ISEAS YUSOF ISHAK INSTITUTE

ISSUE: 2023 No. 53

ISSN 2335-6677

PERSPECTIVE

RESEARCHERS AT ISEAS – YUSOF ISHAK INSTITUTE ANALYSE CURRENT EVENTS

Singapore | 12 July 2023

Rice Production and Food Security in Southeast Asia under Threat from El Niño

*Elyssa Ludher and Paul Teng**

Farmers are joined by children helping to harvest rice in a field in the southern Thai province of Narathiwat on 27 March 2023. (Photo by Madaree TOHLALA/AFP).

** Elyssa Ludher is Visiting Fellow and Professor Paul Teng is Associate Senior Fellow at the Climate Change in Southeast Asia Programme at ISEAS - Yusof Ishak Institute, Singapore. Professor Teng is also Dean and Managing Director of NIE International, Nanyang Technological University Singapore.*[1]

ISSUE: 2023 No. 53
ISSN 2335-6677

EXECUTIVE SUMMARY

- 2023-2024 is now officially an El Niño year. This typically brings drought and warmer temperatures to Southeast Asia, just as the region is in the process of recovering from record-breaking heat waves. The last two "very strong" El Niño events – in 1997-98 and 2015-16 – impacted food crops and livestock in Southeast Asia and caused a notable decline in rice production. This contributed to global inflation in the price of rice of up to 16 per cent.

- Experts are projecting that El Niño will strengthen towards the end of 2023 and early 2024, affecting winter and spring rice production. Rice losses may also be exacerbated by suboptimal harvests due to harsh weather conditions and spoilage due to poor storage infrastructure.

- Countries are already responding by updating policies and interventions: Thailand and Vietnam – both major rice exporters – are projected to reduce rice production in the 2023-24 season, even as major producers (and consumers) China and India experience production losses due to extreme weather conditions.

- Rice is key to the region's food security, and a decline in supply will affect domestic food security in numerous countries, leading to malnutrition and health impairment.

- The region has already adopted early warning systems, irrigation plans, and disaster preparedness plans. More can be done, including educating consumers on staple diversification to drought-resilient crops, increasing rice reserves, strengthening community-based food security, maintaining open rice trade, and facilitating inter- and intra-regional exchange and collaboration on effective action and rice research. The impacts of El Niño have been proven to persist beyond the El Niño year, and authorities and communities should prepare for a prolonged recovery, particularly in agriculture.

INTRODUCTION

The climate phenomenon of El Niño is typically associated with drought and warmer temperatures in Southeast Asia, but also with floods and typhoons globally. It has had an outsized impact on agriculture, particularly rice.

On 8 June 2023, the National Oceanic and Atmospheric Administration (NOAA) officially declared that El Niño conditions had been observed, indicating that 2023-24 will again be an El Niño year.[2]

The last El Niño event, 2015-2016, recorded the hottest year on record and affected 60 million people globally;[3] in Southeast Asia, the warmer temperatures and prolonged drought resulted in an output decline of 15 million tonnes of rice compared to the preceding two years.[4] In Vietnam, the drought, excessive groundwater withdrawals, and subsequent saltwater intrusion up to 90 kilometres into the Mekong Delta and its rice fields resulted in an estimated loss of US$674 million, or 0.35 per cent of its GDP. [5, 6] In the Philippines, close to 200,000 rice and corn farmers were affected, sparking riots[7] and resulting in an 11 per cent drop in production compared to 2014.[8] These disruptions resulted in the global price of rice increasing by 16 per cent.[9] Elsewhere in Southeast Asia, El Niño resulted in reservoirs drying up, forest and peatland fires, and widespread haze.

While the strength of the 2023-24 El Niño event is yet unknown, the unprecedented ocean warming since the early months of 2023 could result in record-breaking temperatures in 2024.[10] Analysts are predicting a shortfall in rice production; one foretelling the worst shortfall in 20 years, surpassing the shortfall in 2015-2016.[11] This shortfall affects the amount of rice available for domestic consumption. The reduction in surpluses for export will affect all major rice importers in Southeast Asia, which includes Indonesia, the Philippines, Malaysia, and Singapore.

Rice is key to food security as Southeast Asians receive more than 76 per cent of their caloric intake from rice.[12] As the saying in many parts of Southeast Asia goes: "it's not a meal without rice". Loss of rice will thus impact food security, specifically causing malnutrition and health impairment. Action is needed to prepare for this probability.

This Perspective provides some insights into the potential impact of El Niño on rice production and food security in Southeast Asia, and suggests actions that can be taken to enhance agri-food resilience in the short and long term.

EL NIÑO'S IMPACT ON RICE PRODUCTION IN SOUTHEAST ASIA

What is El Niño?

El Niño is a climate phenomenon that naturally occurs every two to seven years. [13] It is caused by the warming of sea surface temperatures in the Pacific Ocean, which alters rainfall and

surface winds, that in turn change ocean currents and sea surface temperatures. El Niño typically lasts a year, though every El Niño event is different. An El Niño event is declared when sea surface temperatures in the tropical eastern Pacific are above the long-term average. El Niño conditions are monitored using the Nino3.4 index, and the event is determined when the threshold value for Nino3.4 index (average of SST anomalies over the region 5N-5S, 120W-170W) is above 0.65 °C, based on the 3-month average value for 5 or more consecutive months.[14]

During El Niño, surface air pressures are higher than normal over Southeast Asia, creating drier conditions that increase the risk of smoke haze from land and forest fires in the region. With warmer temperatures typically following drier periods, droughts and heatwaves may become more common, depending on the intensity of El Niño event. While El Niño is not a result of climate change, climate change is believed to amplify its impacts.[15]

El Niño and its impact on rice production

Rice production, like most of agriculture, is highly dependent on favourable climate. The recent heat wave from March to May 2023 – when temperatures rose above 45 degrees Celsius in Thailand, Myanmar, and Laos, and above 40 ºC in Cambodia, Vietnam, and Malaysia[16] – delayed the rice planting season. El Niño is expected to prolong the warm, dry weather in mid-2023 into mid-2024, causing plants to experience heat stress, which impacts growth and ultimately, yield.

Just as humans can experience heat cramps, dehydration or heat stroke, plants too experience debilitating effects.[17] Heat stress causes water loss, delayed growth, reduced pollination, impaired seedling or root growth, withered or yellow leaves, reduced tiller (grain bearing branch) number, and seedling death in plants.

Generally, temperatures above 33 ºC have commonly resulted in rice yield reductions.[18] One study by the International Rice Research Institute (IRRI) in the Philippines has found that for every 1 ºC increase in average night-time temperatures during the dry season, there has been a corresponding 10% yield loss on average.[19] With El Niño likely bringing record-breaking temperatures, yields are expected to be reduced.

Much research has been dedicated to developing thermoresistant and drought resistant strains. Key research centres in Southeast Asia include the IRRI, the Indonesian Centre for Rice Research (ICRR), Vietnam Academy of Agricultural Sciences (VAAS), and the Thai Rice Department's 28 rice centres. Research to develop climate-resilient varieties is important as heat stress's effects on rice yields are dependent on the timing (when it happens), severity (how high the temperature and humidity levels are) and duration (how long it lasts) of the heating event during the growth and developmental stages of the crop.[20] For example, the optimum temperature for rice at seedling stage and germination is 25-28°C[21] and 28-30°C[22] respectively, and temperatures above that reduces yield—for example by increasing sterility, delaying flowering, and shortening fertilisation periods.[23] Heat stress at later (grain filling) stages reduces starch accumulation and may increase chalkiness in grains (presents as reduced translucence of rice and milling quality).[24, 25] The impact is not only on quantity of rice produced, but also the quality of rice – lower grade rice attracts lower commercial values –

resulting in economic losses for farmers. Any genetic improvement in rice varieties therefore needs to address all stages of the plant's development.

The various eco-geological race of rice also responds to heat stress differently. As compared to Japonica rice, Indica rice is more heat-tolerant and suitable for high-temperature environments.[26] Indica rice is the dominant rice grown in Southeast Asia (Jasmine, Phka Rumduol and other fragrant and non-fragrant varieties), while Japonica rice (short grain) is mostly grown in the highlands of the region, though a tropical derivative—the Javanica—is popular in Indonesia. Abnormally warm temperatures in highlands can thus have a greater impact on rice yields than on yields in lowlands.

Country	Total national production 2021 (million MT)	Total national imports/exports 2021 (million MT)
Indonesia	54.4	0.41 / 0.00
Viet Nam	43.9	0.08 / 4.64
Thailand	33.6	0.03 / 6.07
Myanmar	24.9	0.00 / 1.60
Philippines	20.0	2.97 / 0.00

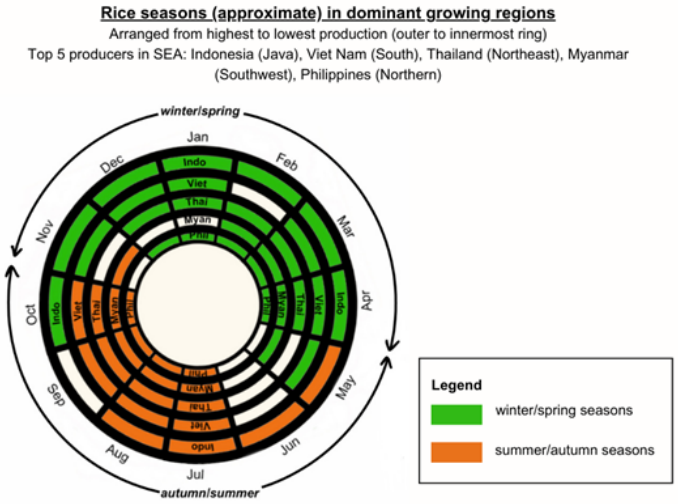

Figure 1: Typical timing of rice cropping seasons for the 5 top rice producers, and their trade quantities, in Southeast Asia (colours denote different seasons). Heat stress at the different stages of growth and development of paddy has corresponding impacts on grain development – and eventual yields – of the crop. (Source: FAOStat, Global Yield Gap; trade data refers to "Rice,paddy (rice milled equivalent)" in FAOStat)

Heat stress can be alleviated with irrigation. However, as El Niño results in reduced precipitation, there is little reprieve for rain-fed rice farms. Irrigated farms also face competing pressures on water use for residential, industrial or biodiversity needs.

Aside from impacting on yield, heat also increases spoilage. This is worsened by the lack of sufficient storage infrastructure in Southeast Asia, as well as destruction from pests and diseases which may become more prevalent in the warmer temperatures. It also impacts on farmers' and those along the value chains' productivity and ability to work, resulting in less-than-optimal output supply.

In the past, Southeast Asia's rice production had been mainly impacted by El Niño events defined as "very strong".[27] The 1997-1998 El Niño event reduced rice production in nearly every country in Southeast Asia, particularly in the Philippines.[28] However, overall production

was buoyed by Vietnam's production increase, resulting in the slight net increase in rice production between 1997-1998 over that of 1995-1996, by approximately 2 million tonnes.[29]

The 2015-2016 El Niño, however, was considered far more severe. Once coined the "Godzilla El Niño",[30] it resulted in a decline of 15 million tonnes of rice compared to the preceding two years. The impact on agriculture, however, went beyond rice. In Vietnam, aside from the impact on rice, El Niño resulted in the loss of over 6,000 heads of livestock and damage to 70,000 hectares of aquaculture. Over two million people were impacted, 1 million of whom were left food insecure.[31] The Philippines too faced drought especially in the central and southern regions, resulting in a productivity decline in the fisheries sector by 20 per cent.[32] In Cambodia, it was estimated that 2.5 million people were affected by drought, and by loss of farmland and livestock.[33]

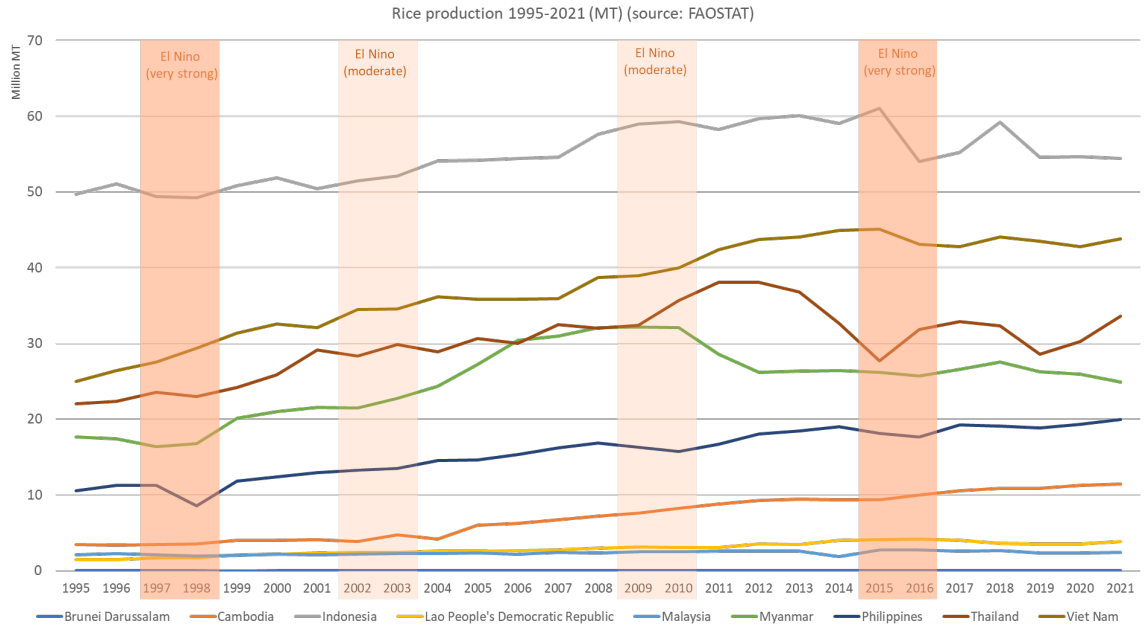

Figure 2: Rice production in Southeast Asia experienced dips, particularly in Indonesia, Thailand Myanmar, Philippines during "very strong" El Niño events. (Source: FAOSTAT, GGweather[34])

Implications for rice production for 2023-2024

Considering 2023's record-breaking ocean temperatures,[35] El Niño could be considered "very strong" towards the end of the year. During this time, El Niño typically results in warmer weather in Thailand, Myanmar, Laos and North Vietnam, and warmer and drier weather in Indonesia, the Philippines, South Vietnam, Cambodia and Malaysia (See maps). Major rice cultivation zones all fall within the areas likely affecting winter and spring paddy seasons.

ISSUE: 2023 No. 53
ISSN 2335-6677

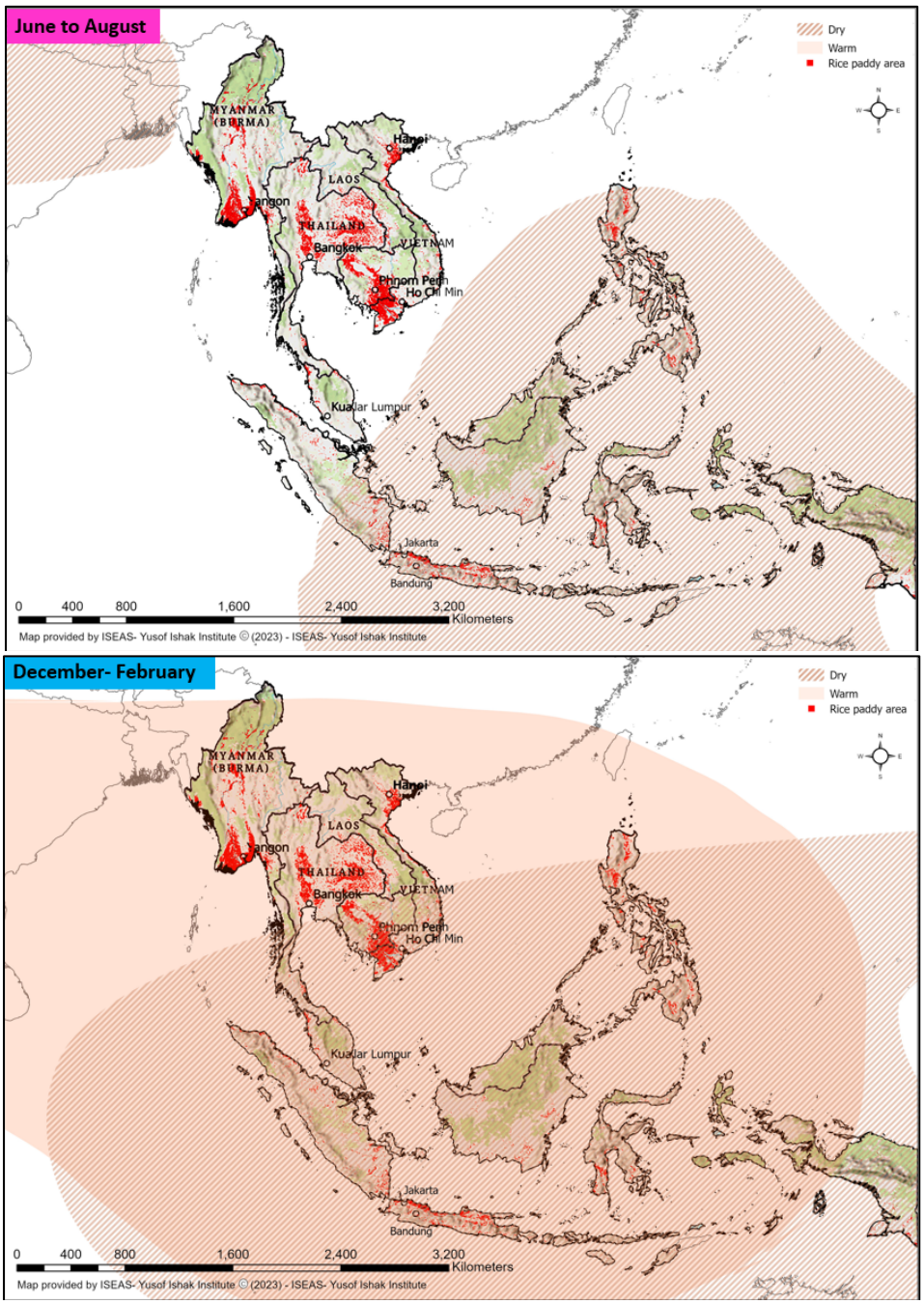

Figure 3: El Niño will impact nearly all of Southeast Asia's rice growing areas, however the impact on the winter and spring rice will be more significant. (Sources of data for maps: NOAA[36] and Han et al[37])

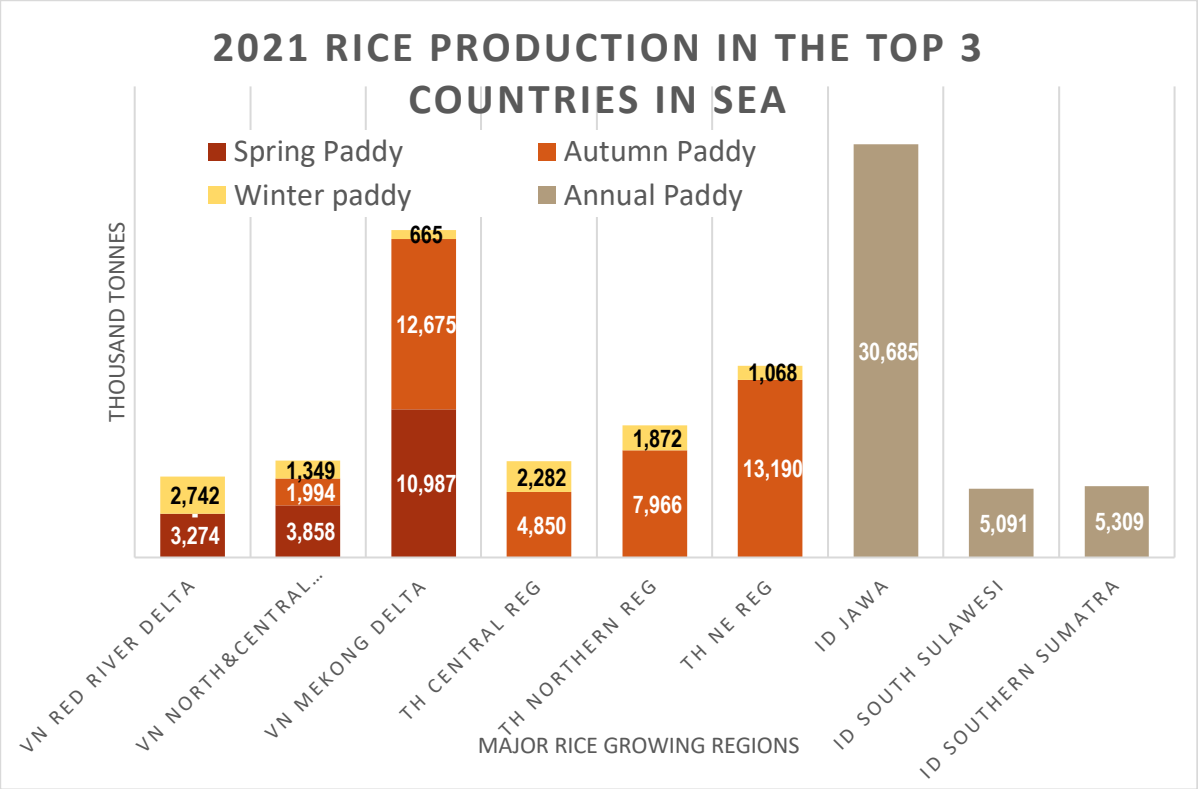

Figure 4: Rice production in the major growing regions in the top 3 rice producing countries in Southeast Asia. Winter paddy likely to have the greatest yield reductions due to El Niño impacts. (Data sources: NSO Thailand, Vietnam General Statistics Office, Badan Pusat Statistik Indonesia)

It is thus anticipated that rice production, particularly winter and spring rice production, will decline as a result of El Niño. Southeast Asian countries are responding through policies and direct intervention. In May 2023, Thailand requested its farmers to cut 2023 rice planting to only the summer/autumn season to conserve water and avoid loss, and instead to switch to other drought-tolerant crops.[38] Vietnam has announced a plan to switch exports to higher quality rice, effectively cutting rice exports from the current 7.1 million tonnes to 4 million tonnes by 2030; the switch will happen gradually from 2023 onwards.[39] Indonesia has ordered the import of one million tonnes of rice from India to counter shortfalls and price inflation.[40]

The reduction in rice supply is coming at a risky time. The Russian invasion of Ukraine in 2022 had strained wheat supplies, raising global demand for rice. Extreme weather has also caused harvest losses in both of the world's largest rice producers—China and India. India, the world's largest exporter of rice, banned broken rice shipments and imposed a 20 per cent duty on rice exports in September 2022, due to a decline in production.[41]

Combined, India, Thailand and Vietnam account for more than half the global rice export (approximately 21, 6 and 5 million tonnes respectively in 2021).[42] Production declines will have huge implications on supply of rice not only in Southeast Asia but across the world.

STRIDES IN PREPARATION FOR EL NIÑO AND NEXT STEPS

Fortunately, Southeast Asia nations have learnt from past El Niño events, and have invested in preparedness, mitigation and risk reduction actions. Southeast Asian countries have developed national and local planning strategies to build risk-informed, resourced and coordinated systems.

Regionally, the ASEAN Specialised Meteorological Centre has further developed its early-warning meteorological capabilities. Other early warning systems have also been established, most recent of which is the regional Fire Danger Rating System (FDRS) in Malaysia in order to assess risk of fires and predict wildfire breakouts up to seven days in advance, and to help to mobilise resources for its prevention.[43] The system relies on 459 weather stations across ASEAN.[44]

As mentioned, efforts have also been made to develop drought-tolerant rice varieties. But more work is needed, and most farmers will not see its benefits in time. To address the projected drought, irrigation and water management plans have also been constructed. Thailand, for example, has developed a whole-of-country water management plan. [45] Malaysia has established a "war room" to monitor its reservoirs.[46] Vietnam is developing a drought response plan that extends until 2025 in case El Niño's impacts extend for 3 years.[47] There is much each Southeast Asian country can learn from each other to improve domestic preparedness.

Other than the above, national safeguards are already in place to prepare for emergencies, including national rice stockpiles, integrated disaster risk management plans, and information broadcasting systems and communication means.
Still, more can be done. The following are a few examples of steps that can be taken to enhance food security:

1. Educating consumers on staple diversification

With the likely rice shortfall, consumers may see higher rice prices and shortages. Often, rice alternatives exist, but it is consumers who are unwilling to switch. Consumer education is needed to diversify from dependence on rice. This is not commonly within the mandates of ministries of agriculture and should be taken up by agencies promoting food security and resilience, along with private sector, media, and even influencers, to produce a whole-of-society effort.
One promising substitute is cassava, which is drought tolerant and native to Southeast Asia. Historically, it was a staple; however due to past pro-rice policies, it is often now seen as an inferior food.[48] While it is still eaten widely in the region, few see it as a rice substitute. Cassava roots, however, have a lower glycemic index and are a rich source of fibre, vitamin C and other nutrients. Thailand, Indonesia, Cambodia and Vietnam are already major global cassava producers.[49] In Indonesia, at least one company has already processed cassava into a product that has the same texture and flavour as regular rice.[50] Innovations such as these need to be made more widely available to encourage consumers to see it as a viable substitute.

ISSUE: 2023 No. 53
ISSN 2335-6677

2. Increase rice reserves at country and regional levels

Most Southeast Asia countries have stockpiles, but these need to be increased or replenished.[51] At the regional level, ASEAN has established the ASEAN Plus Three Emergency Rice Reserve (APTERR) in 2011. This has calmed rice markets more than once since its establishment. For example, when the Philippines was experiencing rice hyperinflation due to supply shortage in 2008, Japan agreed to release its reserves, which then calmed markets.[52]
However, most experts agree that more can be done to bolster rice stockpile effectiveness and responsiveness. ASEAN rice surplus countries should be urged to contribute more of their share to APTERR, which now depends mainly on the "Plus Three" partners (China, Japan, and South Korea). ASEAN could also consider upgrading its shared stockpile database to a real-time system for better coordinated and quicker response times. This is to ensure that it is able to meet its purpose even as multiple shortages occur.

3. Strengthen community-based food security

The impact of El Niño is often a slow-burning issue, as opposed to a disaster such as a one-time extreme storm event. As a result, while impacts are widespread across cities, villages and towns simultaneously, they are often patchily addressed. It is thus necessary to involve more community-based organisations that are able to identify and address distress in a timely manner and work with local government and civil society groups. Akin to the Covid-19 period, it is likely that more volunteer organisations will arise to serve communities when needed. Communities should also work towards resilience by building up community- and household-based farming projects to promote self-reliance, and to reduce exposure to potential food inflation.
As such, governments should regularly stocktake and register formal and ad-hoc community organisations, and maintain a close and cooperative relationship. In turn, these organisations should not only be urged to provide services, but also to capture and relay data and information back to government aid agencies. This would enable more effective aid provision.

4. Maintain open rice trade

Food trade restriction policies, such as export bans and taxes, have been effective in stabilising domestic markets[53]. However, they have often had the negative effect of destabilising regional and global supply and markets. Export restrictions cause panic, leading to price surges and supply chain breakdowns. A domino effect tends to contribute to price spikes for other products, resulting in overall food price inflation, ultimately hurting all consumers. Furthermore, the Food and Agriculture Organisation (FAO) has found that export restrictions often result in lower incomes for farmers, reduced production, a decline in investment, loss of global market share to competitors, decreased foreign exchange revenues and reputational damage.[54]

In 2020, in response to COVID19 supply chain disruptions, ASEAN released a statement that it would maintain open food markets, to enhance resiliency and sustainability of supply chains an promote food security.[55] It is hoped that in the face of likely rice production decline, ASEAN nations will continue to maintain open food supply chains.

5. Facilitate inter- and intra-regional collaborations and rice research

As Southeast Asian nations enter this period of climatic and food uncertainty, they could promote a culture of effective action-sharing and coordination on efforts to mitigate and adapt to climate uncertainty, so as to collectively benefit.

Aside from lessons on how to deal with El Niño, there is also a need to promote greater knowledge and technology exchange from research and development in drought, saline and heat resistant rice varieties. For example, China has developed a perennial rice crop variety that is now being trialled in Southeast Asia.[56] Perennial rice can produce consistent yields for eight harvests, and results in reduced waste, inputs and methane emissions, and labour savings.[57] More platforms for partnerships and action are needed to encourage collective collaboration between plant breeders, researchers, biologists, agronomists, and farmers. [58]

In the past, El Nino resulted in persistent economic impacts, with one study calculating losses globally of US$4.1 trillion and US$5.7 trillion in 1982-83 and 1997-98, respectively.[59] The present El Niño has just begun, and there is still time to put in place plans for the next year and the following years to allay the worst impacts. It is also timely to improve coordination across the many ASEAN mechanisms regarding agriculture, food, and fisheries towards more resilience to this climate phenomenon. Our region's food security and social stability depend on it.

ENDNOTES

[1] The authors would like to thank Dr Anupam Kumar, Senior Research Scientist at the Climate Change Impacts Branch under the Department of Climate Research at Centre for Climate Research Singapore, for his expert assistance on this publication.
[2] Becker, E. (2023 June 8) *June 2023 ENSO update: El Niño is here*. Climate.gov. https://www.climate.gov/news-features/blogs/june-2023-enso-update-el-ni%C3%B1o-here
[3] OCHA, U. (2016). El Niño: Overview of Impact, Projected Humanitarian Needs and Response.
[4] FAOStat (n.d.) United Nations Food and Agriculture Organisation. https://www.fao.org/faostat/en/#home
[5] UNCT Viet Nam. (2016). Viet Nam: Drought and Saltwater Intrusion Situation Update No. 2 (as of 14 April 2016). Relief Web. https://reliefweb.int/report/viet-nam/viet-nam-drought-and-saltwater-intrusion-situation-update-no-2-14-april-2016
[6] UNDP. 2018. *Enhancing Resilience to Extreme Climate Events: Lessons from the 2015-2016 El Niño Event in Asia and the Pacific.* UNDP.
[7] Hookway, J. (2016, May 18). *El Niño wreaks havoc across Southeast Asia*. WSJ. https://www.wsj.com/articles/el-nino-wreaks-havoc-across-southeast-asia-1463587502
[8] UNDP. 2018. *Enhancing Resilience to Extreme Climate Events: Lessons from the 2015-2016 El Niño Event in Asia and the Pacific.* UNDP.
[9] FAOStat (n.d.) United Nations Food and Agriculture Organisation. https://www.fao.org/faostat/en/#home
[10] Dickie, G. (2023, June 9). *How El Niño could impact the world's weather this year and next*. The Japan Times. https://www.japantimes.co.jp/news/2023/06/09/world/el-nino-weather-impact-explainer/

[11] Lee, Y. S. (2023, April 18). *Global rice shortage is set to be the biggest in 20 years*. CNBC. https://www.cnbc.com/2023/04/19/global-rice-shortage-is-set-to-be-the-largest-in-20-years-heres-why.html
[12] Fitzgerald, M. A., McCouch, S. R., & Hall, R. D. (2009). Not just a grain of rice: the quest for quality. *Trends in plant science*, *14*(3), 133-139.
[13] ASEAN Specialised Meteorological Centre (n.d.) http://asmc.asean.org/asmc-el-nino/
[14] ASEAN Specialised Meteorological Centre (n.d.) http://asmc.asean.org/asmc-el-nino/
[15] Dickie, G. (2023, June 9). *How El Niño could impact the world's weather this year and next*. The Japan Times. https://www.japantimes.co.jp/news/2023/06/09/world/el-nino-weather-impact-explainer/
[16] Bhandari, S. R. (2023, May 18). *Asia's heatwaves 30 times more likely due to climate change, scientists say*. Radio Free Asia. https://www.rfa.org/english/news/environment/asia-heatwave-05182023020840.html
[17] WHO. N.d. *Heat and Health*. World Health Organisation. https://www.who.int/news-room/fact-sheets/detail/climate-change-heat-and-health
[18] Arshad, M. S., Farooq, M., Asch, F., Krishna, J. S., Prasad, P. V., & Siddique, K. H. (2017). Thermal stress impacts reproductive development and grain yield in rice. *Plant Physiology and Biochemistry*, *115*, 57-72.
[19] Peng, Shaobing, Jianliang Huang, John E. Sheehy, Rebecca C. Laza, Romeo M. Visperas, Xuhua Zhong, Grace S. Centeno, Gurdev S. Khush, and Kenneth G. Cassman. "Rice yields decline with higher night temperature from global warming." *Proceedings of the National Academy of Sciences* 101, no. 27 (2004): 9971-9975.
[20] Arshad, M. S., Farooq, M., Asch, F., Krishna, J. S., Prasad, P. V., & Siddique, K. H. (2017). Thermal stress impacts reproductive development and grain yield in rice. *Plant Physiology and Biochemistry*, *115*, 57-72.
[21] Xu, Y., Chu, C., & Yao, S. (2021). The impact of high-temperature stress on rice: Challenges and solutions. *The Crop Journal*, *9*(5), 963-976.
[22] Sarsu, F., Ghanim, A. M., Das, P., Bahuguna, R. N., Kusolwa, P. M., Ashraf, M., ... & Sarsu, F. (2018). Screening protocols for heat tolerance in rice at the seedling and reproductive stages.
[23] Arshad, M. S., Farooq, M., Asch, F., Krishna, J. S., Prasad, P. V., & Siddique, K. H. (2017). Thermal stress impacts reproductive development and grain yield in rice. *Plant Physiology and Biochemistry*, *115*, 57-72.
[24] Arshad, M. S., Farooq, M., Asch, F., Krishna, J. S., Prasad, P. V., & Siddique, K. H. (2017). Thermal stress impacts reproductive development and grain yield in rice. *Plant Physiology and Biochemistry*, *115*, 57-72.
[25] Liu, W., Yin, T., Zhao, Y., Wang, X., Wang, K., Shen, Y., ... & Tang, S. (2021). Effects of high temperature on rice grain development and quality formation based on proteomics comparative analysis under field warming. *Frontiers in Plant Science*, *12*, 746180.
[26] Shrestha, S., Mahat, J., Shrestha, J., Madhav, K. C., & Paudel, K. (2022). Influence of high temperature stress on rice growth and development. A review. *Heliyon*, e12651.
[27] Note: There were only "very strong", "moderate" and "weak" El Niño events since 1995. There were no El Niño events defined as "strong". "Weak" El Niños were experienced in 2004-05, 2006-07, 2014-15 and 2018-19. (Source: https://ggweather.com/enso/oni.htm)
[28] FAOStat (n.d.) United Nations Food and Agriculture Organisation. https://www.fao.org/faostat/en/#home
[29] FAOStat (n.d.) United Nations Food and Agriculture Organisation. https://www.fao.org/faostat/en/#home
[30] Schiermeier, Q., 2015. Hunting the Godzilla El Niño. *Nature 526*, 490–491.
[31] UNDP. 2018. *Enhancing Resilience to Extreme Climate Events: Lessons from the 2015-2016 El Niño Event in Asia and the Pacific.* UNDP.

[32] UNDP. 2018. *Enhancing Resilience to Extreme Climate Events: Lessons from the 2015-2016 El Niño Event in Asia and the Pacific.* UNDP.
[33] UNDP. 2018. *Enhancing Resilience to Extreme Climate Events: Lessons from the 2015-2016 El Niño Event in Asia and the Pacific.* UNDP.
[34] Golden Gate Weather Service n.d. *El Niño and La Niña Years and Intensities.* Golden Gate Weather Service. https://ggweather.com/enso/oni.htm
[35] Harvey, F. (2023, April 26). *Record ocean temperatures put earth in 'uncharted territory', say scientists*. the Guardian. https://www.theguardian.com/environment/2023/apr/26/accelerating-ocean-warming-earth-temperatures-climate-crisis
[36] NOAA (n.d.) *El Niño Theme Page*. NOAA Pacific Marine Environmental Laboratory. https://www.pmel.noaa.gov/elnino/impacts-of-el-nino.
[37] Han, J., Zhang, Z., Luo, Y., Cao, J., Zhang, L., Cheng, F., ... & Zhang, J. (2021). AsiaRiceMap10m: High-resolution annual paddy rice maps for Southeast and Northeast Asia from 2017 to 2019. *Earth Syst. Sci. Data Discuss*, *211*, 1-27.
[38] Wipatayotin, A. (2023, May 11). *Farmers urged to reduce rice crops*. Bangkok Post. https://www.bangkokpost.com/thailand/general/2568442/farmers-urged-to-reduce-rice-crops
[39] Vu, K. (2023, May 27). *Vietnam to cut annual rice exports by 44% to 4 million tonnes by 2030*. U.S. https://www.reuters.com/article/vietnam-rice-idUSKBN2XI01B
[40] Ghifari, D. (2023, June 16). *RI to import 1 million tonnes of rice from India, citing El Niño concerns*. The Jakarta Post. https://www.thejakartapost.com/business/2023/06/16/ri-to-import-1-million-tonnes-of-rice-from-india-citing-el-nio-concerns.html
[41] ET Online. (2022, September 9). *India may see up to 12 million tonnes slump in rice production, food Secretary says*. The Economic Times. https://economictimes.indiatimes.com/news/economy/agriculture/india-may-see-up-to-12-million-tonnes-slump-in-rice-production-food-secretary-says/articleshow/94092463.cms?from=mdr
[42] FAOStat (n.d.) United Nations Food and Agriculture Organisation. https://www.fao.org/faostat/en/#home
[43] Hong, L. (2023, June 10). *Malaysia establishes monitoring and warning system to predict level of fire risk for south-east Asia*. The Straits Times. https://www.straitstimes.com/singapore/environment/msia-establishes-monitoring-and-warning-system-to-predict-level-of-fire-risk-for-south-east-asia
[44] Hong, L. (2023, June 10). *Malaysia establishes monitoring and warning system to predict level of fire risk for south-east Asia*. The Straits Times. https://www.straitstimes.com/singapore/environment/msia-establishes-monitoring-and-warning-system-to-predict-level-of-fire-risk-for-south-east-asia
[45] Wipatayotin, A. (2023, May 11). *Farmers urged to reduce rice crops*. Bangkok Post. https://www.bangkokpost.com/thailand/general/2568442/farmers-urged-to-reduce-rice-crops
[46] N.a. (2023, June 1). *Malaysia to set up 'war room' to check water levels ahead of expected El Niño*. The Straits Times. https://www.straitstimes.com/asia/se-asia/malaysia-to-set-up-war-room-to-check-water-levels-ahead-of-expected-el-nino
[47] Viet Nam News. (2023, May 19). *Response plan to El Niño is imperative, say Vietnamese experts*. Asia News Network. https://asianews.network/response-plan-to-el-nino-is-imperative-say-vietnamese-experts/
[48] Tatix, N. (2021, December 13). *Before identical common food, now more expensive than rice.* climatetracker. https://climatetracker.org/indonesia-common-food-expensive-rice-leye/
[49] FAOStat (n.d.) United Nations Food and Agriculture Organisation. https://www.fao.org/faostat/en/#home
[50] Rustandi, C. (2020, December 16). *Indonesia introduces cassava rice in a strategic shift from popular grain*. KOMPAS.com. https://go.kompas.com/read/2020/12/16/214021774/indonesia-introduces-cassava-rice-in-a-strategic-shift-from-popular-grain?page=all

[51] Teng, P.S., and B.A.C. Darvin. (2019). *Food Reserves: A Comparative Study on Food Reserve Management and Policies in Southeast Asia.* SEARCA College, Los Baños, Laguna, Philippines.
[52] Timmer, P. (2023, April 5). *Does food protection equal food security? Lessons from ASEAN's experience with rice*. FULCRUM. https://fulcrum.sg/aseanfocus/does-food-protection-equal-food-security-lessons-from-aseans-experience-with-rice/
[53] Kleimann, D. (2022, June 22). *Food security: The role and limits of international rules on export restrictions*. Bruegel | The Brussels-based economic think tank. https://www.bruegel.org/blog-post/food-security-role-and-limits-international-rules-export-restrictions
[54] FAO. (2020). *Why export restrictions should not be a response to COVID-19: Learning lessons from experience with rice in Asia and the Pacific*. Food and Agriculture Organisation of the United Nations. https://www.fao.org/3/ca9362en/CA9362EN.pdf
[55] FAO. (2020). *Why export restrictions should not be a response to COVID-19: Learning lessons from experience with rice in Asia and the Pacific*. Food and Agriculture Organisation of the United Nations. https://www.fao.org/3/ca9362en/CA9362EN.pdf
[56] N.a. (2022, November 14). *What is perennial rice and why is it making history?* Open Access Government. https://www.openaccessgovernment.org/perennial-rice-making-history/147157/
[57] N.a. (2022, November 14). *What is perennial rice and why is it making history?* Open Access Government. https://www.openaccessgovernment.org/perennial-rice-making-history/147157/
[58] Shrestha, S., Mahat, J., Shrestha, J., Madhav, K. C., & Paudel, K. (2022). Influence of high temperature stress on rice growth and development. A review. *Heliyon*, e12651.
[59] Callahan, C. W., & Mankin, J. S. (2023). Persistent effect of El Niño on global economic growth. *Science*, eadf2983.

ISEAS Perspective is published electronically by: **ISEAS - Yusof Ishak Institute** 30 Heng Mui Keng Terrace Singapore 119614 Main Tel: (65) 6778 0955 Main Fax: (65) 6778 1735 Get Involved with ISEAS. Please click here: https://www.iseas.edu.sg/support/get-involved-with-iseas/	ISEAS - Yusof Ishak Institute accepts no responsibility for facts presented and views expressed. Responsibility rests exclusively with the individual author or authors. No part of this publication may be reproduced in any form without permission. © Copyright is held by the author or authors of each article.	Editorial Chairman: Choi Shing Kwok Editorial Advisor: Tan Chin Tiong Editorial Committee: Terence Chong, Cassey Lee, Norshahril Saat, and Hoang Thi Ha Managing Editor: Ooi Kee Beng Editors: William Choong, Lee Poh Onn, Lee Sue-Ann, and Ng Kah Meng Comments are welcome and may be sent to the author(s).