per cent. According to Easterling et al., on account of the continuous impact of climate change in the event of a temperature increase of less than 1°C, rice yield in tropical countries would decrease by only around 2 per cent.[92] The Food and Agriculture Organization of the United Nations (FAO) has predicted that the rice yield decrease in Vietnam (Mekong River Delta) in 2020 would be between -0.25 per cent and -3.71 per cent.[93] By 2050, rice yield decrease due to global warming is expected to increase to between -1.71 per cent and -12.48 per cent.

[90] Yuji Masutomi et al., 'Impact assessment of climate change on rice production in Asia in comprehensive consideration of process/parameter uncertainty in general circulation models', *Agriculture Ecosystem Environment* 131, nos. 3–4 (2009): 281–91.

[91] For example, see S. S. Mathauda et al., 'Impact of projected climate change on rice production in Punjab (India)', *Tropical Ecology* 41, no. 1 (2000): 95–8.

[92] William Easterling et al., 'Food, fibre and forest products', in *Climate change 2007: Impacts, adaptation and vulnerability*, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, eds Martin Parry et al. (Cambridge, UK, and New York: Cambridge University Press, 2007), 273–313.

[93] Food and Agriculture Organization of the United Nations (FAO), *The state of world fisheries and aquaculture*, 2012 (Rome: FAO, 2012), http://www.fao.org/docrep/016/i2727e/i2727e00.htm.

Changes in the onset and length of the rainy season will hinder the opportunity to improve planting intensity in the future. For instance, Naylor et al. have projected that global warming would increase the probability of monsoon delay and changes in the annual cycle of rainfall in the Java-Bali main rice-growing area of Indonesia.[94] These authors found that there would be a significant increase in the probability of a 30-day delay in monsoon onset in 2050 for these islands. A 30-day delay in monsoon onset would reduce planting area for the rainy season, potentially reducing rice production in Java and Bali by up to 14 per cent. However, the impact of global warming on season length, in general, could be opposite to what would happen in Java and Bali elsewhere.

Changes in temperature, rainfall and season, to a certain extent, also cause changes in pest and disease severity. A higher temperature increases the pressure from weeds, diseases and insect pests.[95] Elevated temperature increase the survival rate of pests, leading to higher initial inoculums of many pathosystems, while precipitation and season changes will influence spatial distribution, transmission intensity and transmission period of vector-borne diseases.[96] A number of country-specific studies have reported these impacts. For instance, in Indonesia, brown planthopper populations usually increase when rainfall in the transitional season is higher than normal.[97] Changes in cropping patterns as part of adaptation efforts to climate change may also alter crop pest and disease problems in the region. Invasion by new types of pests and diseases are likely to occur in a changing climate. Changes in temperature and rainfall may also modify the domination of certain crop pests and diseases. Field observations in a number of districts of Java in Indonesia (such as Indramayu, Magelang, Semarang, Boyolali, Kulonprogo and Ciamis) provide evidence of this phenomenon.[98]

Salt intrusion affects both vegetative and reproductive phases of crops, and different crops respond differently to salinity. Rice ranks among the most sensitive crops to salinity, especially in its reproductive phase.[99] Salinisation also influences soil quality and may create a nutritional disorder to crop growth.

94 Rosamond L. Naylor et al., ‘Assessing risks of climate variability and climate change for Indonesian rice agriculture’, *Proceedings of the National Academy of Sciences of the United States of America* 104, no. 19 (2007): 7,752–7.

95 U.S. Global Change Research Program (USGCRP), *Global climate change impact in the United States: Agriculture* (New York: Cambridge University Press, 2009), http://nca2009.globalchange.gov/ agriculture; Curtis Petzoldt and Abby Seaman, ‘Climate change effects on insects and pathogens’, in *Climate change and agriculture: Promoting practical and profitable responses*, eds University of Vermont Extension, New York State College of Agriculture and Life Sciences (Geneva and New York: New York State IPM Program, New York State Agricultural Extension Station, 2006), http://www.climateandfarming.org/pdfs/FactSheets/III.2Insects.Pathogens.pdf.

96 V. Kudela, ‘Potential impact of climate change on geographic distribution of plant pathogenic bacteria in Central Europe’, *Plant Protection Science* 45 (2009): S27–S32; Rayees A. Ahanger et al., ‘Impact of climate change on plant diseases’, *International Journal of Modern Plant & Animal Sciences* 1, no. 3 (2013): 105–15.

97 Ministry of Environment, Republic of Indonesia, *Indonesia country report*, op. cit.

98 Nastari Bogor dan Klinik Tanaman IPB, *Laporan Safari Gotong Royong Sambung Keperluan untuk Petani Indonesia di 24 Kabupaten-Kota di Pulau Jawa 4 April–2 Mei 2007* [Bahasa Indonesia] (Yayasan Nastari Bogor-Klinik Tanaman IPB, 2007).

99 Maas E. V. and Grattan S. R., ‘Crop yields as affected by salinity’, in *Agricultural drainage*, eds R. W. Skaggs and J. van Schilfgaarde (Agronomy Monograph No. 38, Madison: American Society of Agronomy, Crop Science Society of America and Soil Science Society of America, 1999), 55–108.

Increasing concentration of CO^2 in the atmosphere under a changing climate tends to increase the rate of photosynthesis for many crops, especially for C3 plant species, such as rice.[100] Increasing concentration of CO^2 induces plants to be more water efficient. However, some crops do not necessarily benefit from this scenario, as the harvested products are often less nutritious, that is, have lower nitrogen and protein contents.[101]

Discontinuous impacts

Discontinuous impacts of climate change are mostly a result of increasing ECEs, such as floods or droughts, leading to increasing crop failures. A number of studies have suggested that global warming would exacerbate the intensity and frequency of ECEs in the long term (for e.g., by 2100). Slight changes in the frequency (for e.g., an event with a return period of 30 years could change into one with a 20-year return period) and intensity of extreme events within the shorter timeframe may also emerge. Much like the paucity of quantitative studies on the impact of climate change in terms of the increasing intensity and frequency of ECEs in ASEAN, studies on its impact on agriculture and food security in the region are even more scarce.

Permanent impacts

Permanent impacts are irreversible conditions caused by climate change, such as the loss of arable land in coastal areas due to sea level rise. While the rise in sea level within the 2010–2020 timeframe or by 2050 would not significantly result in permanent inundation of agriculture land in ASEAN countries, it may worsen the salinity problem (or, continuous impact), resulting in yield reduction.[102] In addition, low increase in sea level rise within the study's timeframe may increase the probability of coastal areas being exposed to damaging storm surges (or, discontinuous impacts). These potential impacts were also excluded due to the limited information available for ASEAN countries.

A number of studies assume sea level rise of 100 cm, which is expected to occur by 2100.[103] According to Gommes et al., a 1m sea level rise would lead to a

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100 Andrew D. B. Leakey, 'Rising atmospheric carbon dioxide concentration and the future of C4 crops for food and fuel', *Proceedings of the Royal Society Biological Sciences* 276, no. 1666 (2009): 2,333–43; Elizabeth A. Ainsworth, Alistair Rogers and Andrew D. B. Leakey, 'Targets for crop biotechnology in a future high-CO2 and high-O3 world', *Plant Physiology* 147, no. 1 (2008): 13–19; B. A. Kimball and S. B. Idso, 'Increasing atmospheric CO2: Effects on crop yield, water use and climate', *Agricultural Water Management* 7, nos. 1–3 (1983): 55–72.

101 U.S. Global Change Research Program, *Global climate change impact in the United States*, op. cit.

102 Redfern, Azzu and Binamira, 'Rice in Southeast Asia', op. cit.

103 S. Jevrejeva, J. C. Moore and A. Grinsted, 'How will sea level respond to changes in natural and anthropogenic forcings by 2100?' Geophysical Research Letters 37, no. 7 (2010); L07703, doi:10.1029/2010GL042947; Stefan Rahmstorf, 'A semi-empirical approach to projecting future sea-level rise', Science 315, no. 5810 (2007): 368–70; Hannah Förster et al., 'Sea-level rise in Indonesia: On adaptation priorities in the agricultural sector', Regional Environmental Change 11 (2011): 4,893–904.

loss of 12–15 per cent of agricultural land.[104] Forster et al. have predicted that the area of agriculture land in Indonesia that would be permanently inundated due to sea level rise of 1 m was around 120,446 hectares (ha), which would be equivalent to rice production losses of about 885,430 tonnes (or, 1.5 per cent of national production).[105] The Ministry of Natural Resources and Environment (MONRE) of Vietnam has projected a sea level rise of about 0.65–1m in Vietnam by 2100, relative to the baseline period of 1980–1999, based on the high-emission A1FI scenario of the IPCC.[106] However, the increase of sea level within the 2010–2020 timeframe is predicted to be around 11–28 cm (SRESB1).[107] Under new emission scenarios (or, representative concentration pathways [RCPs]), by 2100, sea level rise is projected to be between 0.57–1.10 m.[108]

Projections from existing studies indicate that less risk is to be envisaged within a short timeframe, such as by 2020 or 2050. However, in the longer term, the impact is much more severe and the adaptation will be costly if action is taken too late. This is important to understand, as decisions being made soon or before 2050 will last beyond 2050 and be impacted by these more severe impacts (for e.g., infrastructure being planned today is expected to be effective towards the end of the century). For this to happen, climate change over a longer timeframe needs to be taken into account. Infrastructure designed for impacts up to 2050 in mind, but expected to be effective for much longer, are likely to become dysfunctional during their lifetime (for e.g., irrigation and other water management infrastructure, roads, processing plants, storage facilities, etc.). This indicates an urgent need to think beyond the 2050 policy time horizon, which typically is related with shorter timeframes when it comes to the impact of climate change on decisions.

104 Gommes R. et al., Potential impacts of sea-level rise on populations and agriculture (Food and Agriculture Organization of the United Nations, Sustainable Development Dimension, 1998), www.fao.org/WAICENT/FAOINFO /SUSTDEV/Eldirect/Elre0045.htm.

105 Förster et al., 'Sea-level rise in Indonesia', op. cit.

106 Ministry of Natural Resources and Environment of Vietnam (MONRE), 'Climate change, sea level rise scenarios for Vietnam' (Hanoi: MONRE, 2009).

107 Ibid.

108 S. Jevrejeva, J. C. Moore and A. Grinsted, 'Sea level projections to AD2500 with a new generation of climate change scenarios', Global and Planetary Change 80–81 (2012): 14–20.

Global Food Demand

Looking at 2030 and beyond, FAO indicates that world cereals per capita consumption is expected to decline from an average of 165 kg in 1999/2001 to 162 kg in 2050.[109] However, net trade in most of the countries is projected to remain in the negative, implying that this decline in per capita consumption will not be followed by significant increase in production to achieve a positive balance between supply and demand for a country. The study also highlighted that the world average of self-sufficiency rate will decline from 101 per cent in 1999/2001 to 100 per cent in 2050 while that specifically for developing countries is projected to decline from 91 per cent in 1999/2001 to just 86 per cent in 2050. Self-sufficiency rate represents the ratio of production and domestic demand. Given that Southeast Asia is the production centre of major agricultural products, the growth of its production capacities will affect world supply. It is necessary to sustain the surplus of agricultural production in ASEAN countries to at least maintain self-sufficiency within the region.

In the near term, climate change impact may not seem to be a very urgent and high-priority issue yet. However, it is likely to put us at the risk of significant losses later and may even lead to maladaptation. Early actions would reap benefit at later stages. As Asian Development Bank has reported, the annual benefit in terms of avoided climate change is likely to exceed the annual cost of adaptation after 2050.[110] The study also identified the annual cost of adaptation for agriculture and coastal zones to be around USD 5 billion by 2020.

[109] Food and Agriculture Organization of the United Nations (FAO), *World agriculture: Towards 2030/2050*, Interim report: Prospects for food, nutrition, agriculture and major commodity groups (Rome: Global Perspective Studies Unit and FAO, 2006).

[110] Asian Development Bank (ADB), *The economics of climate change in Southeast Asia: A regional review* (Manila: ADB, 2009), 224.

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