ASIAN DEVELOPMENT OUTLOOK 2021 UPDATE

Theme Chapter: Transforming Agriculture in Asia

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Transforming agriculture in Asia

In the last 50 years, agriculture has played a critical role in Asia and the Pacific's development and structural transformation. In the 1960s, most economies in the region were low-income, primarily agrarian, and struggling to feed their growing populations. The green revolution technologies that were adopted from the 1960s onward led to a sharp rise in yields and incomes, and helped to greatly reduce hunger and malnutrition in the region (ADB 2020a). By raising agricultural productivity, it also freed up labor, which enabled the rapid structural transformation of many economies and facilitated the emergence of the region's vibrant manufacturing and services sectors.

Even today, Asian agriculture is crucial to the region's development. One-third of developing Asia's workers are still employed in agriculture. But the sector is beset by low productivity and incomes. As a result, an estimated four of five people living below the international poverty line live in rural areas. This means that raising productivity in the sector is critical to making further inroads into poverty reduction and advancing the region's economic transformation. Agriculture also plays a central role in safeguarding the region's food supply and achieving the second Sustainable Development Goal of ending hunger, achieving food security and improved nutrition, and promoting sustainable agriculture.

But agriculture in developing Asia faces challenges from three ongoing shifts—in consumer demand, demographics, and a changing and fragile environment. As Asian economies become richer and more urbanized, food demand is increasing and shifting in composition, including toward animal products that are much more resource intensive. And despite the region's growing prosperity, malnourishment persists in various forms. Meanwhile, agricultural production is challenged by rural populations that are shrinking, as many people migrate to cities, leaving older workers and women on the farm. And agriculture is exposed to risks from a changing climate and from farm practices that are not environmentally sustainable.

This chapter was written by Takashi Yamano (lead), Manisha Pradhananga (co-lead), Jindra Samson, Ruth Francisco, Reneli Gloria, and Daryll Naval. It draws on the background papers listed at the end of the chapter. Inputs from Shingo Kimura and Aiko Kikkawa Takenaka are gratefully acknowledged. Other contributions are listed in the Acknowledgments section.

This chapter takes stock of the various challenges currently facing agriculture in developing Asia and examines possible solutions. The next section lays out the challenges in detail. Some challenges like changing consumer demand come from outside the sector; others such as unsustainable farming practices come from within. Many of the challenges and their possible solutions are interrelated. For example, one response to consumers' increased demand for seafood products—increased aquaculture production—comes with environmental challenges of its own. And some solutions, such as diversification into high-value crops, address more than one challenge. It is thus not easy to compartmentalize the various ways that policy makers and the private sector can respond. This chapter categorizes solutions into two groups, although the split is by no means clean. Section 2.2 lays out solutions whose impact is primarily at the place of production itself. These include innovations that help smallholder farmers benefit from greater mechanization; practices like organic farming and volumetric water pricing that help farmers produce more without overusing chemicals or water; and regulations that ensure sustainable agriculture and aquaculture practices. Section 2.3 then looks at support systems that help farmers beyond the place of production, some of which need to be implemented at the macro level. These include early warning systems and crop insurance schemes; the expansion of agriculture value chains and use of contract farming; and the adoption of digital technologies to help farmers and traders reach new markets. Section 2.4 concludes by discussing how government policies toward agriculture should focus less on traditional production support and, instead, encourage market-oriented innovation.

2.1 Agriculture in Asia faces multiple challenges

Agriculture in developing Asia is at a critical juncture, facing several challenges in its ability to provide nutritious and diverse food, while ensuring a sustainable and resilient future. On the consumption side, rising income and urbanization have shifted food preferences toward meat, fish, eggs, dairy, fruit, and vegetables. This change in food preference requires more resource-intensive production, which has implications for land and water use, as well as for climate change. Improved access to nutritious food has allowed developing Asia to make significant progress in the past 2 decades in its fight against hunger, lifting more than 200 million people from undernourishment. Despite this progress, undernourishment persists while the prevalence of obesity is rising in many parts of the region. On the production side, agriculture in the region faces multiple challenges. As higher-paying jobs in urban areas draw out workers, population in rural areas is shrinking and aging. Extreme weather events, which are increasing in frequency and intensity, expose many people and vast agricultural areas in Asia and the Pacific to climate-related disasters. And overuse of chemical inputs and water threatens long-term sustainability of agriculture.

2.1.1 Rising incomes and urbanization are transforming food consumption

Food consumption in developing Asia continues to grow, alongside changes in dietary preferences that reflect rising household income and rapid urbanization. The region is currently home to more than half of the world population, which is projected to reach 8.5 billion in 2030. While a slowdown is forecast for global population growth, two regions—Africa and South Asia—are expected to persist in showing significant increases. By 2030, the population of developing Asia is expected to reach 4.3 billion, while gross domestic product (GDP) per capita is forecast to reach $14,000 in purchasing power parity terms, more than double its value in 2015 (ADB 2019a). The number of people living in urban areas in developing Asia increased from 375 million in 1970 to 1.84 billion in 2017. By 2030, some 55% of the population in the region will dwell in urban areas (ADB 2019a).

These demographic changes are expected to increase food demand and shift food preferences away from food staples toward more diverse diets with higher shares of animal-sourced meat, seafood, eggs, and dairy products, as well as more fruit and vegetables.

Caloric intake in developing Asia has been increasing quickly but remains below that of high-income economies. The increase in income has helped developing economies put more food on the table and reach or even surpass the recommended daily dietary intake of 2,000 kilocalories (kCal) in 1961 to 3,206 kCal in 2018 (Figure 2.1.1a).

Meat consumption in the region is increasing but remains significantly lower than in advanced economies outside of Asia. In 2018, protein intake in developing Asia from meat stood at 10.0 grams per capita per day, and in Japan at 17.3 grams, both well below the 34.6 grams average in advanced economies outside of the region. In the People's Republic of China (PRC), daily protein intake per capita from meat increased almost twentyfold from 1.1 grams in 1961 to 19.7 grams in 2018. In India, meanwhile, meat consumption was stagnant at 1.4 grams over the same period, despite a sixfold increase in income (Figure 2.1.1b).

Figure 2.1.1 Income and food preference

Rising income levels in Asia and the Pacific have been accompanied by higher caloric intake and higher consumption of meat and seafood.

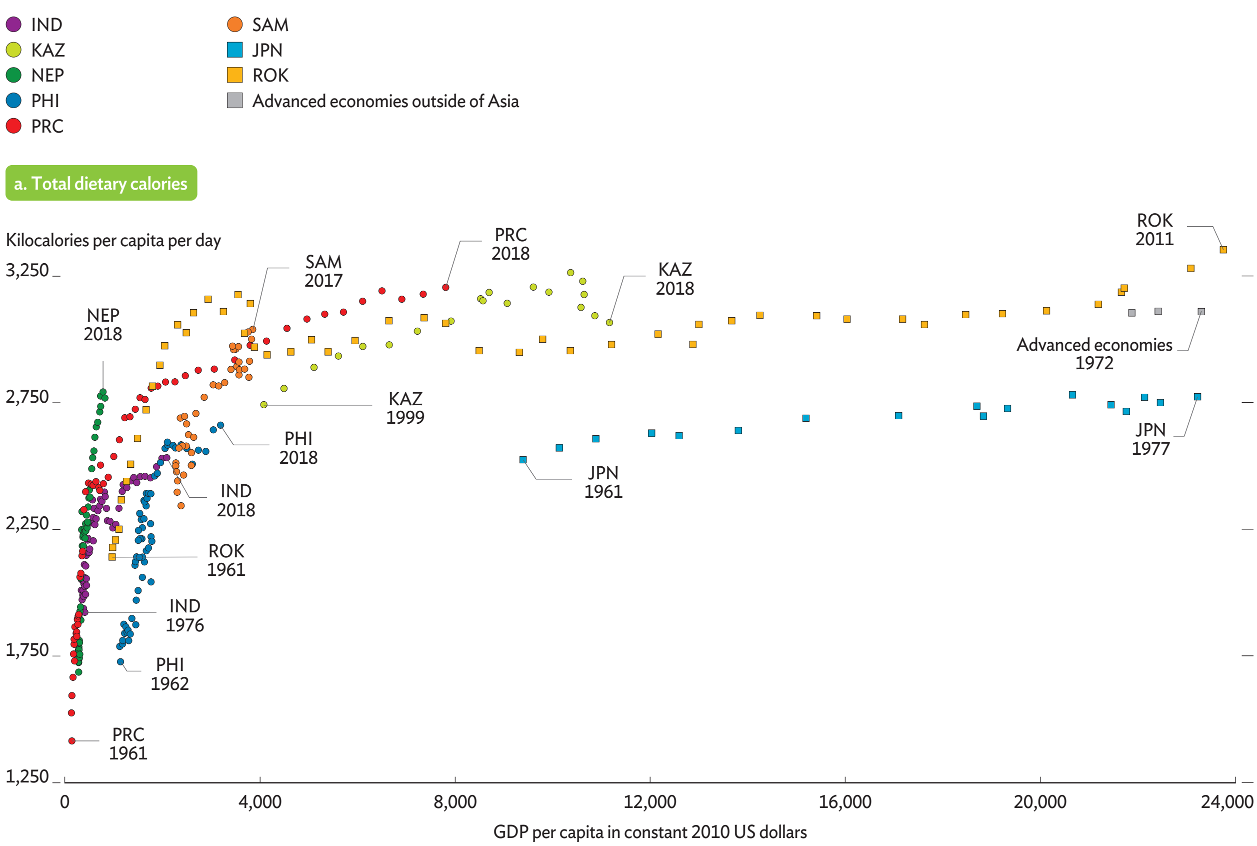

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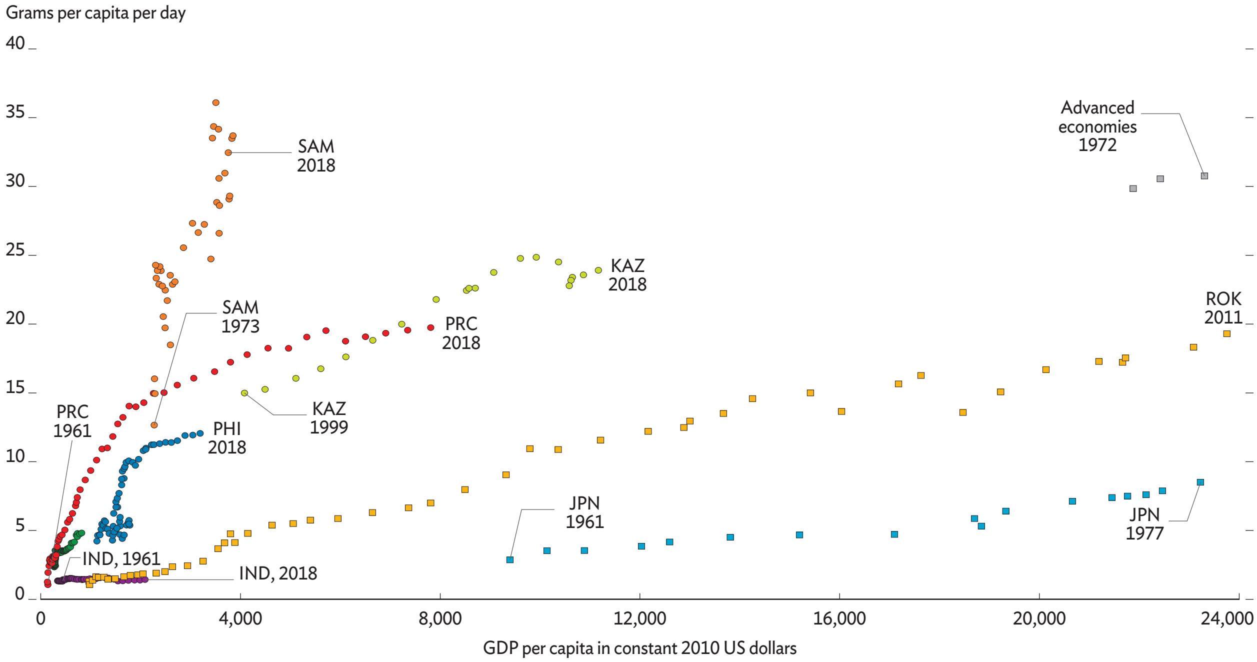
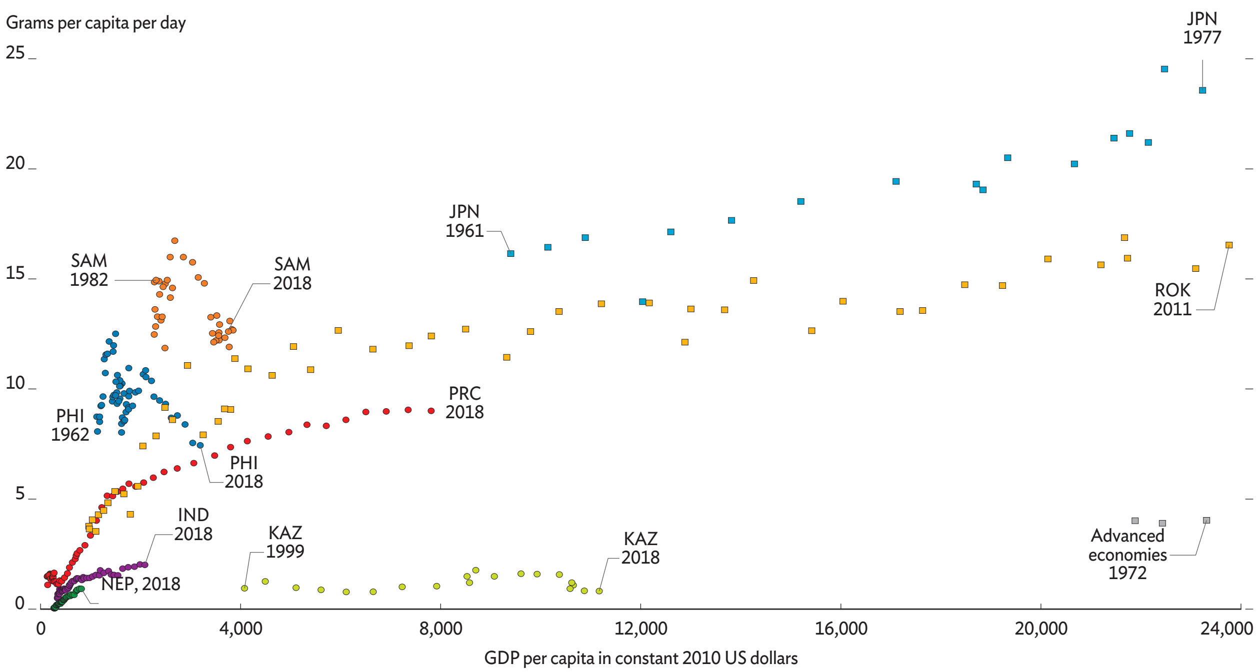
Figure 2.1.1 *Continued*

b. Animal meat[a]



c. Seafood[b]



GDP = gross domestic product, IND = India, JPN = Japan, KAZ = Kazakhstan, NEP = Nepal, PHI = Philippines, PRC = People's Republic of China, ROK = Republic of Korea, SAM = Samoa.

Notes: Consumption per capita is deduced from country average consumption as derived from FAOSTAT food balance sheets. Advanced economies outside of Asia and the Pacific are Australia, Austria, Canada, Denmark, Finland, France, Germany, Ireland, the Netherlands, Norway, Sweden, the United Kingdom, and the United States.

[a] Animal meat comes from pigs, sheep, goats, poultry, and other land livestock.

[b] Seafood fish includes freshwater fish, demersal fish, pelagic fish, marine fish, crustaceans, cephalopods, and mollusks.

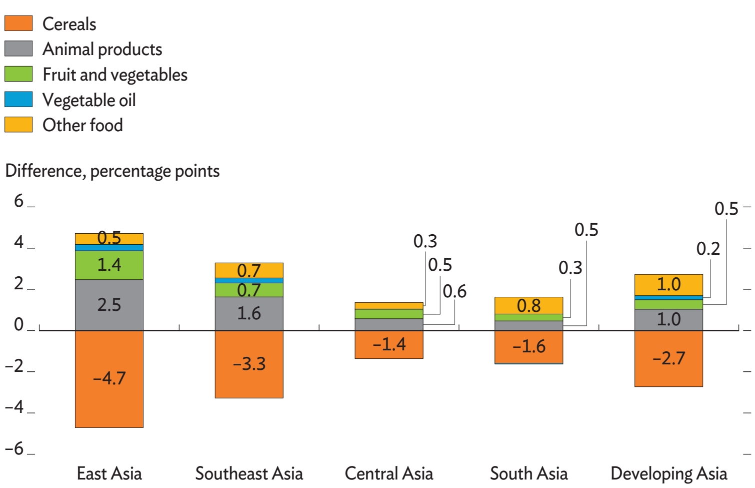
Sources: Dietary calories from FAO. FAOSTAT Food Balance Sheets. http://www.fao.org/faostat/en/#data/FBS (accessed 12 April 2021); GDP per capita from World Bank. World Development Indicators. https://databank.worldbank.org/source/world-development-indicators (accessed 12 April 2021).

In contrast, daily protein intake from fish in developing Asia slightly has surpassed the average in advanced economies outside of the region. Fish consumption is increasing in India, but not as quickly as elsewhere in the region (Figure 2.1.1c). Aquaculture in Asia has responded to the increase in fish demand and has witnessed rapid growth. Asia now accounts for 88% of world aquaculture production.

These trends are expected to continue in the future, with daily energy supply from food intake expected to increase until 2030 in all regions (FAO 2018a).[1] High-income economies will reach saturation at 3,400 kCal/day early, beyond which no further food consumption is regarded as necessary or desirable, while low-income economies will reach 2,860 kCal/day by 2030. In developing Asia, daily energy consumption per capita is expected to reach 2,844 kCal by 2030. Over the same period, the share of cereals in food intake will decrease by 2.7 percentage points, while the share of animal products will increase by 1.0 percentage point, and of fruit and vegetables by 0.5 percentage point. Figure 2.1.2 shows that these trends are more pronounced in East and Southeast Asia.

Figure 2.1.2 Difference in daily energy supply by food group, from 2012 to 2030

Asian consumption is shifting away from cereals toward animal products, fruit, and vegetables.



Note: East Asia is represented by Mongolia and the People's Republic of China; Central Asia by Armenia, Azerbaijan, Georgia, Kazakhstan, the Kyrgyz Republic, Tajikistan, Turkmenistan, and Uzbekistan; South Asia by Afghanistan, Bangladesh, India, Nepal, Pakistan, and Sri Lanka; and Southeast Asia by Cambodia, Indonesia, the Lao People's Democratic Republic, Malaysia, Myanmar, the Philippines, Thailand, and Viet Nam.

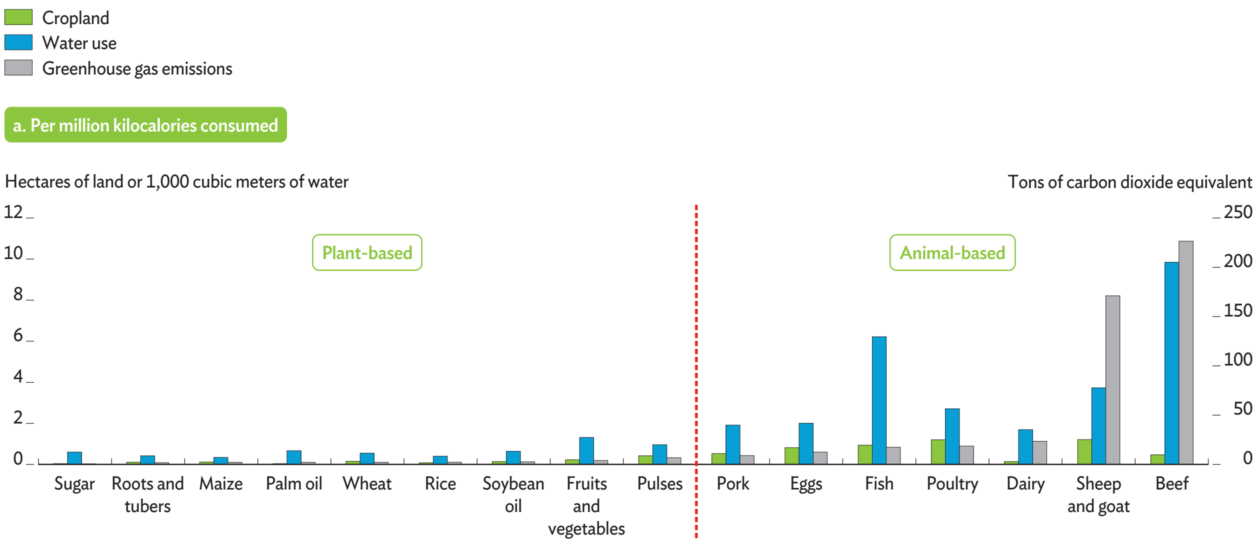
Source: ADB estimates using data from FAO. 2018. *The Future of Food and Agriculture—Alternative Pathways to 2050.* Food and Agriculture Organization of the United Nations.

1 Estimates assume a business-as-usual scenario in which the global community fails to address many challenges of food access and sustainable food production.

This shift in food preference away from staples toward animal-based products requires more resource-intensive production. As shown in Figure 2.1.3a, animal-based products consume more resources and produce higher emissions than plant-based products. This has significant implications for the environment.

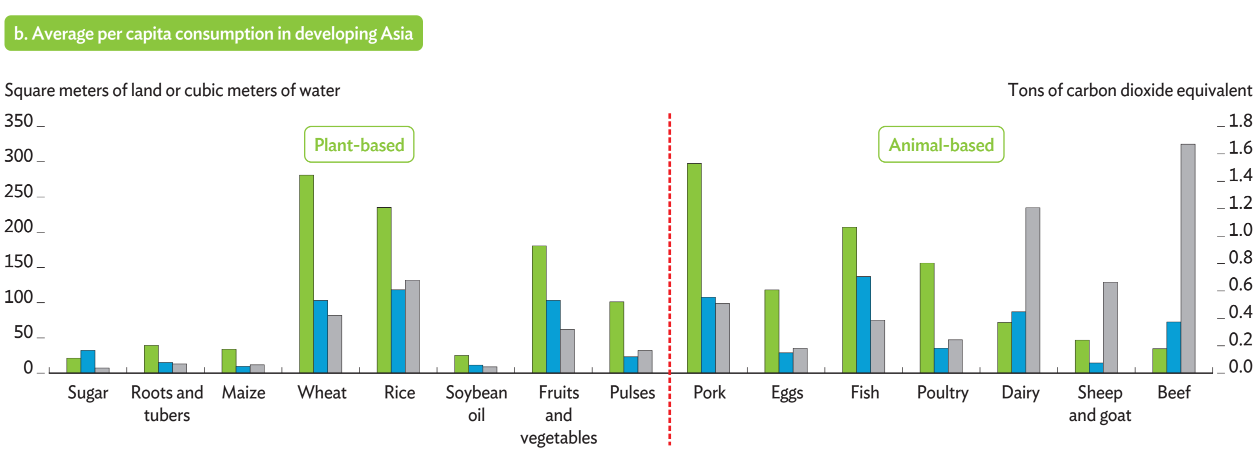
Figure 2.1.3 Resource use and environmental impacts from plant-based versus animal-based products

Animal-based products consume more land and water resources than do plant-based products, and they generate more greenhouse gas emissions.



Notes: Data presented are global means. Plant entries are ordered left to right by the amount of land used. Indicators for animal-based foods include resources used to produce feed, including pasture. Tons of harvested products were converted to quantities of calories and protein using the global average edible calorie and protein contents of food types. Fish include all aquatic animal products. Freshwater use for farmed fish products is shown as rainwater and irrigation combined. Estimates of land use and greenhouse gas emissions are based on marginal analysis, calculating additional agricultural land use and emissions per additional million calories or tons of protein consumed. In line with the approach taken by the European Union for estimating emissions from land-use change for biofuels, land-use change impacts are amortized over a period of 20 years and then shown as annual impacts. Land use and greenhouse gas emission estimates for beef production are based on dedicated beef production, not beef that is a coproduct of dairy. Dairy figures are lower in GlobAgri than some other models because GlobAgri assumes that beef produced by dairy systems displaces beef produced by dedicated beef-production systems.

Source: T. Searchinger et al. 2019. *World Resources Report: Creating a Sustainable Food Future (Final Report).* World Resources Institute.



Notes: The figure was created by multiplying data on global means for cropland use, water use, and greenhouse gas emissions by data on average daily consumption per capita in developing Asia. The resulting product was then multiplied by 365 days to yield annual data. See Searchinger et al. (2019) for more information about the assumptions used to generate the original calculations. Consumption is deduced from country average consumption as derived from FAOSTAT food balance sheets. The countries covered are Afghanistan, Armenia, Azerbaijan, Bangladesh, Cambodia, the People's Republic of China, Fiji, Georgia, India, Indonesia, Kazakhstan, the Kyrgyz Republic, the Lao People's Democratic Republic, Malaysia, Maldives, Mongolia, Myanmar, Nepal, Pakistan, the Philippines, Samoa, Solomon Islands, Sri Lanka, Tajikistan, Thailand, Uzbekistan, Vanuatu, and Viet Nam.

Sources: Cropland use, water use, and greenhouse gas emissions from T. Searchinger et al. 2019. *Creating a Sustainable Food Future (Final Report).* World Resources Institute; dietary consumption from FAO. FAOSTAT Food Balance. http://www.fao.org/faostat/en/#data/FBS (accessed 12 August 2021).

Beef generates the most greenhouse gas (GHG) emissions per million kilocalories consumed, at 226.5 tons of carbon dioxide equivalent (tCO_2e), and has the biggest water footprint, at 9,850 cubic meters (m^3), compared with plant-based GHG emissions at 7 tCO_2e and water use at 1,300 m^3. A slightly different picture emerges from calculating resource use and environmental impacts based on current average consumption per capita in developing Asia (Figure 2.1.3b). Beef still dominates in terms of GHG emissions, at 1.67 tCO_2e per capita, followed by dairy at 1.2 tCO_2e. However, higher average consumption of rice per capita in the region makes GHG emissions per capita from rice significant at 0.68 tCO_2e. Rice and wheat also use a lot of water per capita, closely following fish. In terms of land footprint, pork has the highest utilization per capita, at 297 m^2, followed by wheat and rice.

It is important to move toward sustainable and healthy diets that are also socially acceptable and economically accessible for all. Searchinger et al. (2019) estimate that a 30% shift from meat derived from ruminants such as cows, sheep, and goats, to plant-based proteins by 2050 could close half of the GHG mitigation gap and nearly all of the combined land-use gap.[2] Some ways to achieve this are to promote mostly plant-based diets, reduce red meat consumption, promote fish obtained from sustainable stocks, and reduce food loss and waste throughout the supply chain.

Reducing food loss and waste provides another way to reduce the environmental impact.[3] Food loss and waste contribute 8% of annual GHG emissions and consume a quarter of all water used in agriculture (World Resources Institute 2019). The Food and Agriculture Organization of the United Nations (FAO) food loss index for 2019 showed 14% of the world's food lost in postharvest and wholesale. A further 17% of global food production, 931 million tons, is wasted further down the supply chain (UNEP 2021). Households are the primary wasters of food at 61%, followed by food service at 26% and retail at 13%. According to some estimates, the COVID-19 pandemic has worsened consumer food waste by 12% (Aldaco et al. 2020).

2 Land-use gap is the difference between the projected area of land needed to produce all the food the world will need at a specified future time and the amount of agricultural land in use in a given reference year. The GHG mitigation gap is the difference between agriculture-related GHG emissions projected at a specified future time and a target for emissions from agriculture and related land-use change for that future time that is deemed necessary to arrest global warming at an acceptable temperature difference.

3 Food loss is the quantity or quality diminished because of decisions and actions in postharvest and food wholesaling, and food waste in food retailing, food service provision, and consumption.

2.1.2 Despite the region's growing prosperity, malnourishment persists

In the past 2 decades, developing Asia has made significant progress in its fight against hunger, lifting more than 200 million people from undernourishment. Table 2.1.1 shows that, from 2001 to 2019, the prevalence of undernourishment in the region fell steadily from 15.3% to 8.7% (FAO 2021a).[4] Similarly, the region has reduced the prevalence of stunting in children under 5 years from 38.7% in 2000 to 23.2% in 2020.[5] East Asia achieved the steepest reduction, pushing the prevalence of stunting down to 4.6%, and Central Asia followed at 10.4%.

Table 2.1.1 Malnutrition in Developing Asia

Developing Asia has made progress against its fight against malnutrition, but significant challenges remain.

	Number of Undernourished (million)		Prevalence of Undernourishment (%)		Prevalence of Stunting in Children under 5 Years (%)		Prevalence of Wasting in Children under 5 Years (%)	Prevalence of Obesity in Children and Adolescents 5–19 Years (%)	
Subregion	**2001**	**2019**	**2001**	**2019**	**2000**	**2020**	**2019**	**2000**	**2016**
Central Asia	9.1	1.1	13.9	3.3	27.7	10.4	2.8	1.8	4.6
East Asia	134.1	0.9	9.7	2.5	19.5	4.6	1.9	2.2	11.6
South Asia	269.0	264.9	19.0	14.5	49.4	31.8	15.4	0.4	2.2
Southeast Asia	106.3	46.7	20.1	7.1	38.0	27.4	9.1	1.5	5.7
The Pacific	2.1	2.7	22.0	21.6	36.3	42.1	4.2	3.9	10.2
Developing Asia	**520.6**	**316.3**	**15.3**	**8.7**	**38.7**	**23.2**	**10.3**	**1.2**	**5.4**
World	817.8	650.3	13.1	8.4	33.1	22.0	6.8	2.9	6.7

Note: Small samples in the Pacific mean that stunting figures for this subregion should be viewed with caution.

Sources: For prevalence of undernourishment and the number of undernourished from FAO. FAOSTAT Suite of Food Security Indicators. http://www.fao.org/faostat/en/#data/FS (accessed 10 August 2021); for prevalence of obesity in children and adolescents from WHO. The Global Health Observatory. https://www.who.int/data/gho/data/indicators (accessed 10 August 2021); for prevalence of stunting and wasting from UNICEF, WHO, and World Bank. 2021. Joint Child Malnutrition Estimates. https://data.unicef.org/topic/nutrition/malnutrition (accessed 12 July 2021).

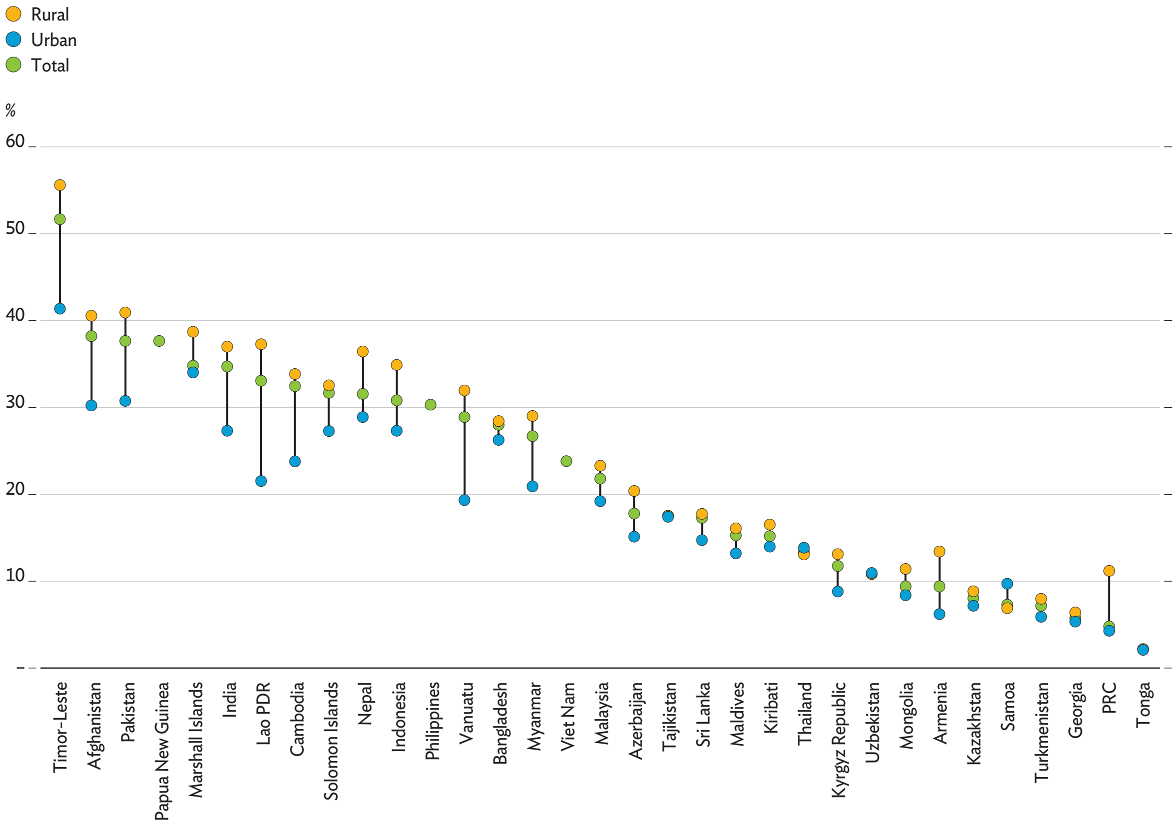
Despite this progress, the number of children in the region under age 5 who still suffer stunting remained significant at 74.7 million in 2020. South Asia accounted for a majority of them at 53.8 million followed by Southeast Asia at 15.3 million. In the past, child stunting was more prevalent in rural areas. With a rise in urban poverty, however, child stunting is no longer just a rural phenomenon.

[4] Hunger is caused by insufficient consumption of dietary energy. It becomes chronic when a person does not consume sufficient calories regularly to have a normal, active, and healthy life. FAO uses the prevalence of undernourishment as an indicator to monitor hunger globally and regionally.

[5] Stunting is defined as low height-for-age. It is a result of chronic or recurrent undernutrition, usually associated with poverty, poor maternal health and nutrition, frequent illness, and/or inappropriate feeding and care in early life.

Figure 2.1.4 Stunting among children under 5 years in developing Asia, 2019

Child stunting persists in developing Asia, as more than half of the countries in the region still suffer prevalence above 20%, with significant shares in both rural areas and urban centers.



Lao PDR = Lao People's Democratic Republic, PRC = People's Republic of China.

Notes: Stunting is defined as low height for age, affecting those falling 2 standard deviations or more below the median in the child growth standards of the World Health Organization. Stunting figures here are the latest year available from 2013 to 2019. Urban–rural stunting estimates are based on an earlier year than overall stunting prevalence where the latest estimate does not disaggregate urban–rural: in Malaysia 2016 for urban–rural, 2019 for stunting overall, and in the PRC 2013 for urban–rural, 2017 for stunting overall. Papua New Guinea, the Philippines, and Viet Nam lack disaggregated urban–rural stunting estimates.

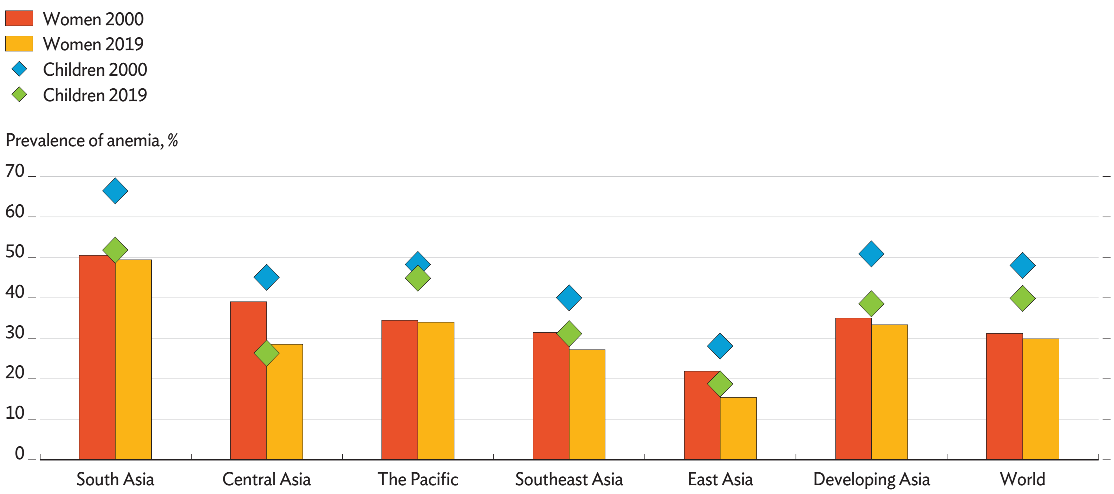
Sources: UNICEF, WHO, and World Bank. 2021. *UNICEF-WHO-World Bank Joint Child Malnutrition Estimates*. United Nations Children's Fund, World Health Organization, and World Bank; UNICEF. 2021. Malnutrition in Children. https://data.unicef.org/topic/nutrition/malnutrition/ (accessed 7 May 2021).

Figure 2.1.4 shows that more than half of the economies in developing Asia still suffered stunting prevalence above 20% in 2019, with significant shares of stunted children in both rural areas and urban centers.

Child wasting is another condition of undernutrition that can cause prolonged illness and higher risk of death when left untreated. Wasting is defined as low weight for height and occurs when a child has not had food of adequate quality and quantity. In developing Asia, child wasting prevalence in 2019 was 10.3%, much higher than the world average of 6.8% and the Sustainable Development Goal target of less than 5% by 2025. Progress has been slow and mixed. Laggard subregions in meeting this target are South Asia at 15.4% and Southeast Asia at 9.1%, while Central Asia has reduced child wasting to 2.8% and East Asia to 1.9%.

Figure 2.1.5 Prevalence of anemia in children under 5 and women aged 15–49, 2000 and 2019

The prevalence of anemia among women and children remains high, especially in South Asia.



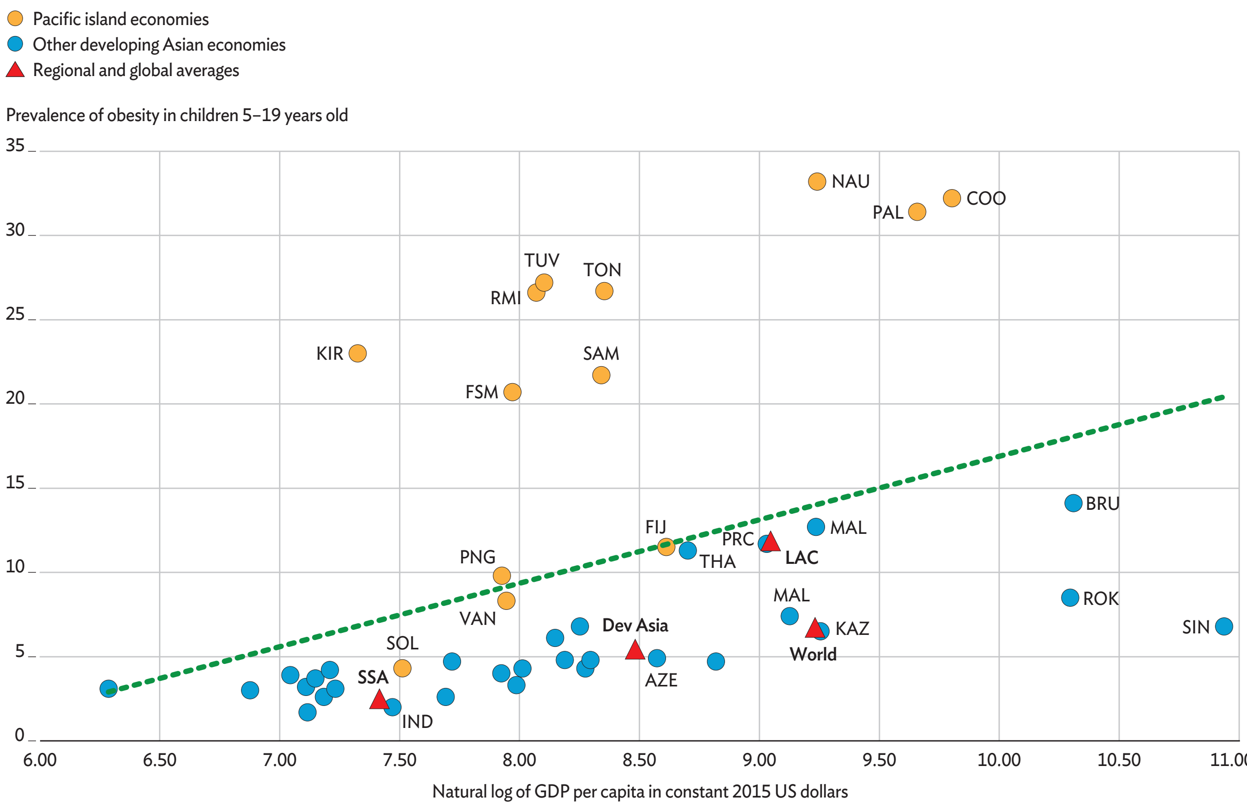
Sources: Data on country prevalence from the World Health Organization. The Global Health Observatory. https://www.who.int/data/gho/data/indicators (accessed 12 August 2021); for population weighting, United Nations. 2019 Revision of World Population Prospects. https://population.un.org/wpp/ (accessed 31 August 2021).

Developing Asia has made some progress in reducing the prevalence of anemia, though rates are still high. Iron deficiency is the most common micronutrient deficiency in the world, affecting 570.8 million women aged 15–49 and 269.4 million children under the age of 5 (WHO 2021). As its health impacts are not always visible, micronutrient deficiency is sometimes called "hidden hunger" and may persist even in economies that have achieved high calorie intake per capita. Figure 2.1.5 shows that the prevalence of anemia among children under 5 is still high at 51.7% in South Asia and 44.8% in the Pacific. More than one in three women in the region aged 15–49 faces anemia, with the prevalence in South Asia stubbornly high at 49.4%. Poor maternal nutrition has direct and lasting effects on child development, as chronic malnutrition in early childhood can affect physical and cognitive development (Grantham-McGregor et al. 2007). This can reduce an individual's potential for economic productivity and, in the long run, diminish the quality of human capital (Hickson and Julian 2018; Madjdian et al. 2018).

The prevalence of obesity is a growing problem in the region. In 2016, over 163 million adults in developing Asia were obese, almost 3.2 times higher than in 2000. Adult obesity prevalence averages 5.8% in the whole region but reaches 23.5% in the Pacific and 18.3% in Central Asia. Obesity can cause noncommunicable diseases such as diabetes and cardiovascular diseases. Ten Pacific economies have rates of adult obesity among the highest in the world, and the Pacific has 4 of the 10 economies in the world with the highest prevalence of diabetes among those aged 20–79 (International Diabetes Federation 2019).

Figure 2.1.6 Obesity in children 5–19 years old and GDP per capita, 2016

The prevalence of obesity among children and adolescents is high in several Pacific countries.



AZE = Azerbaijan, BRU = Brunei Darussalam, COO = Cook Islands, FIJ = Fiji, FSM = Federated States of Micronesia, GDP = gross domestic product, IND = India, KAZ = Kazakhstan, KIR = Kiribati, LAC = Latin America and the Caribbean, MAL = Malaysia, NAU = Nauru, PAL = Palau, PNG = Papua New Guinea, PRC = People's Republic of China, RMI = Marshall Islands, ROK = Republic of Korea, SAM = Samoa, SIN = Singapore, SOL = Solomon Islands, SSA = Sub-Saharan Africa, THA = Thailand, TON = Tonga, TUV = Tuvalu, VAN = Vanuatu.

Note: Computation of regional, developing Asia, and world GDP per capita averages includes only countries with data on obesity prevalence for children and adolescents aged 5–19 years.

Sources: For country obesity prevalence, World Health Organization. The Global Health Observatory. https://www.who.int/data/gho/data/indicators (accessed 10 August 2021); for population 5–19 years old, UN DESA. World Population Prospects 2019. https://population.un.org/wpp/Download/Standard/Interpolated (accessed 10 August 2021); for constant 2015 US dollars, United Nations. UNdata. http://data.un.org/Explorer.aspx (accessed 10 August 2021).

Figure 2.1.6 shows a trend for child obesity. Obesity prevalence among children and adolescents in the Pacific is at 10.2%, and in East Asia, at 11.6%, double the regional average of 5.4%. Though Southeast Asia has lower obesity prevalence at 5.7%, Brunei Darussalam, Malaysia, and Thailand registered the largest increases from 2000 to 2016, by about 8 percentage points. According to WHO (2014), obesity in childhood is linked to higher risk of incurring noncommunicable diseases in adulthood such as type 2 diabetes, asthma and other respiratory problems, high blood pressure, and liver disease, which can cause disability and premature death.

Increased physical inactivity and consumption of processed food are contributing to developing Asia's obesity problem. While urbanization correlates with economic growth and improved standards of living, it is also associated with lifestyle changes that often reduce physical activity and encourage poor food preferences.

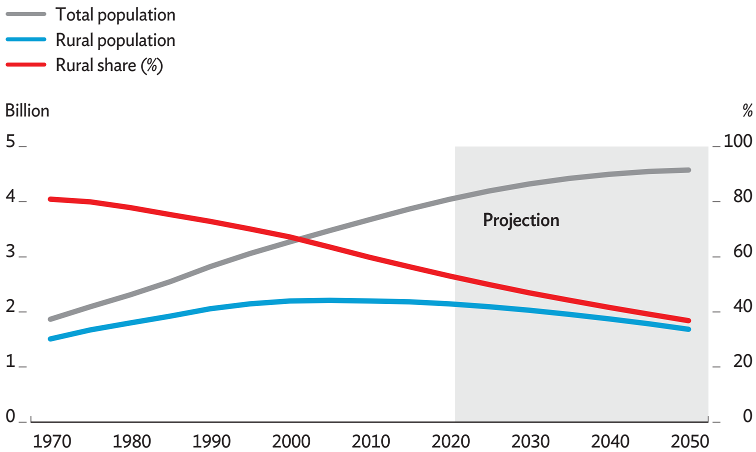
About 25% of developing Asia's population is physically inactive, which is defined as not doing weekly at least 150 minutes of moderately intense physical activity, 75 minutes of vigorous activity, or an equivalent combination of the two. Partly because time-poor urban dwellers work longer hours, they have shifted to ultra-processed food that is convenient but often higher in salt, fat, and sugar (Popkin 2001). Poverty and inequality in urban and peri-urban areas also impede access to healthy food. In the Pacific, sharp increases in obesity associated with noncommunicable diseases are attributed to heavy reliance on imported processed foods high in sugar, salt, and animal fat—and to increasingly sedentary lifestyles (World Bank 2016). More importantly, the region has been moving away from the production of healthy agricultural produce, a development strongly linked to a lack of arable land (Taylor, McGregor, and Dawson 2016). Recommendations to reduce the prevalence of obesity aim to change consumer behavior and promote healthy diets by imposing mandatory labeling of trans fat, raising taxes on sugar-sweetened beverages, and restricting the marketing to children of food high in calories and low in nutrients (FAO 2021a).

2.1.3 Asia's rural communities are rapidly shrinking, feminizing, and aging

Rapid structural transformation has led to a steady decline in the share of rural population. A rapid and enormous structural transformation has characterized Asian development since the 1970s (ADB 2020a). This has dramatically reduced the economic share of agriculture in terms of both output and employment. The decline in agriculture's share of GDP has been especially steep in the PRC, where it dropped from 32% in the 1970s to 7% in 2019, and in India, where the decline was from 40% to 16%. Although agriculture remains a major employer in many developing economies in Asia, the overall share has declined over the years. Higher-paying jobs in manufacturing and services in urban areas have attracted workers out of rural areas, causing a steady decline in the share of the rural population of developing Asia from 80% in 1970 to 52% in 2020. The rural population started to shrink in the 2000s, despite a steady increase in total population. The rural share is expected to decline further to 38% by 2050, and the absolute number to drop below 600 million (Figure 2.1.7). In East Asia, the rural population share is already below 40% and is expected to sink to less than 25% by 2050. In Southeast Asia, the rural population share is seen contracting from about 50% in 2021 to below 40% by 2050. South Asia currently has over 60% of its population in rural areas, but this share is likewise declining rapidly.

Figure 2.1.7 Urban and rural population in developing Asia, 1970–2050

The share of rural population has declined as people moved to cities in search of better economic opportunities.

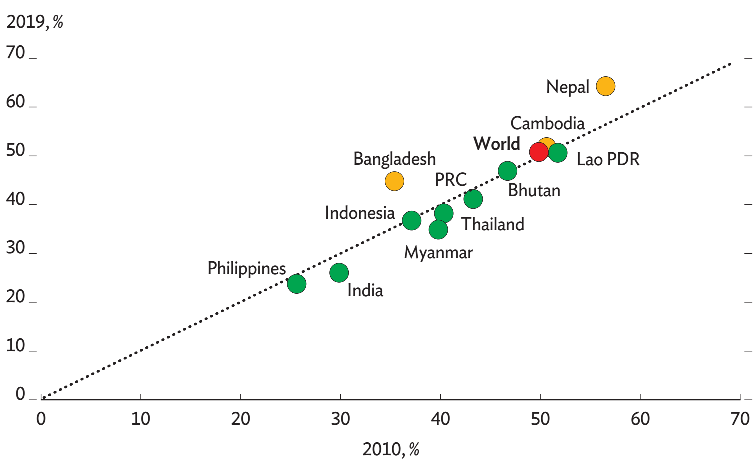


Source: United Nations. World Urbanization Prospects 2018. https://population.un.org/wup/Download/ (accessed 18 August 2021).

As the outmigration of male workers continues, Asia's agriculture is increasingly reliant on women and elderly to provide labor. This trend is particularly pronounced in Bangladesh, Cambodia, and Nepal, three economies with high labor migration (Figure 2.1.8). Bangladesh saw the share of female workers in agriculture rise by 9.3 percentage points from 2010 to 2019, and Nepal by 7.7 points.

Figure 2.1.8 Share of women in agricultural employment, 2010 and 2019

Asian agriculture relies increasingly on women...



Lao PDR = Lao People's Democratic Republic, PRC = People's Republic of China.
Source: ADB estimates based on ILO. ILOSTAT. https://ilostat.ilo.org/data/ (accessed 10 August 2021).

In Cambodia and the Lao People's Democratic Republic (Lao PDR), where male migration is also high, the share of females employed in agriculture remained above 50% in the same period. Such aggregated data may not capture changes in actual work responsibilities and the hours women devote to agricultural activity. In labor surveys, farm households may simply list male members as engaged in agriculture and neglect to report that female family members work their own fields or tend domestic animals.

Women's role and degree of involvement in agriculture vary within and across economies, regions, communities, and cropping systems. They are guided by norms and formal and informal rules that define gender roles and the division of labor, as well as by socioeconomic characteristics such as caste, class, and ethnicity. In South Asia, men take the lead in seedbed and land preparation, crop management, machine operation, and marketing, while women are mainly responsible for postharvest activities, as well as assisting men with seedbed and nursery preparation (Ahmed et al. 2013). In Southeast Asia, men similarly take the lead in seedbed and land preparation, as well as pesticide and fertilizer application. Aside from postharvest activities, women in Southeast Asia are likewise involved in crop establishment, weeding, manual harvesting, and marketing (Akter et al. 2017; Akter et al. 2016). Women in Southeast Asia are more visible than their counterparts in South Asia and exercise more decision-making power and autonomy. Likewise, compared with women in South Asia, those in Southeast Asia face less of a gender gap in access to agricultural extension services and control over farm income and resources (Akter et al. 2017; Akter et al. 2016; Malapit et al. 2020). In Central Asia, the Kyrgyz Republic and Tajikistan rely heavily on remittances from international migrants, who are mostly men. One recent study in Tajikistan found that about half of surveyed rural households had at least one person working abroad, leaving women to take up more responsibility for irrigation management and agriculture production (ADB 2020b). Women in many Asian economies are also responsible for safeguarding seed stores and traditional knowledge of seed varieties, including those that are drought resistant. Women's active participation in community seed banks has been vital in preserving biological diversity, which will be increasingly important under climate change.

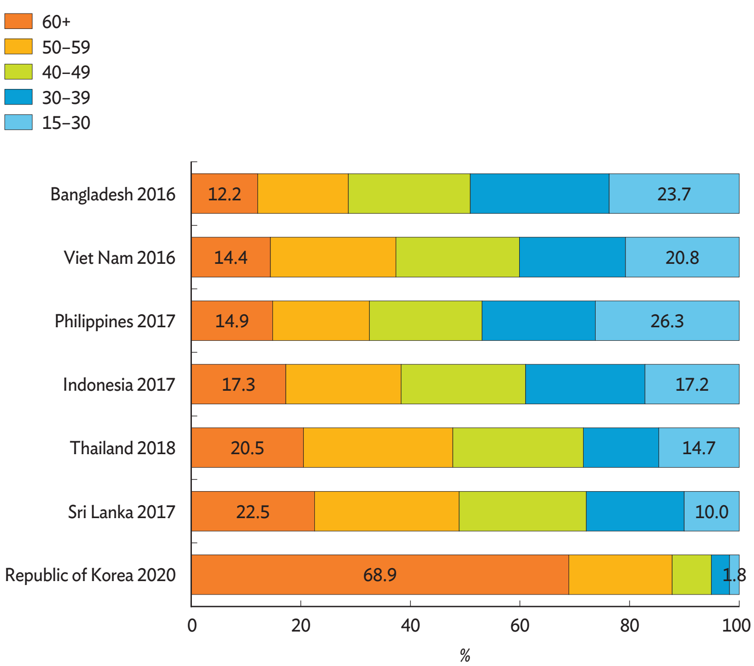
Women face discrimination in access to land, capital, inputs, information, and training. Despite their active role in agriculture and their invaluable contribution to global food security, women have limited access to resources, especially land. Evidence of gender inequality in access to land is compelling across all developing regions. Most inheritance systems disadvantage women, who are also vulnerable to loss of land when their household structure changes, especially if the husband dies or leaves (FAO 2011; Doss et al. 2018).

Ensuring women's access to land and other resources is increasingly important in the context of feminization of agriculture in many Asian economies.

The share of older farmworkers has increased over time, especially in economies with low birth rates and rapid rural–urban migration (Figure 2.1.9). In the Republic of Korea, a low birth rate and rapid rural–urban migration has left almost 70% of the agricultural workforce aged 60 or older. In Sri Lanka and Thailand, the share of agricultural workers aged 50 or older rose from only a third in the mid-2000s to almost half in the past few years. The average age of farmworkers was 69.8 years in the Republic of Korea in 2020, 51.0 in Sri Lanka in 2017, and 49.7 in Thailand in 2018. In other economies in Figure 2.1.9, the average age of farmworkers is over 40. It is noteworthy that older farmworkers tend to work fewer hours than do workers in their prime. More than half of agricultural workers in the selected Asian economies aged 60 or older work less than 40 hours per week.

Figure 2.1.9 Age distribution of agricultural workers

...and on older workers.



Sources: Labor force surveys of various countries.

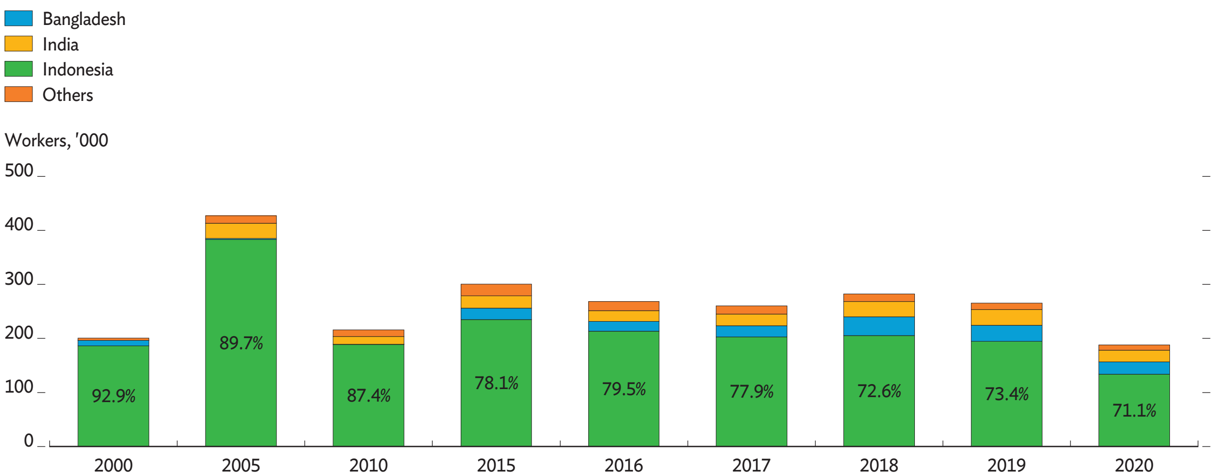
As people age, their physical strength and fitness deteriorate, affecting balance, agility, muscle strength, hand precision, and body coordination (Trombetti et al. 2016; Verhaegen and Salthouse 1997). Although older workers tend to be less productive at more physically demanding tasks, such as manual farmwork onsite, they usually have more farm experience and knowledge. An aging workforce requires more intensive agricultural mechanization and adoption of other labor-saving technologies. This may ease labor burdens and improve labor productivity, especially among older farmers and farmworkers.

Some high-income economies have responded to the declining availability of local labor by inviting international migrants to fill seasonal farm jobs. According to the Database on Immigrants in OECD Countries, the number of Asian migrant workers in agricultural jobs in the OECD grew fivefold from 68,000 in 2001 to 328,000 in 2016. About 70% of them were from South or Southeast Asia. In the fiscal year ending in 2016, 2.3% of migrant farmworkers in Australia and New Zealand were from the Pacific and 2.4% from South Asia. Since 2012, Australia's Seasonal Worker Programme has provided more than 40,000 seasonal jobs to workers from the Pacific and Timor-Leste (Clarke and Dercon 2016). While addressing workforce shortages in Australia, the programs provide opportunities for Pacific and Timorese workers to gain experience, earn income, and send remittances home to support their families and communities. Similarly, New Zealand allows overseas workers from the Pacific in horticulture and viticulture, through its Recognized Seasonal Employer (RSE) scheme. From less than 5,000 placements in 2008, the number of visas under the RSE scheme had more than doubled to over 12,000 in 2019, before it declined in 2020 due to the COVID-19 pandemic. Most RSE workers are from Vanuatu, followed by Samoa and Tonga. Most workers in the past years have been men, reflecting a strong gender bias in recruitment (Bedford 2020).

Some middle-income economies in Asia and the Pacific also host Asian migrants, mostly to fill low-skilled farm jobs. Malaysia, for instance, is a large employer of overseas migrant workers. In the 1980s, the Government of Malaysia allowed increasingly large numbers of migrants to work in jobs vacated by locals, especially in agriculture (Kaur 2010). Malaysia and Indonesia signed in 1984 the Medan Agreement, which allowed male workers from Indonesia to work on Malaysian plantations (Abubakar 2002). Malaysia subsequently signed similar agreements with Bangladesh and Thailand. For decades, Indonesian migrants provided labor for planting and harvesting, but the mounting success of Indonesia's own plantations has stemmed this labor flow, with fewer Indonesians choosing to migrate to work on Malaysian plantations.

Figure 2.1.10 Foreign workers on Malaysian plantations

Many migrants, mostly from Indonesia, are employed on Malaysian plantations.



Source: ADB estimates using data from the Ministry of Primary Industries and the Immigration Department cited in P. Wickramasekara. 2020. *Malaysia: Review of Admission and Recruitment Practices of Indonesian Workers in the Plantation and Domestic Work Sectors and Related Recommendations.* International Labour Organization.

Malaysian Palm Oil Board data show that 86% of plantation workers, mostly field and general workers, are foreign migrants (Wickramasekara 2020). According to the Ministry of Primary Industries and the Immigration Department, most plantation migrant workers are Indonesian. However, the Indonesian share declined from almost 93% in 2000 to 71% in 2020 as more workers arrived from other Asian economies, mainly Bangladesh and India (Figure 2.1.10).

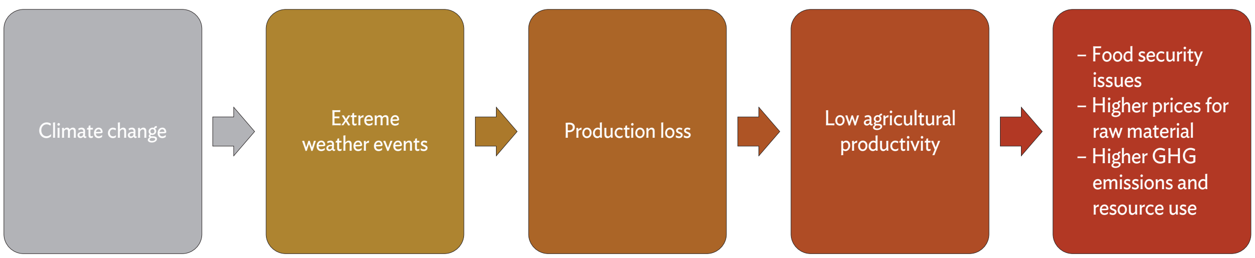
The COVID-19 pandemic has highlighted the vital role that migrants play in agricultural supply chains. Many Asian migrant workers have returned to their home countries, notably Cambodia, India, the Lao PDR, and Timor-Leste. As the pandemic evolves, concerns emerge about shortages of migrant workers for planting and harvesting (FAO 2020a). International travel restrictions and the quarantine requirements of subnational states and territories are significantly delaying new recruitment under the Pacific Labour Scheme. From March and October 2020, no Tongan workers entered or left Australia because of complete border closure. In Malaysia, the pandemic is exacerbating labor shortage in its palm oil industry. Thousands of migrant workers have left plantations to head home as borders closed. A foreign labor shortage induced by COVID-19 was expected to disrupt food production, processing, and distribution.

2.1.4 Climate change poses ever greater challenges to agriculture in Asia

Given its reliance on weather and climate, agriculture is especially vulnerable to risks posed by climate change. Changes in temperature and rainfall patterns, and extreme weather events, which are increasing in frequency and intensity due to climate change, cause significant damage and losses to Asian crop and livestock production, as well as fisheries. Aside from the negative agricultural production impacts of these events over the short and medium term, these events have negative long-term impacts as they damage natural resources and the ecosystem services of land and water that sustain agriculture.[6] Figure 2.1.11 illustrates the impact of climate change on agriculture and food security.

Figure 2.1.11 Impact of climate change on agriculture and food security

Agriculture is vulnerable to climate change and extreme weather.



Long-term change in average weather patterns
- Rising temperatures
- Increased precipitation
- More variable temperature

Increase in the frequency and intensity of extreme weather events
- Droughts
- Floods
- Storms
- Heat and cold waves

- Extreme temperatures, water stress, and water scarcity limiting growth and reproduction of crops
- Extreme temperatures causing livestock and fishery losses

- Lower crop yield
- Lower livestock and fishery production

- Lower food supply
- Lower supply of raw materials
- Higher food production cost, such as for livestock
- Higher GHG emissions per calorie

GHG = greenhouse gas.
Note: The classification adopted draws on the EM-DAT CRED Guidelines.
Source: ADB illustration.

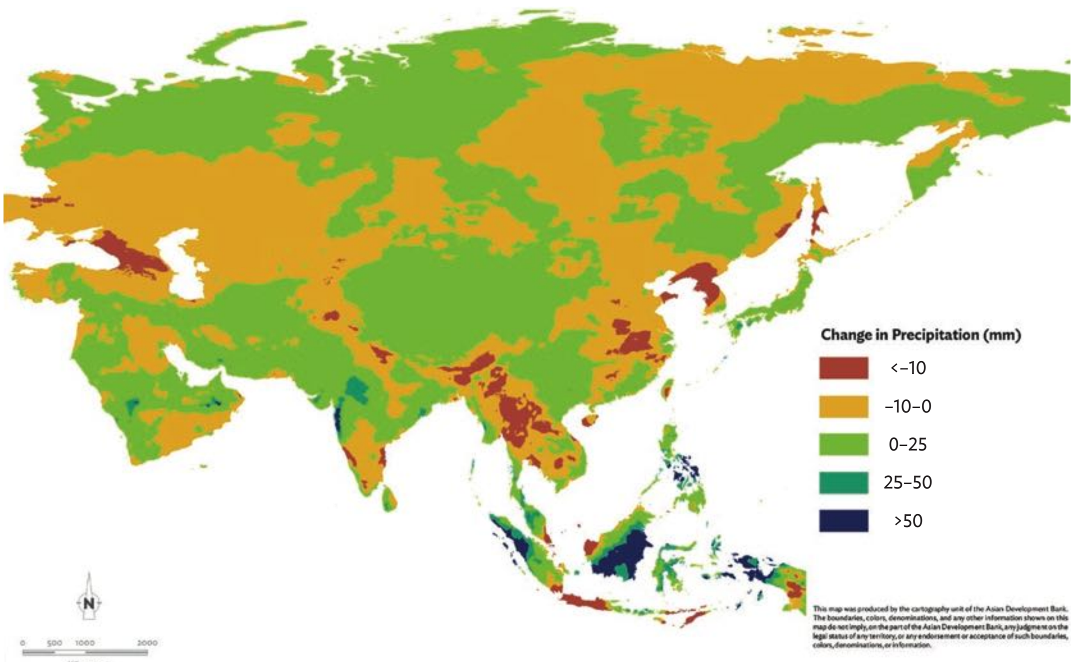
Crop growth and yields are highly sensitive to significant changes in temperature and precipitation. In the past 6 decades, Asia experienced significant changes in precipitation. Many parts of East, South, and Southeast Asia have experienced declines in precipitation, while precipitation increased in other parts of the region (Figure 2.1.12). As the average temperature continues to rise, the risk of precipitation extremes will further increase over Asia and the rest of the world (Ge et al. 2019; Guo et al. 2016; Li, Zhou, and Chen 2018). Climate change studies predict that, as global warming continues, most of the monsoon area in East and Southeast Asia will experience large increases in precipitation.

[6] Climate change may benefit some areas, such as Mongolia, with expected increases in temperature.

Figure 2.1.12 Observed changes in precipitation and temperatures in Asia, 1958–2019

Asia has experienced changes in precipitation and maximum and minimum temperatures.

a. Precipitation change (millimeters)



b. Maximum temperature change (°C)

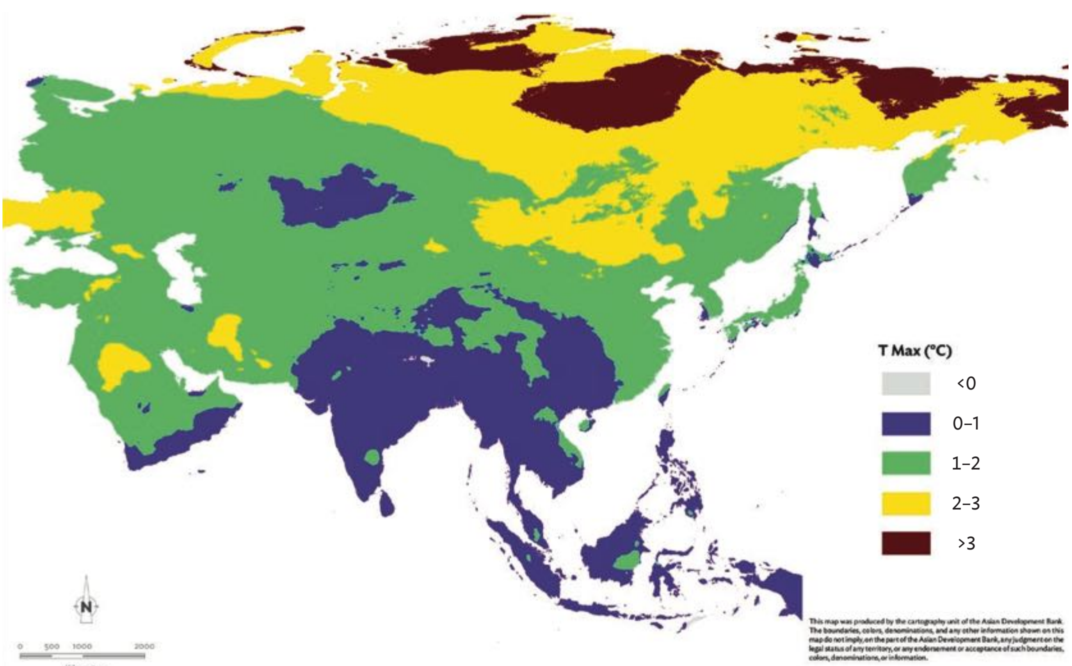


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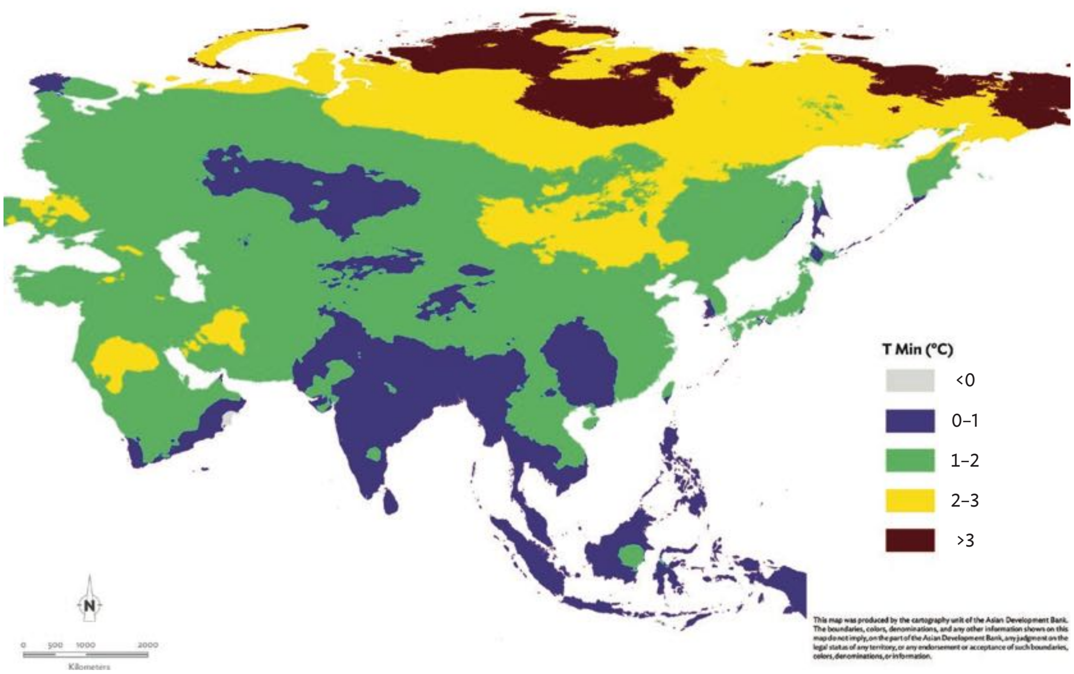
Figure 2.1.12 *Continued*

c. Minimum temperature change (°C)



Source: Gumma (2021) based on climate data from J. T. Abatzoglou et al. 2018. Terraclimate, a high-resolution global dataset of monthly climate and climatic water balance from 1958–2015, Scientific Data. Data available at TerraClimate. Climatology Lab. http://www.climatologylab.org/terraclimate.html (accessed 26 March 2021).

Under the worst-case scenario of high GHG emissions—designated representative concentration pathway (RCP) 8.5—by 2050 South Asia will experience an average increase in monsoon precipitation by 6.4% (Mani et al. 2018). Extreme precipitation and floods are also seen increasing in certain areas in Southeast Asia and Central Asia (McKinsey & Company 2020; IPCC 2018; Huang et al. 2014; Jie et al. 2019).

Climate change studies predict higher frequency and intensity of drought as warming accelerates (Sheffield and Wood 2008; Dai 2010). With accelerated warming, studies expect increased water stress and drought in Asia and the Pacific (Kraaijenbrink et al. 2017; Liu et al. 2018; Gao et al. 2018; Wang et al. 2021; Naumann et al. 2018; Cook et al. 2020). Higher drought frequency and intensity are expected in East and Southeast Asia (Amnuaylojaroen and Chanvichit 2019; Zhai et al. 2020). In some areas of West and South Asia, periods of drought are likely to lengthen and occur 5–10 times more frequently (Naumann et al. 2018). For instance, worsening drought severity and frequency are expected across the central, northern, and western parts of India (Gupta and Jain 2018; Shrestha et al. 2020).

Extreme heat stress during the reproductive stage of crop growth can diminish yields in certain crops, notably rice and corn (Wang et al. 2019; Shi et al. 2017; Deryng et al. 2014). Changes in maximum and minimum temperatures accurately describe climate variability over larger areas. They give a frame of reference that allows meaningful comparisons of locations and provide reliable calculations of temperature trends. One study found past drought and extreme heat significantly reducing global grain production by 9%–10% (Lesk, Rowhani, and Ramankutty 2016). While there is less research on the impact on agriculture from heat waves in Asia and the Pacific, evidence hints at their negative impacts on both crop production and human health in the region. Agricultural workers are expected to be the worst affected as their work capacity and productivity are compromised by heat stress, considering that they expend physical effort usually while working outdoors. According to ILO (2019), agriculture is projected to account for 60% of global working hours lost to heat stress in 2030. Pregnant women and people aged over 50 face especially high health risks from heat exposure. Under a scenario of high GHG emissions such as RCP 8.5, at least 600 million and perhaps 1 billion people in Asia will by 2050 be living in areas at risk of lethal heat waves—ones that exceed the human survivability threshold (McKinsey & Company 2020).

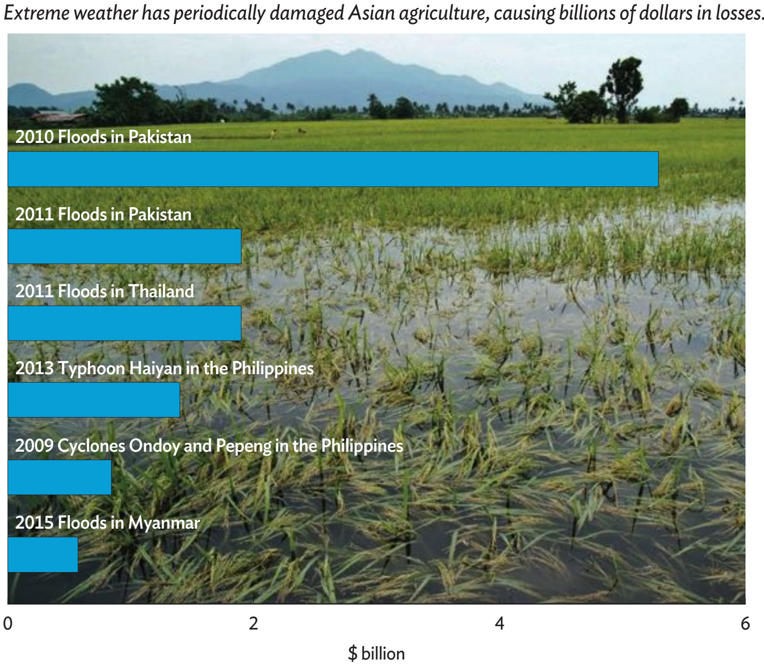
More frequent and more intense extreme weather events have caused significant damage and losses to crop and livestock production, as well as fisheries. In developing economies, agriculture absorbs 63% of the damage and loss caused by climate-related disasters across all economic sectors, or 26% of all damage and loss (FAO 2021b). These effects include physical damage from disasters to agricultural infrastructure and assets such as standing crops, farm tools and equipment, postproduction infrastructure, irrigation systems, livestock shelters, and fishing boats, as well as losses from lower crop production, lower income from livestock products, higher input prices, reduced agricultural revenue, higher operational costs, and increased unexpected expenditure to meet immediate needs in the aftermath of a disaster. Damage and loss cascade through the food value chain and other industries such as manufacturing that have backward linkages to agriculture.

Crops absorb 49% of all damage and loss from disasters triggered by natural hazards (FAO 2017). By causing water shortage and heat stress, drought directly affects crop and livestock yields. Recurring or prolonged drought have persistent ecosystem impacts that affect agricultural productivity over the long term. Drought caused by far the most damage and loss in livestock from 2008 to 2018, at 86%. It accounted for 14.6% of damage and loss in crops, albeit far less than 57.7% from floods and 25.4% from storms. Fisheries were damaged mostly by tsunamis, at 68.9%, and storms, at 18.1%.

Extreme weather events have exposed many people and vast agricultural areas in Asia to climate-related disasters (FAO 2015a). Six of the world's 10 climate-related disasters most damaging to agriculture from 2003 to 2013 were in Asia (FAO 2017). They include floods in Pakistan in 2010 and 2011 from extraordinary rainfall that caused $5.3 billion in agricultural damage and loss in one year and $1.9 billion the next. These disasters are followed in ranking by floods in Thailand in 2011 costing $1.9 billion, Typhoon Haiyan in 2013 in the Philippines costing $1.4 billion, a tsunami in 2004 in Indonesia costing $0.9 billion, and Cyclones Ondoy and Pepeng in 2009 in the Philippines costing $0.8 billion (Figure 2.1.13).

Figure 2.1.13 Climate-related disasters that most severely damaged Asian agriculture

Extreme weather has periodically damaged Asian agriculture, causing billions of dollars in losses.



Note: Figures include damage and loss from climate-related disasters, including floods, drought, and tropical storms, based on 2015 and 2017 estimates from the Food and Agriculture Organization (FAO). The classification of disasters adopted by FAO draws on guidelines from the Emergency Events Database (EM-DAT) of the Centre for Research on the Epidemiology of Disasters (CRED) and aligns with United Nations Office for Disaster Risk Reduction definitions and terminology.

Background photo: Drowned harvest. This rice field in the Philippines was flooded by Cyclone Ondoy (photo from the image collection of the International Rice Research Institute. www.irri.org; CC BY-NC-SA 2.0).

From 2008 to 2018, Asia and the Pacific suffered $207 billion in crop and livestock production losses to disasters, or 74% of the global total (FAO 2021b).[7] Of this amount, the PRC accounted for over $153 billion, or 55% of the global agricultural loss,

[7] This equals 283 calories per capita per day, or 11% of the recommended daily allowance.

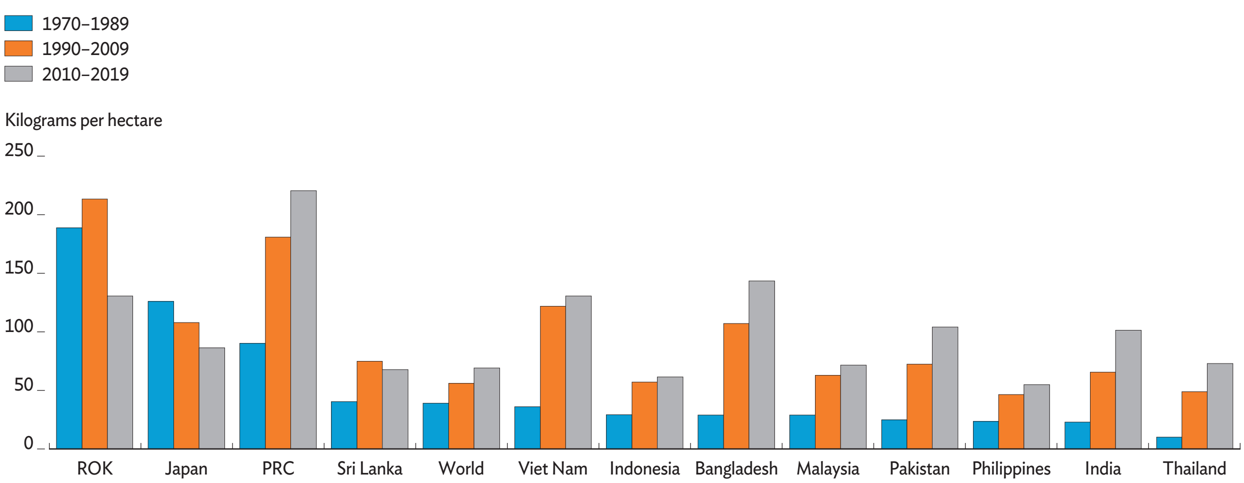
while developing economies including low and lower-middle income economies in Southeast Asia accounted for $21 billion and in South Asia for $25 billion. The frequency and scale of such events and the damage they cause are rising under climate change and threaten to reverse the economic gains of past decades and worsen poverty, especially in Asia and the Pacific.

2.1.5 Agriculture faces environmental challenges of its own making

The green revolution succeeded in part through heavy use of chemical fertilizers and pesticides, subsidized by governments. To stimulate agricultural production and achieve food self-sufficiency, many Asian governments launched production support programs. These government subsidies lowered the price of fertilizers and encouraged their overuse, which not only burdened national fiscal positions but also caused environmental degradation. Indonesia, for example, began subsidizing fertilizer in 1971, as did the Philippines in 1973, to encourage its use with high-yielding modern rice varieties and reduce rice production cost (Esguerra 1981; Hedley and Tabor 1989). In both Indonesia and the Philippines, average nitrogen fertilizer use per hectare of cropland in 2010–2019 was more than double average use in 1970–1989 (Figure 2.1.14). Nitrogen use likewise intensified in other Southeast Asian economies—most notably Thailand and Viet Nam—and in South Asia, especially Bangladesh, India, and Pakistan.

Figure 2.1.14 Nitrogen fertilizer use in selected Asian economies, 1971–2018

The use of nitrogen fertilizer has intensified in developing countries in Asia.



PRC = People's Republic of China, ROK = Republic of Korea.
Source: FAO. FAOSTAT. http://www.fao.org/faostat/en/#data (accessed 21 June 2021).

Fertilizer subsidies have placed a fiscal burden on Asian governments. While intensified fertilizer use contributed to past improvement in agricultural production and food security, their fiscal and environmental costs have outweighed their benefits. Fertilizer subsidies absorbed 1.6% of the national budget in Bangladesh in fiscal 2019, for example, and 1.2% in Indonesia (FPMU 2020; Suryana 2019; Kementerian Keuangan 2019). Further, the primary beneficiaries of fertilizer subsidies have been generally larger, better-off farmers. In Indonesia, for instance, 60% of fertilizer subsidies benefit 40% of the largest farmers (Osorio et al. 2011). Because fertilizer subsidies have consumed a considerable share of government expenditure, phasing out fertilizer subsidy programs offers significant fiscal savings. In the PRC, for instance, the government phased out fertilizer subsidies and invested in nitrogen and waste management (Searchinger et al. 2020).

Fertilizer overuse has caused unwanted phosphorus deficiency, increased water pollution, and led to greater GHG emissions. Fertilizer accounts for 12% of the GHG emissions from agriculture. The manufacture of synthetic nitrogen fertilizer generates significant GHG emissions, while its application is a significant contributor to direct nitrous oxide (N_2O) emissions from agricultural soils. In the PRC, for instance, GHG emissions associated with the manufacture of synthetic nitrogen fertilizers in 2015–2017 were 41.4 metric tCO_2e for wheat and 59.7 metric tCO_2e for maize. In the same period, annual direct N_2O emissions from 12.63 tons/year of synthetic nitrogen application were estimated at 35.82 gigagrams of N_2O for wheat and 69.44 for maize (Chai et al. 2019).

Chemical pesticides are also extensively used in modern agriculture. The success of green revolution encouraged widespread production of only a few varieties of rice, which made production more susceptible to pests and increased the need for pesticides. Farmers started overusing them in the belief that more was better, though studies later found that the use of pesticide during early plant growth was unnecessary, as leaf-feeding insects seldom affected yield (Heong, Escalada, and Mai 1994). Further, pesticides pose threats to farmers' health and food safety (Gomes et al. 2020; Zhang, Zeiss, and Geng 2015; Pingali, Marquez, and Palis 1994).

Water shortages affect a large share of rural population in Asia. FAO (2020a) estimated that 500 million rural people globally are subject to very high water stress in the case of irrigated areas, or very high drought frequency affecting rainfed cropland and pasture. Among them, 453 million people, or 91%, are in Asia, though only 21% of the affected agricultural land is in this region (Figure 2.1.15a). In Asia, 77% of affected areas and 87% of affected rural populations are in only four economies: India, Indonesia, Pakistan, and the PRC. Climate change is expected to further exacerbate water shortages by changing rainfall patterns.

Meanwhile, demand for water is expected to grow because of expanding industrial and residential needs.

Irrigation management, which played an important role in Asia's agriculture, is facing structural challenges. Asia has 70% of the world's irrigated farmland, or 238 million hectares (ha) of the 339 million ha total. About 40% of Asian cropland is irrigated (Figure 2.1.15b). South Asia has 111 million ha of irrigated agricultural land, followed by East Asia with 79 million ha, making about half of cropped area in these two subregions irrigated. However, outmigration of farmers is posing community collective action problem in maintaining the efficiency of irrigation systems. Some farmers have stopped farming altogether, leaving fallow plots in the middle of irrigation systems. While better-off farmers have invested in private irrigation systems using pumps, wells, ponds, sprinklers, and drip irrigation, thereby becoming independent of community irrigation management.

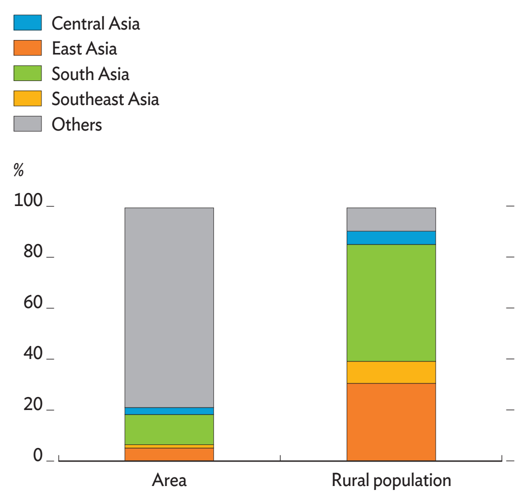
In areas where groundwater use is necessary, private and public irrigation systems need to coexist. Studies have found that the use of private wells in areas with surface irrigation systems can start a vicious cycle (Kajisa et al. 2018). As users of private wells exit surface irrigation systems, their collective management suffers. As surface irrigation systems decline, so does their function of recharging groundwater resources, leaving users of private wells worse off, especially as the increased use of individual wells threatens the water table. Coordination between users of private and public irrigation systems is crucial to finding sustainable modes of irrigation system management (Kajisa 2012). For better coordination, public irrigation systems need to shift conceptually from managing the system to serving users. This transition may require additional user fees and higher water prices. Water pricing has become a fundamental issue. In some cases, farmers pay little or nothing in fees for irrigation water. In many cases, farmers form water-user associations and pay for irrigation water under the principle of the user pays. Yet, when they pay for irrigation water, individual farmers are typically charged according to the size of their landholdings. Because fees may include levies for pump fuel or other operating costs that depend on the volume of irrigation water, association members may collectively have incentive to save water, but the individual user does not. As a result, without effective peer pressure, individual farmers tend to overuse water.

The aquaculture industry faces environmental sustainability concerns. Environmental challenges facing aquaculture include land salinization, which hinders agricultural yields; land subsidence from overuse of groundwater; frequent outbreaks of shrimp disease under

Figure 2.1.15 Agricultural land under water stress and irrigation

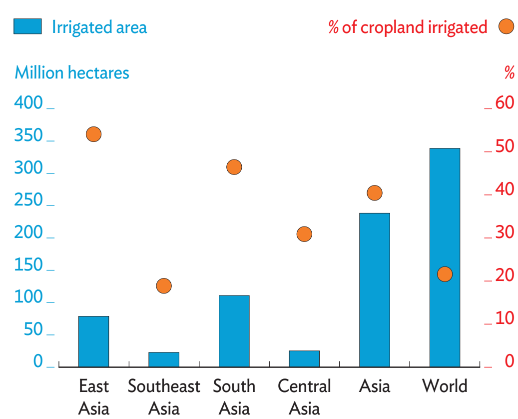
Only 21% of agricultural land under water stress is in Asia, but it is home to 91% of affected rural populations.

a. Water stress



About 70% of irrigated agricultural area is in Asia.

b. Irrigation systems



Note: Rainfed areas with very high frequency of drought or irrigated areas with very high levels of water stress.

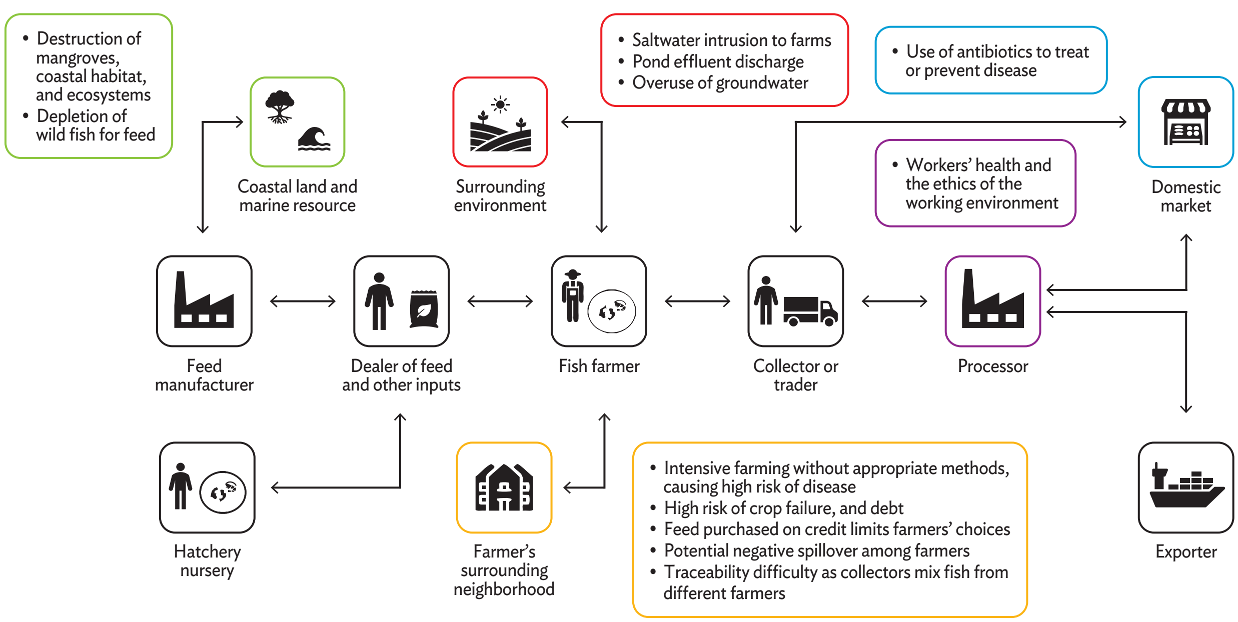
Source: FAO. FAOSTAT. http://www.fao.org/faostat/en/#data (accessed 21 June 2021).

intensified farming methods; misuse of prohibited antibiotics to prevent and treat shrimp disease, which threatens consumer health; destruction of mangroves, threatening biodiversity in coastal areas; and dependence on wild fish catch for feed, which depletes marine resources.

Some of these environmental problems affect the immediate environment, while others affect coastal land and marine resources, and the health of final consumers. Figure 2.1.16 illustrates a typical market structure for farmed fish and associated environmental problems. Immediate environmental damages occur if excessive groundwater pumping causes ground subsidence or if brackish water directed to ponds affects the salinity of surrounding land. Pond water quality is not easily observable without tests, the equipment for which is not readily available to many fish farmers. Pond effluents can thus spill over and affect neighboring farmers. The conversion of mangrove forests into aquacultural ponds severely affects biodiversity, as natural mangroves function as nurseries and shelters for many aquatic species. As inland aquaculture technologies and practices have been established, there is less need to expand coastal aquaculture. Another important issue is that because feed for farmed shrimp and fish depends heavily on wild-caught fish, the rapid growth of aquaculture worsens the depletion of marine resources. Intensive farming worsens the risk of shrimp disease, and farmers are reported to use antibiotics to prevent or treat them, their residues possibly threatening consumer health.

Figure 2.1.16 Typical market structure and challenges for farmed fish

The market for farmed fish suffers many problems and needs better management for sustainability.



Source: A. Suzuki. 2021. Rising Importance of Aquaculture in Asia: Current Status, Issues, and Recommendations. Background paper for *Asian Development Outlook 2021 Update*. Asian Development Bank.

Finally, fish processing has often been criticized for health and ethical problems affecting workers. Long hours of work while standing in cold factories can undermine workers' health. Child labor and migrants working in environments with subpar labor standards have been reported in media and academic papers, posing ethical issues that if not fully addressed, challenge the sustainability of aquaculture.

The international community has made various efforts to mitigate the negative effects of aquaculture, but problems persist. International standards such as the Code of Conduct for Responsible Fisheries (FAO 1995), International Principles for Responsible Shrimp Farming (FAO et al. 2006), and Better Management Practices have been adopted in many Asian economies. In addition, national standards and certifications and various private standards, such as the Aquaculture Stewardship Certification, have also been established. Yet problems persist because aquaculture is location-specific, with the fish farming community typically comprising numerous smallholders, making it difficult to control good practices. Spillover via canals of others' bad practices discourages farmers from trying to keep their own ponds clean. Other contributing factors include lack of strict monitoring of input markets, constraints on farmer credit, farmers' lack of appropriate knowledge, and difficulty of maintaining clear traceability along the supply chain. The multipolarity of global aquaculture also complicates compliance with numerous standards.

2.2 Innovation to boost productivity and ensure sustainability

Innovative solutions are required to help farmers raise productivity while ensuring long-term environmental sustainability. Faced with increasing labor shortages, innovative arrangements that help Asia's smallholder farmers access agricultural machine services have emerged. Improved technologies and practices such as site-specific nutrient management and volumetric water tariffs can help farmers minimize the negative impact on the environment. The private sector can play an important role in providing these farm extension and advisory services. Finally, the rapidly growing aquaculture sector can provide consumers with animal protein and other essential nutrients, but it needs to be well-regulated to ensure sustainability.

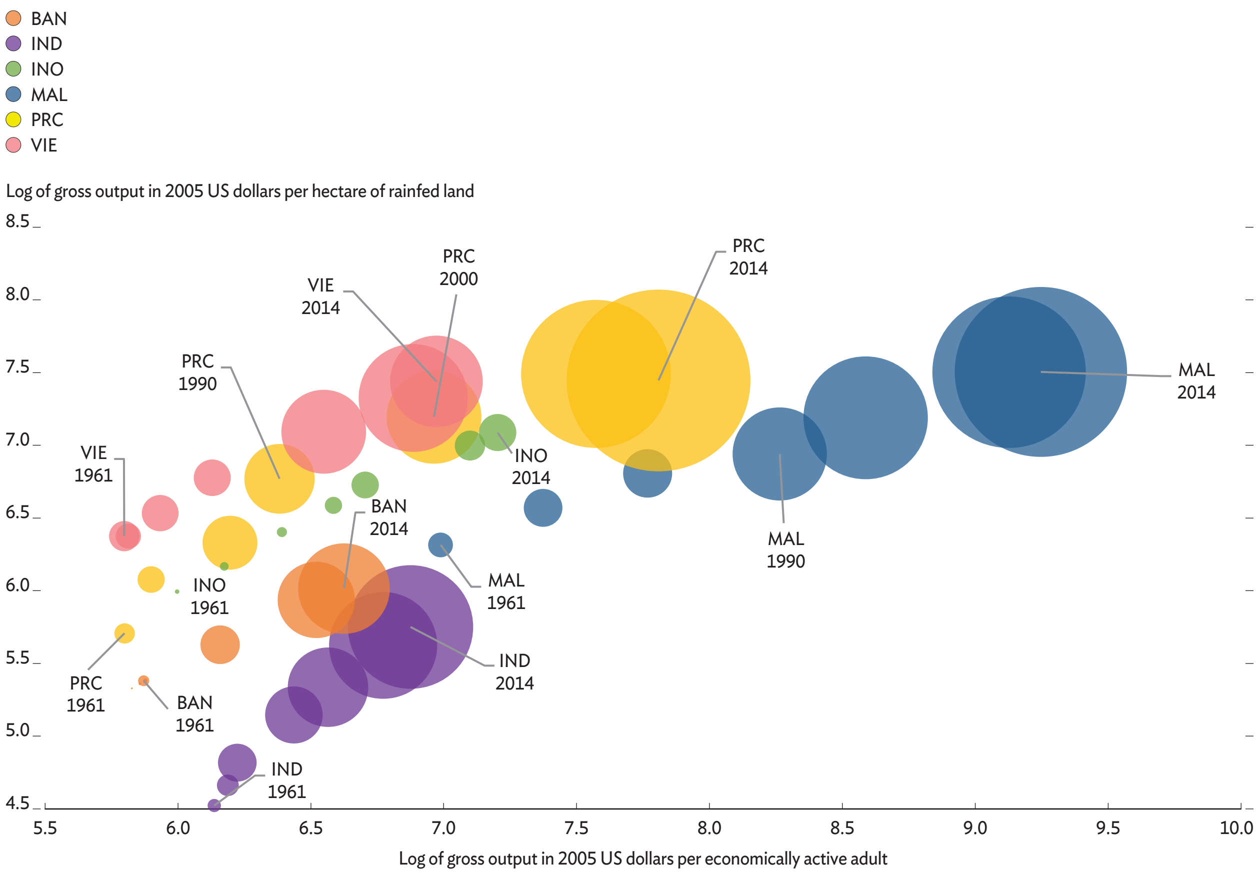
2.2.1 Access to machines for smallholder farmers can be improved

Higher demand for greater agricultural mechanization came in response to rising labor costs under industrialization. Labor scarcity caused by higher demand for industrial labor has encouraged many farmers in Thailand, for example, to increasingly adopt farm machinery such as four-wheeled tractors with harvesters to till their land and harvest their crops (Srisompun, Athipanyakul, and Somporn 2019). Trade liberalization in Asia in the 1990s brought increased supply of agricultural machinery, mainly imported from the PRC, the Republic of Korea, and Japan. In some South and Southeast Asian economies, such as Bangladesh, India, the Philippines, Sri Lanka, and Thailand, local manufacture of adapted small-scale agricultural machinery and parts expanded further as the market for them continued to grow in the 2000s (Diao, Takeshima, and Zhang 2020).

The use of farm machinery saves time and labor. A single hour of combined harvester use, for example, saves some 28 or 29 labor hours of hand harvesting and threshing. The adoption of farm machinery increased over time, albeit at varied rates across economies (Figure 2.2.1). Low-horsepower or small four-wheel tractors were used mainly for land preparation, while small to medium-sized harvesters were also widely used, even by smallholders (Diao, Takeshima, and Zhang 2020).

Figure 2.2.1 Agricultural land productivity, labor productivity, and mechanization, 1961–2014

Agricultural mechanization (shown in circles) has increased labor productivity, but many countries in the region lag behind.



BAN = Bangladesh, IND = India, INO = Indonesia, MAL = Malaysia, PRC = People's Republic of China, VIE = Viet Nam.

Notes: Dots represent data points in 1961, 1970, 1980, 1990, 2000, 2010, and 2014, the last year being when the Food and Agriculture Organization stopped reporting on the use of agricultural machinery. Circle size represents the rate of mechanization as measured by the ratio of machinery in metric horsepower to the number of economically active adults in agriculture. The X axis shows gross agricultural output in 2005 US dollars per economically active adult in agriculture. The Y axis shows gross agricultural output in 2005 US dollars per hectare of rainfed cropland equivalent. On the X and Y axes, equivalent United States dollar values for log 6 is $405, 8 is $3,000, and 9 is $8,150.

Source: US Department of Agriculture. Economic Research Service. https://www.ers.usda.gov/data-products/international-agricultural-productivity/ (accessed 7 October 2019).

Adoption of labor-saving agricultural machinery is critical in the context of the shrinking, aging, and feminizing rural population. Such labor-saving advances enable older workers to prolong their careers and encourage the greater participation of rural women in the workforce. Time-saving agricultural machinery can make it easier for older workers and women to perform heavy, backbreaking agricultural tasks, such as transporting agricultural supplies and produce to and from warehouses. In farming systems in the Philippines and Timor-Leste, with little mechanization, female farmworkers suffer health problems and time poverty because of their workload, especially during peak season.

In contrast, farm mechanization has considerably alleviated women's drudgery in Indonesia and Thailand (Akter et al. 2017; Akter et al. 2016). Time-saving technology—such as a tiller that reduces the need for weeding, a laborious farm task often carried out by women—allow women to pursue work off the farm.

Land productivity has reached a plateau for some advanced Asian economies. In Malaysia, the PRC, and Viet Nam, land productivity has reached a plateau in 2005 at about $3,000 per hectare. This reflects the physical and biological limits of land. These economies have continued to increase agricultural productivity by increasing labor productivity, through mechanization, moving the dots in Figure 2.2.1 to the right. As the dots move from left to right, they become larger to reflect the ratio of machinery in metric horsepower to the number of economically active adults in agriculture.

Compared with advanced Asian economies, labor productivity remains low in other economies where most farmers continue to be smallholders. Asia has 350 million smallholder farmers, or those who manage areas measuring up to 10 ha (FAO 2020b). About 95% of all farms in Asia are smaller than 5 ha (FAO 2020a). In the PRC, 98% of farmers cultivate less than 2 ha (FAO 2015b). In India, 80% of farmers are smallholders. Many of them are poor and food insecure, with little access to capital, markets, or services. Credit is likewise difficult to obtain for lack of collateral and because of the high risks associated with agriculture. These farmers face critical constraints on their adoption of agricultural machinery, as their economic advantage depends critically on scale. Even small agricultural machinery that would be advantageous may be unaffordable without heavy government subsidies. To help smallholder farmers benefit from agricultural machines, innovative arrangements have emerged.

First, farmland consolidation has been promoted through market transactions and institutional arrangements. Historically in many Organisation for Economic Co-operation and Development (OECD) countries, consolidation was achieved largely through market transactions. In the PRC, land transactions were seriously constrained by insecurity affecting farmers' individual land rights. Since the 2000s, however, a variety of institutional innovations consolidated small operations into larger units (Kimura 2021; Yamauchi 2021; Liu et al. 2020). These reforms granted farmers more complete land-use rights and the right to derive nonagricultural income from land, making land transfer much more likely. The PRC Ministry of Agriculture and Rural Affairs reported that "transferred" land soared from 3.9 million ha in 2004 to 31.4 million ha in 2016. With increased land market movements, large-scale agriculture operations have emerged. Caution is needed, however, on land consolidation.

Niroula and Thapa (2005) highlighted that, in the past, land consolidation was not successful partly because of weak land rights, difficulty in evaluating land values, and problems affecting contract enforcement. The study suggested that success in any land consolidation program depends on how well farmers' needs, capabilities, and aspirations are reconciled and integrated.[8]

Second, instead of consolidating land through land rental, there are schemes that consolidate farm activities. In Viet Nam, the Small Farmers, Large Field scheme has received significant attention as a solution to smallholders' problems of mechanization and lack of bargaining power in buying inputs and marketing output. Under the scheme, participating farmers organize themselves into groups and synchronize their operations by adopting a single rice variety to plant, establishing a group nursery, and transplanting and harvesting at about the same time, thus essentially converting their small landholdings into a large field. A similar scheme is now under operation for rice and potatoes in eastern India (Mohanty et al. 2017). In the PRC, the institutional framework to establish farmer professional cooperatives (FPCs) was promulgated in 2007. In addition to jointly owned farm machines, FPCs provide diverse services including technical training and processing, marketing, and purchasing assistance. According to the PRC's State Administration for Market Regulation (2020), the number of legally registered cooperatives reached 2.2 million at the end of 2019. In some cases, FPCs evolved into shareholding cooperatives in which farmers transfer land-use rights in exchange for shares in the cooperative. This arrangement allows members to participate in the allocation of cooperative dividends.

Third, rural entrepreneurs are providing farm machine rental and operation services. By assisting many smallholder farmers, service providers enjoy economies of scale while making labor-saving machines accessible to smallholder farmers. In the PRC, two types of mechanization services exist. One is mechanical services provided by specialized custom plow, planter, and harvester teams that own large machines. The other provides machine rental to farm households that operate the machines themselves. Farmer professional cooperatives and specialized custom plow, planter, and harvester teams have become major driving forces behind agricultural modernization, supported by government machine subsidy program. In addition to offering a wide range of mechanized operation services such as field preparation,

8 Issues related to land tenure, rights, and regulations are complicated and beyond the scope of this chapter but demand more discussion elsewhere.

planting, harvesting, transportation, and storage, these service providers deliver agricultural machinery technical services and guidance on maintenance and other technical matters, reinforcing smallholder capacity to further mechanize their farms. While these innovations are expected to allow farmers to benefit from agricultural mechanization, careful monitoring and proper regulation are needed to ensure the fair sharing of benefits to participating farmers.

The COVID-19 pandemic continues to hurt rural households (Box 2.2.1). An expansion of innovative services mentioned above may help farmers rebound from the lasting impacts of the pandemic.

2.2.2 Improved practices can help farmers reduce environmental damage

Fertilizer subsidies have encouraged their overuse. Since the beginning of the green revolution, fertilizers have been subsidized in many Asian economies to increase the yields of improved varieties of cereal crops. As fertilizer subsidies are gradually phased out or scaled down in recent decades, farmers have incentive to use fertilizer more efficiently. Even within a single farm plot, the need for fertilizer differs depending on soil condition, topography, and residual from past application. Yet many farmers simply apply fertilizer uniformly, sometimes following outmoded recommendations from local extension services. In response, site-specific nutrient management has been developed. It is a low-tech approach based on plant need for optimally applying fertilizers such as nitrogen, phosphorus, and potassium to crops (Pampolino et al. 2007). Studies found that this approach made nitrogen use more efficient. Mobile phone applications have been developed to help farmers optimize the amount and timing of applications of different types of fertilizers.

Besides chemical fertilizers, excessive use of chemical pesticides is also a problem. The green revolution success encouraged the widespread production of only a few varieties, which made rice production more susceptible to pests and increased the need for agricultural pesticides. Farmers started overusing them in the belief that more was better, though studies later found that the use of pesticide during early plant growth was unnecessary, as leaf-feeding insects seldom affected yield (Heong, Escalada, and Mai 1994). Further, pesticides pose threats to farmers' health and to food safety. To reduce the inappropriate use of pesticide, integrated pest management (IPM) was introduced in the major rice-producing areas of Asia, especially in Southeast Asia.

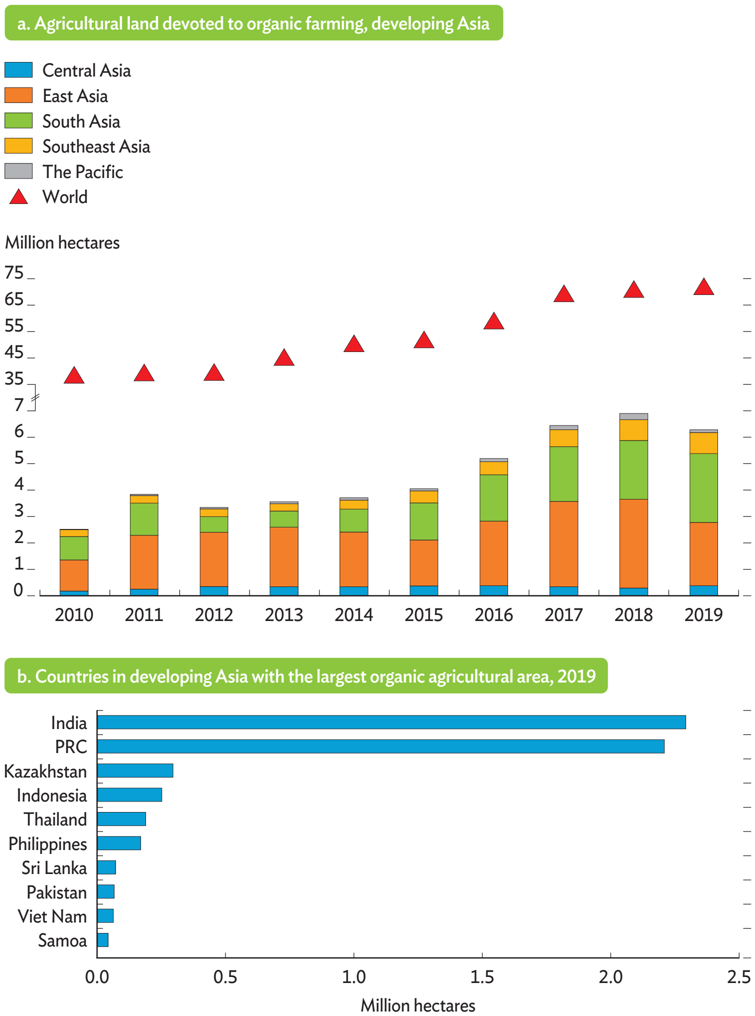
IPM is an ecosystem-based strategy that aims to control pests and their damage over the long term through a combination of techniques—most notably biological control, habitat manipulation, modification of cultural practices, and the use of resistant crop varieties—to complement, reduce, or replace the application of synthetic pesticides. IPM practices were transferred to farmers not through lectures but by experiential learning in farmer field schools, which attracted the participation of over 2 million rice farmers across Asia.

Although practiced by relatively few farmers in Asia, organic agriculture has gradually expanded in the region. Organic agriculture uses ecologically sound pest controls and biological fertilizers to optimize the productivity and fitness of diverse communities within the agro-ecosystem, including soil organisms, plants, livestock, and people. In 2019, developing Asia had 5.9 million ha of agricultural land under organic agriculture, or 8.2% of the world's total (Figure 2.2.2a). India had the largest share of organic agricultural land in the region, at 38.8%, followed by the PRC, at 37.4%. Southeast Asia had 12.7%, mainly in Indonesia, Thailand, and the Philippines (Figure 2.2.2b). According to *The World of Organic Agriculture, Statistics and Emerging Trends* (Willer et al. 2021), 49.2% of organic agricultural land is used to produce field crops such as cereals, oilseeds, textile crops, and medicinal and aromatic plants, while 13.5% is devoted to permanent crops like coconuts, tea, fruits, and coffee. About 36.2% of organic agricultural land have no specific details on land use, while 1.1% is permanent grassland. There are nearly 1.6 million organic farm producers in Asia, 1.4 million of which are in India and nearly 119,000 are in Thailand. These numbers are believed to be underestimated, as many economies do not report on organic production.

Obtaining organic certification is a complex and expensive process for many farmers in the region. Estimates based on FAOSTAT database suggest that in 2018, only 54% of the organic agricultural land in developing Asia was certified. The low rate of certification may reflect slow adoption of organic regulations in many economies. Table 2.2.1 shows that, as of 2020, only 72 economies globally had fully implemented organic regulations (Willer et al. 2021), and only 10 of them were in Asia. Organic certification requires annual inspections and monitoring that are logistically difficult and costly. Obtaining international certification is even more tedious, expensive, and time consuming, thus not economical for small and marginal farmers. Lack of support in terms of organic product distribution and marketing systems makes it even harder for farmers to meet certification requirements and standards.

Figure 2.2.2 Organic farms in developing Asia

Organic agriculture is expanding in Asia, with most organic agricultural land in the region in India and the People's Republic of China.



PRC = People's Republic of China.

Notes: Data are from the Research Institute of Organic Agriculture (FiBL), which is one of the world's leading institutes in organic agriculture. FiBL has long been committed to the international development of organic agriculture, sponsoring the umbrella organization of the organic agriculture movement: IFOAM—Organics International. For research and development projects, FiBL partners with the European Union, the Food and Agriculture Organization, and other national and international institutions.

Source of data: Research Institute of Organic Agriculture FiBL. FiBL Statistics. statistics.fibl.org (accessed 21 June 2021).

An alternative community-based certification system has emerged, as an alternative to costly international certification. The International Federation of Organic Agriculture Movements (IFOAM) has introduced a community-oriented participatory guarantee system (PGS) to build trust, social networks, and local knowledge. PGS employs a peer-to-peer monitoring system and is designed to meet the needs of small farmers producing for local markets. Asia has the largest group of producers and operational PGSs in the world, with 1.1 million certified PGS producers.

Table 2.2.1 Status of organic agriculture regulation

Organic agriculture regulations exist in Asia, but most are not yet fully implemented.

Region	Economies Drafting	Economies Fully Implemented	Economies Partly Implemented	Total
Africa	5	1	4	10
Asia	7	10	11	28
Europe		39	4	43
Latin America and the Caribbean	2	16	3	21
North America		2		2
Oceania		4		4
Total	**14**	**72**	**22**	**108**

Source: IFOAM—Organics International. https://www.ifoam.bio/ (accessed 17 September 2021).

In India, farmers have, for the past 2 years, joined a government initiative called PGS-India, implemented by the National Center of Organic Farming.

As the COVID-19 pandemic shut down markets and other economic activities, the organic food supply chain has been seriously affected by declining demand. The pandemic has also, however, highlighted the importance of healthy food and a healthy lifestyle. Indonesia, the Philippines, and the PRC are among the economies that have recorded significant increases in demand for fresh produce. This generates new opportunities that turn organic production into a hotspot for investment. As economies recover from the pandemic, a strong rebound is expected in demand for high-quality food in restaurants and at home. The post-pandemic period could be a turning point for organic agriculture in Asia.

2.2.3 Irrigation systems need to be upgraded and fit farmers' incentives

Modernizing irrigation infrastructure and management systems is imperative for tackling water stress. Many irrigation systems that were constructed decades ago and have since been poorly maintained are long due for upgrades. Irrigation systems need to be climate resilient, especially able to withstand floods, as climate change is expected to increase the number of floods. More intense flood damage has often been observed in recent years. In addition, investments in irrigation infrastructure need to be designed to be labor saving and supportive of agricultural mechanization and diversified farming. Further, irrigation management systems need to be flexible to allow public and private irrigation systems to coexist and contribute to sustainable water management.

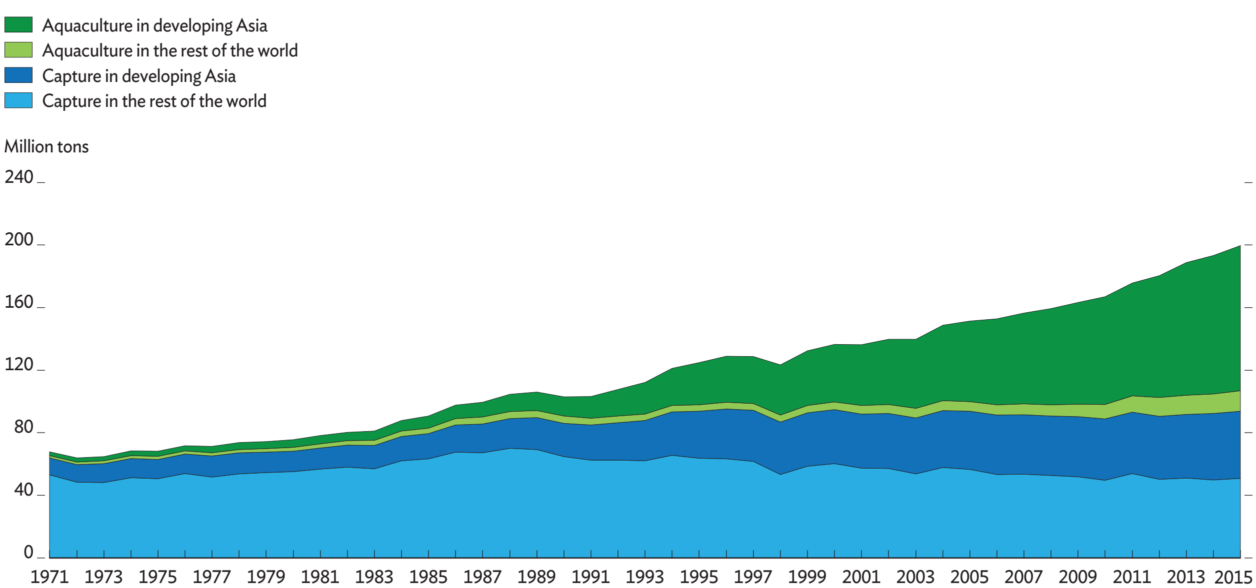
Innovative technologies can promote more sustainable use of water. Implementation of remote water-sensing and control systems, water-saving irrigation technologies such as satellite-based irrigation advisory systems, and such innovative methods as volumetric water charging can lead to a more efficient use of water. However, volumetric water charging systems require effective collective action, highly sophisticated infrastructure that enables accurate volume measurement, and the provision of water supply on demand (Box 2.2.2). Designing appropriate and effective policy for groundwater use must consider the particular agro-ecological and socioeconomic conditions of the area where it applies. To discourage overuse, flat charges should be replaced with metered charges and a so-called Pigouvian tax, levied to compensate for negative externalities associated with both private or communal extraction of groundwater (Kajisa 2012; Kajisa, Palanisami, and Sakurai 2007).

2.2.4 A well-regulated aquaculture sector can support Asian consumers' seafood consumption

The past 3 decades have seen rapid growth in aquaculture in Asia. In 2015, aquaculture provided 53.1% of fishery production, and Asia dominated global aquaculture with an 88% share. Figure 2.2.3 shows that the wild fish catch has been flat at a little above 80 million tons annually since the late 1980s.

Figure 2.2.3 Annual capture fishery and aquaculture production, world and developing Asia

Aquaculture is growing rapidly with developing Asia, which comprises 88% of the global total.



Source: World Bank. World Development Indicators. https://databank.worldbank.org/source/world-development-indicators (accessed 28 July 2021).

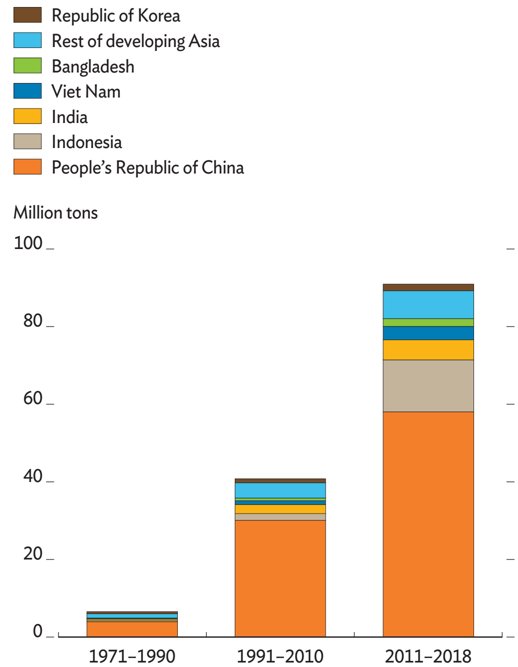
Increased human fish consumption has thus been supplied by aquaculture. Growth has come more from inland aquaculture than from marine aquaculture, which has expanded little in the past decade. New technologies and practices have helped the rapid expansion of inland aquaculture. The PRC is by far the world's largest producer of farmed fish, outproducing the rest of the world combined since 1991 (Figure 2.2.4). Aquaculture is growing quickly in East, Southeast, and South Asia. While most of fishery production in the PRC and South Asia is consumed domestically, the share of exports is rising in some Southeast Asian countries, notably Thailand and Viet Nam.

Aquaculture contributes to good nutrition and employment in Asia. While animal protein intake in Asia is generally low, as discussed in section 2.1, the share of dietary protein from fish is larger in Asia than the world average. Employment generated in aquaculture is substantial and rising, providing more work for women than do male-dominated capture fisheries. Further, more than half of workers in fish processing are women (Kruijssen et al. 2018). These income opportunities have empowered women and improved their standing in the household. However, the distribution of benefits from aquaculture is reported to be unequal as men tend to hold jobs in processing with higher pay and benefits (FAO 2021a). Further, aquaculture can serve as a useful social safeguard for people displaced by dam construction, as demonstrated by the Saguling-Cirata dam in Indonesia.

Freshwater fish and shrimp are two major forms of aquaculture in Asia. The success of freshwater aquaculture in Bangladesh, celebrated as a "blue revolution," provides an example of the former. The increase of fish production from inland aquaculture has reduced fish prices in domestic markets, notably benefiting poor consumers. Growth has been spurred by rising domestic demand under stable economic development. Shrimp farming, mainly for export, became widespread after technological innovation intensified shrimp farming in Taipei,China in the 1980s. Private actors, notably conglomerates in Japan and Thailand, played important roles in the growth of shrimp aquaculture in terms of both strengthening the supply side and expanding global demand (Hall 2004). Viet Nam, now one of the world's largest shrimp producers, started allowing the conversion of rice fields to fishponds in 2000, prompting immediate expansion in the fishpond area in coastal areas suitable for fish farming (Box 2.2.4).

Figure 2.2.4 Aquaculture production in Asia

Aquaculture production is rapidly growing in Asia, led by the People's Republic of China.



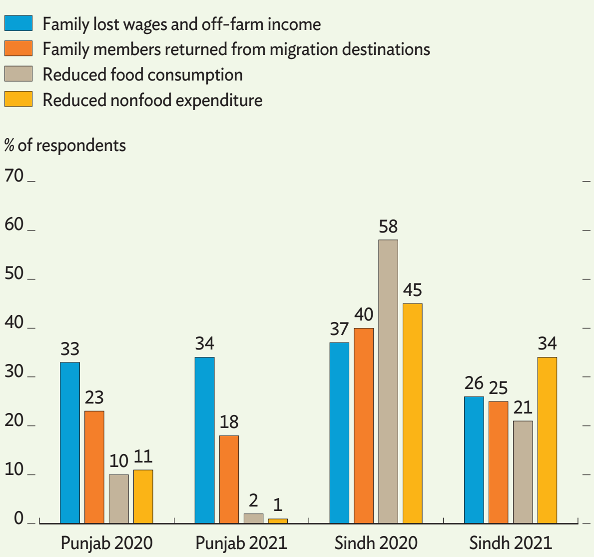
Source: World Bank. World Development Indicators. https://databank.worldbank.org/source/world-development-indicators (accessed 28 July 2021).

Mobile phone technology use can help promote inclusive growth. By providing affordable access to technical information and market access to farmers in remote areas, many phone applications have hastened farmers' adoption of good agricultural practices. Social media can provide platforms for disseminating information and farmers' sharing their experiences (Box 2.2.5). A major concern on the future of aquaculture is its sustainability as discussed in section 2.1. Effective monitoring on environmental effects of aquaculture production, reliable inspections on food safety, and functional regulations are imperative for the sustainable growth of aquaculture in Asia.

Box 2.2.1 Into the second year: farm households under COVID-19 in Pakistan

The COVID-19 pandemic continues to hurt rural households. To empirically investigate the welfare and agricultural marketing of farmers in Pakistan, the Asian Development Bank conducted mobile phone surveys in Punjab and Sindh provinces in June 2020 and 2021. The 2020 survey interviewed 839 farmers, and the 2021 survey re-interviewed 744 of them, or 89% of the original sample. The two surveys found that the COVID-19 pandemic has continued to negatively impact farm households, especially in Sindh province (box figure).

Continuing impact of COVID-19 in Sindh and Punjab, 2020 and 2021



Sources: Yamano, Sato, and Arif (2021a, 2021b).

In Punjab, one-third of farmer households experienced loss of wages and off-farm earnings in 2020, and the reduction has remained unchanged into 2021. Almost one-quarter reported that at least one family member had returned from urban areas in 2020, and the proportion has remained at 18% in 2021. On the other hand, consumption of food and other goods has returned to the pre-pandemic level from about a 10% decline in 2020.

In Sindh Province, negative impacts remain at high levels. In 2020, 37% of rural households in the province experienced reduced wages and off-farm income, and the number remained high at 26% in 2021. One-fourth of rural households continue to report returned family members in June 2021. The percentage of rural households reporting reduced food consumption declined from 58% in 2020 to 21% in 2021, and those reporting lower nonfood expenditure declined from 45% to 34%. These results indicate greater hardship in Sindh than in Punjab. As Pakistan and other economies struggle under the pandemic and prepare for recovery, it is critical to monitor and understand how the pandemic leaves lasting impacts.

Sources:

Yamano, T., N. Sato, and B. W. Arif. 2021a. The Impact of COVID-19 and Locust Invasion on Farm Households in Punjab and Sindh: Analysis from Cross-Sectional Surveys in Pakistan. *ADB Central and West Asia Working Paper Series* No. 10. Asian Development Bank.

——. 2021b. The Impact of the COVID-19 Pandemic into the Second Year: Panel Survey Analysis of Farm Households in Punjab and Sindh Provinces in Pakistan. Mimeo. Asian Development Bank.

Box 2.2.2 Lessons learned from volumetric water pricing in the PRC and the Philippines

Volumetric pricing is an economic approach to saving water. Under such a policy, a fee is based on the volume passing through a canal intake of a water-user group (WUG). Saving water under this scheme requires effective collective action by members of the WUG, who pay a portion of the fee. How effectively such a scheme saves water relies on how well the WUG solves the free-rider problem. While the group has an incentive to save water, individual farmers within a group may overuse water unless they are closely supervised. Facing a rapid increase in water demand for urban and industrial use, the PRC sought to save water in agriculture, especially in rice farming, by replacing area-based pricing with volumetric water pricing.

A case study in the Zhanghe irrigation system in Hubei, PRC, highlighted the importance of setting an appropriate volumetric price and enforcing collective management to prevent free-riding (Kajisa and Dong 2017). The study found that effective collective monitoring and management of water use within a WUG was feasible only when volumetric prices were moderate. If the price was too high, farmers tended to exit the WUG, leaving it with a discontinuous irrigated area, which complicated collective monitoring and management of water use. To keep all members in a WUG, the water price needs to remain at a moderate rate. Another study in northern Luzon, Philippines, similarly highlighted the importance of collective action by WUG members (Kajisa et al. 2018). First, the study confirmed the tremendous difficulty of measuring water volume in irrigation systems. It also found that the volumetric system has to be sophisticated enough to supply water on demand, or users will not pay fees based on use. These two problems can be solved by upgrading irrigation infrastructure for accurate volume measurement and reliability. A third problem is also complicated. As groundwater flows downhill and recharges wells there, downstream farmers need to buy less water to meet their irrigation needs. Upstream farmers may regard this as unfair. Resolving this problem requires coordination and agreement among water users.

Sources:

Kajisa, K. 2019. Role of Community and Government in Irrigation Management in Emerging States: Lessons from Japan, China, and India. In K. Otsuka and K. Sugihara, eds. *Paths to the Emerging State in Asia and Africa, Emerging-Economy State and International Policy Studies*. Springer. https://doi.org/10.1007/978-981-13-3131-2_12.

Kajisa, K. and B. Dong. 2017. The Effect of Volumetric Pricing Policy on Farmers' Water Management Institutions and Their Water Use: The Case of Water User Organization in an Irrigation System in Hubei, China. *World Bank Economic Review* 31(1).

Kajisa, K. et al. 2018. Lessons from Volumetric Water Pricing Trials at the Three Surface Irrigation Systems in Northern Luzon, Philippines. *DLSU Business & Economic Review* 28(1).

Box 2.2.3 Alternate wetting and drying

Rice production emits 22% of greenhouse gas (GHG) emissions from agriculture in Asia. Under flooded rice fields with little oxygen, microbes decay organic matter in the soil and generate methane gas, which is 28 times more potent a GHG than carbon dioxide. Instead of continuously flooding rice fields, a water-management technique called alternate wetting and drying (AWD) allows rice fields to dry out periodically for one to several days before reflooding (box figure 1). Studies found that AWD reduces methane emissions by 30%–50% and water use by 10%–20% without reducing rice yield (Setyanto et al. 2018).

In 2016 and 2017, over 500 farmers in Chittagong, Bangladesh were trained in AWD water management. With the support of ADB, the Muhuri Irrigation Project demonstrated that AWD requires 22% less water than continuous standing water. In the dry season of 2016, methane emissions were 41%–42% lower from AWD plots than from those with continuous flooding (box figure 2).

Despite AWD's potential benefits, its adoption has been limited for several reasons. First, most irrigation systems charge farmers a fixed irrigation fee for the season, in many cases subsidized by public agents or never collected. Farmers thus have little financial incentive to save water. Second, farmers are not charged for methane and other GHG emissions from their rice fields and are unaware of them. To encourage farmers to adopt AWD, awareness and incentive programs are needed. In light of high GHG emissions from flooded rice fields, it may be reasonable to devise incentive systems that compensate farmers for adopting AWD and reducing their GHG emissions.

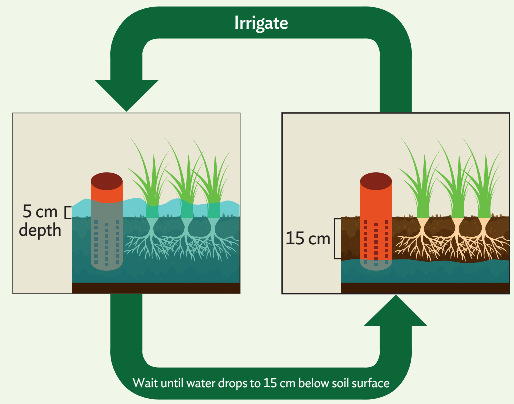
Sources:

ADB. 2019. *Climate-Smart Practices for Intensive Rice-Based Systems in Bangladesh, Cambodia, and Nepal.* Asian Development Bank.

Setyanto, P. et al. 2018. Alternate Wetting and Drying Reduces Methane Emission from a Rice Paddy in Central Java, Indonesia without Yield Loss. *Soil Science and Plant Nutrition* 64(1).

1 Alternate wetting and drying

Alternate wetting and drying is a water-management technique that allows rice fields to dry periodically before reflooding...



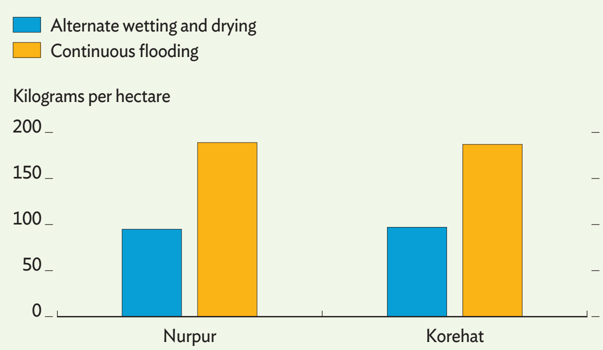
AWD = alternate wetting and drying, cm = centimeter.

Note: Under flooded rice fields (left panel), microbes decay organic matter and generate methane gas, which contributes to global warming. Alternate wetting and drying allows rice fields to dry for one to several days (right panel). Studies found that AWD reduces methane emissions by 30%–50% and water use by 10%–20%.

Source: ADB (2019).

2 Methane emissions under AWD and continuous standing water

...reducing both greenhouse gas emissions and water use.



AWD = alternate wetting and drying.

Source: ADB (2019).

Box 2.2.4 Shrimp aquaculture development in Viet Nam

Shrimp farming in Viet Nam grew dramatically as the Government passed a resolution in 2000, allowing the conversion of less-productive rice land in coastal areas to aquaculture ponds. A problem soon developed, however, as many importing economies rejected shrimp from Viet Nam, often citing high antibiotic residue in the product. In some cases, prohibited antibiotics were used, and in others the amount of antibiotic used exceeded maximum limits set by many developed markets (Suzuki and Nam 2018; Lee, Suzuki, and Nam 2019).

Several problems were identified. First, the authorities did not adequately monitor input markets, which allowed the use of uncertified shrimp seed and other prohibited inputs. Second, farmers often purchased shrimp feed on credit from input sellers, which locked them into rigid financial relationships with their input suppliers and deprived them of other options. Third, lab testing was costly and cumbersome for farmers, leaving invisible residues undetected. Fourth, shrimp buyers did not check for residue when making purchases and often mixed shrimp obtained from multiple farmers, scrambling traceability along the supply chain.

Solutions were identified to address these problems. A randomized controlled trial was conducted to investigate how farmers could be induced to adopt better practices (Suzuki, Nam, and Lee 2020). The study conducted three experiments that (i) offered technical training, (ii) quantified antibiotic residue, and (iii) offered price premiums if shrimp passed a quality test. In the second experiment, shrimp were collected from farmers' ponds and lab tested for the presence of four antibiotic markers, and the test results returned to individual farmers in the treatment group. The study found that quantifying antibiotic residue had a positive effect in reducing the antibiotic residue. This finding suggested that providing farmers with the means to detect residue in shrimp was an effective way to change their behavior. In Thailand, such laboratory testing is freely accessible to shrimp farmers who register with the government. Further, the traceability system in Thailand is well structured, requiring a "movement document" to be updated whenever shrimps are transferred between two parties at every stage, from hatcheries to processing factories (Suzuki and Nam 2019). Through these efforts, antibiotic residues are no longer an issue in Thailand. In recent years, rejection rates for shrimp exports from Viet Nam have declined at Japanese ports. Indeed, Viet Nam has been considered a successful shrimp producer during the COVID-19 pandemic (Fletcher 2020; VASEP 2020). According to the Vietnam Association of Seafood Exporters and Producers, shrimp exports from Viet Nam to the US, its largest market, grew by 33% year on year in January–September 2020. In the same period all shrimp exports from Viet Nam expanded by 11%.

Sources:

Fletcher, R. 2020. *Shrimp Aquaculture: A Tale of Two Pandemics*. Fish Site. 11 August. https://thefishsite.com/articles/shrimp-aquaculture-a-tale-of-two-pandemics.

Lee, G., A. Suzuki, and V. Nam. 2019. Effect of Network-Based Targeting on the Diffusion of Good Aquaculture Practices among Shrimp Producers in Vietnam. *World Development* 124.

Suzuki, A. and V. Nam. 2018. Better Management Practices and Their Outcomes in Shrimp Farming: Evidence from Small-Scale Shrimp Farmers in Southern Vietnam. *Aquaculture International* 26.

Suzuki, A. and V. Nam. 2019. Marketing Risks and Standards Compliance: Challenges in Accessing the Global Market for High-Value Agricultural and Aquacultural Industries. In K. Tsunekawa and Y. Todo, eds. *Emerging States at Crossroads*. Springer.

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VASEP. 2020. Vietnam Association of Seafood Exporters and Producers. http://seafood.vasep.com.vn/.

Box 2.2.5 Digital aquaculture extension

Farmers have formed online groups to share information and crowdsource solutions for their farm problems. For instance, a group of seven shrimp farmers in Asia formed a Facebook group in 2011 to share information and raise issues they encountered on their farms. It grew rapidly to 18,271 by 2017. Administrators of the group closely monitor members' posts and intervene if they see any inappropriate information. While most of the members are shrimp farmers, academic aquaculture experts also joined the group, allowing them to correct misinformation as needed. Lee and Suzuki (2020) examined nearly 11,000 posts in this group from 2011 and 2017 and found that the most common topics were farm skills, inputs, and equipment, followed by disease and prices. This showed that shrimp farmers' major interest in joining this type of virtual group was to obtain information on farming techniques. Other social media and instant messaging platforms, such as Line, WhatsApp, and Telegram, are also widely used by aquaculture producers. YouTube channels that offer technical lessons or interviews with aquaculture producers have been posted in many languages.

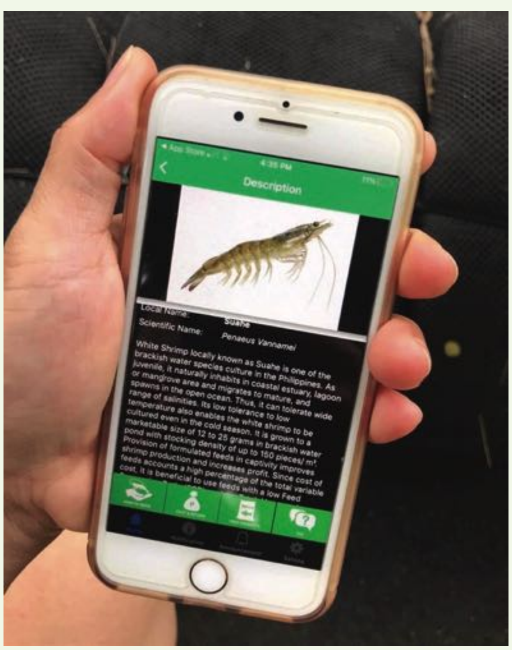
Information and communication technology helps measure quality and enables precision aquaculture. Many aspects of aquaculture are not directly observable. If farmers can quantify these aspects, they may be able to improve their performance or mitigate their negative effects on the surrounding environment. Digital meters to test water quality, for example, can measure important water quality parameters such as acidity, dissolved oxygen, oxides of nitrogen, and ammonia. The simple liquid solution test kits often available to farmers offer variable results. A wireless network system has been developed to disseminate results of water quality measures for more consistent monitoring (Tuan 2019). Various phone apps have been developed to help farmers use more appropriate farm practices. One app allows farmers to evaluate shrimp health and growth by taking a smartphone picture and automatically calculating appropriate feed amounts and scheduling (Fish Site 2020).

Sources:

Fish Site. 2020. Vietnamese Shrimp Farmers Flock to New App. 21 October. https://thefishsite.com/articles/vietnamese-shrimp-farmers-flock-to-new-growth-app#:~:text=An%20app%20that%20lets%20shrimp,reviews%20from%20farmers%20in%20Vietnam.

Lee, G. and A. Suzuki. 2020. Motivation for Information Exchange in a Virtual Community of Practice: Evidence from a Facebook Group for Shrimp Farmers. *World Development* 125.

Tuan, K. N. 2019. A Wireless Sensor Network for Aquaculture Using Raspberry Pi, Arduino and Xbee. Paper prepared for the International Conference on System Science and Engineering, Dong Hoi, Viet Nam, 20–21 July.



(Left) A mobile application has been developed to help farmers on shrimp feeding and health management. (Right) Mobile phones used by farmers to check buyers and market prices (photos by Jindra Samson and Mike Cortes).

2.3 Support systems are needed for Asia's farmers

Innovative practices and solutions on the farm need to be supported by complementary systems and technologies. These systems and technologies will help build climate resilience and ensure that farmers benefit from the ongoing agricultural transformation. The future of agriculture depends crucially on the ability of farm communities to cope with climate change. Early warning systems and crop insurance programs that use advanced spatial information systems can mitigate farmers' exposure to climate risks and protect their livelihoods. Agriculture production in Asia is shifting toward high-value crops such as vegetables and fruit supported by new practices and technologies. Contract farming has the potential to benefit both farmers and contractors by allowing product specialization but requires the capacity of local government agencies to monitor and enforce contracts. Similarly, digital technologies can promote inclusive development by helping farmers in remote areas access technical and market information, but this will require better access to mobile technology. To support the ongoing agricultural transformation, agriculture policy should facilitate greater market orientation through research and development.

2.3.1 Early warning systems offer efficient protection from weather risks

Disaster risks can be managed by adopting integrated climate mitigation and adaptation measures. Given intensifying adverse weather events, action to prepare for them is important. At the national level, long-term predictions of extreme weather caused by climate change can guide government agencies and stakeholders to invest in climate-resilient infrastructure and support climate-resilient agricultural production and marketing systems. Investments that offer multiple synergistic dividends in resilience, such as early warning systems for extreme weather, can—combined with other infrastructure such as cyclone shelters in Bangladesh and social capital to facilitate compliance—help government agencies and agricultural producers prepare for such events (ADB 2019c; Shoji and Murata 2021). Various early actions, ideally flexible, can range from cash transfers for fishing communities to safely storing nets ahead of an impending cyclone, livestock vaccination and treatments for herders as drought intensifies, and flood defenses constructed before a severe rainy season to protect crops. In 2019, timely information on floods in northern Bangladesh helped communities and the government prepare and secure necessary supplies, reducing economic losses by two-thirds (FAO 2021b).

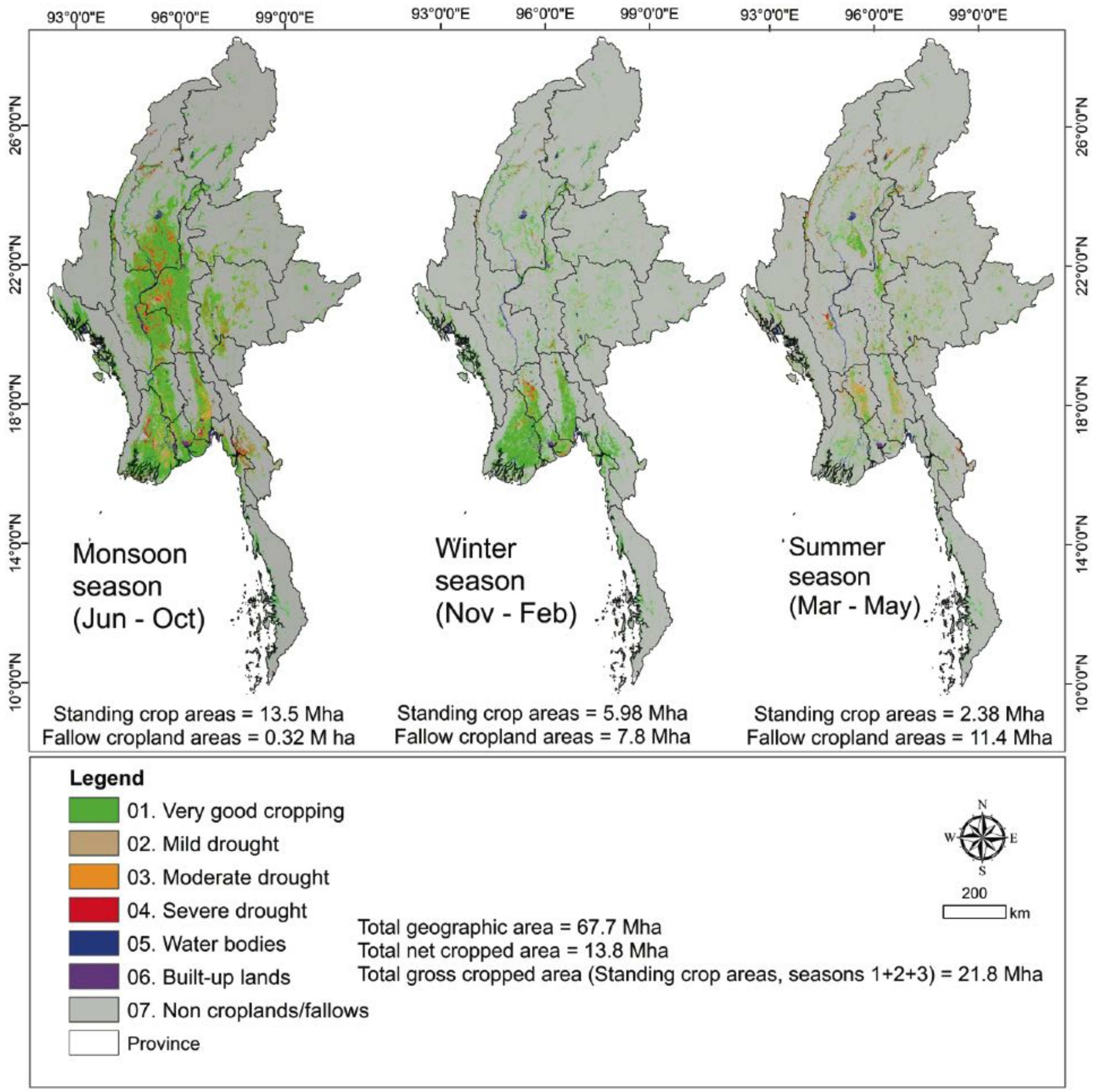
Developing and developed economies around the world have implemented drought warning systems at different levels of governance. Studies have demonstrated how effectively such systems empower vulnerable farmers to act early (Pulwarty and Sivakumar 2014). In Mongolia, for instance, pre-season drought predictions motivated government agencies and animal herders to build up stocks of animal feed in preparation for inadequate grazing under drought (FAO 2018b). Because water stress and drought intensity can vary substantially across regions, and crude assessments may miss hotspots in need of appropriate intervention, high-resolution spatial analysis is important. Figure 2.3.1 shows an example of how maps can be used to identify drought areas and assess the magnitude and severity of damage, especially in agricultural areas.

Advanced spatial information systems have several useful applications in agriculture. These advanced systems, which combine high-resolution satellite images, detailed crop models, ground data on agricultural production and management, and machine-learning algorithms, are critically important in developing early warning systems. They are likewise useful for predicting the potential impact on agricultural production from predicted weather events such as cyclones, floods, and drought. Researchers in India, for example, developed a machine-learning algorithm to predict crop types using satellite data in several production areas with mixed crops (Gumma et al. 2020). Area estimates of different crops were more accurate than government statistics derived from ground estimates. This system can likewise inform crop insurance programs as they assess weather-related damage to agricultural production, as discussed below. It can be used to supplement government agricultural statistics, which depend on field observations by government officers and are slow to become available.

Improved site-specific weather monitoring and reliable early warning systems are essential to farmers. These systems enable them to adapt to climate change and mitigate impact on agriculture. Early detection of extreme weather events can help farmers anticipate them and plan accordingly. With advances in crop science toward adaption to climate change, farmers can now select crop varieties that are more resilient under flooding, drought, and high temperatures.

Figure 2.3.1 Spatial distribution of agricultural drought in Myanmar, 2017–2018

Advanced spatial information systems can identify drought areas and reduce damage from extreme weather.



ha = hectare.

Source: M. K. Gumma et al. 2018. Mapping Cropland Fallow Areas in Myanmar to Scale Up Sustainable Intensification of Pulse Crops in the Farming System. *GIScience & Remote Sensing* 55(6): 926–949.

Crop scientists continue to develop varieties that can survive weather stresses or yield well with less water. Such varieties can help make agriculture more climate resilient and render water use more sustainable. However, scaling up the use of climate-resilient crops and production practices requires that farmers have access to timely information and technical support, as discussed in Box 2.3.1.

2.3.2 Innovative crop insurance builds resilience in farm communities in Asia

In the past 2 decades, agricultural insurance systems in the region have evolved and expanded quickly. Disaster risk insurance in Asia has increased from only 35 schemes operating in 2012 to 53 schemes in 2018 (Surminski, Panda, and Lampert 2019). In the past, crop insurance programs have frequently failed for low-income holders mainly because of informational problems, such as adverse selection and moral hazard (Skees et al. 2004; Besley 1995; Binswanger 1986). Index-based agricultural insurance programs have expanded in many Asian economies in recent years. They are attractive because of their potential to overcome asymmetric information problems associated with traditional insurance: adverse selection, when farmers at high risk are more likely to participate in a program than farmers at low risk, and moral hazard, when farmers fully insulated from risk lack incentive to prevent bad outcomes. Also attractive is their potential to attract private sector participation in the management of agricultural risk (Hazell and Hess 2017).[9] Of the 198 million farmers with index-based crop insurance in 2014, 194 million were in Asia—mostly in the PRC, with 160 million, and India, with 33 million (Hazell and Hess 2017).

Public–private insurance arrangements have broadly expanded in recent years. In 2017 and 2018, a third of economies with crop insurance were operating it under public–private partnership, while the public sector operated alone in four economies (Panda 2021). In South Asia, 32% of agricultural insurance was subsidized by governments. Many schemes are voluntary, such as Pradhan Mantri Fasal Bima Yojana and the Restructured Weather Based Crop Insurance Scheme in India.

Although 20 economies in developing Asia have crop insurance, only four governments have fully operational national crop insurance schemes (Table 2.3.1). The four governments include the PRC, India, the Philippines, and Sri Lanka. In Southeast Asia, Cambodia, Malaysia, Myanmar, and Viet Nam are at the cusp of scaling up their agricultural insurance schemes, while Brunei Darussalam, the Lao PDR, and Timor-Leste do not have any form of agricultural insurance. In Azerbaijan, Armenia, and Bangladesh, crop insurance schemes are likewise in pilot stages. Meanwhile, considerable gaps remain in terms of insurance coverage, uptake, and demand among the more established crop insurance schemes.

9 Crop insurance schemes need to adopt practices that avoid adverse selection and discourage moral hazard in participating farmers. Advanced information technology is expected to help insurance schemes select farmers with good records and provide incentive for them to avoid moral hazard.

Table 2.3.1 Crop insurance programs in Asia

Many economies in developing Asia have crop insurance schemes, but most are in early stages of development.

Type	Economy	Inclusion	Subsidized	Indemnity or Index Based
Private crop insurance				
	Bangladesh	Voluntary	Yes	Both
Public crop insurance				
	Nepal	Voluntary	Yes	Indemnity based
	Philippines	Voluntary	Yes	Both
	Sri Lanka	Mandatory	Yes	Both
	Uzbekistan	Voluntary	No	Indemnity based
Public–private partnership pilots, planning, and preparation at an advanced stage				
	Georgia	Mandatory	Yes	Indemnity based
	India	Voluntary	Yes	Both
	Indonesia	Voluntary	Yes	Both
	Kazakhstan	Mandatory	Yes	Indemnity based
	Kyrgyz Republic	Voluntary	Yes	Indemnity based
	Mongolia	Voluntary	No	Index based
	Myanmar	Voluntary	No	Index based
	Pakistan	Mandatory	Yes	Both
	People's Republic of China	Voluntary	Yes	Both
	Taipei,China	Voluntary	Yes	Indemnity based
	Thailand	Mandatory	Yes	Indemnity based
	Turkmenistan	Voluntary	No	Not applicable
	Viet Nam	Voluntary	Yes	Both

Notes: Premium subsidy can either be in part or full. Indemnity-based crop insurance compensates insured farmers based on verifiable loss at the end of the growing season. Index-based insurance provides claim payments based on the realization of an objectively measured index, such as a weather variable, correlated with production loss.

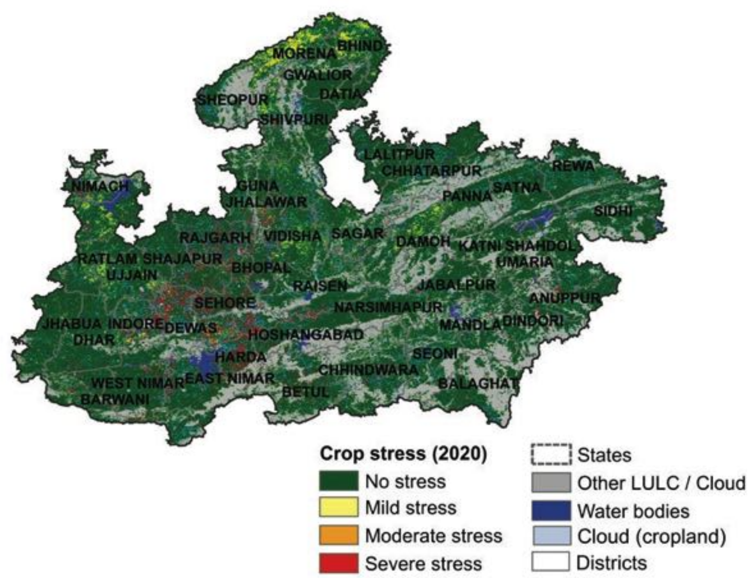
Source: A. Panda. 2021. Climate Change and Agricultural Insurance in the Asia and the Pacific Region. Background paper for *Asian Development Outlook 2021 Update*. Asian Development Bank.

Farmers covered by insurance are highly concentrated in only a few economies, notably the PRC, India, the Philippines, and Sri Lanka. Coverage and demand for agricultural insurance products remain limited in other economies. While uptake of any formal insurance stands at 16% in a selection of several ADB developing member economies, uptake for crop insurance is less than 2% (Panda, Lambert, and Surminski 2020). Hastening the development of national crop insurance schemes is critical for expanding coverage, especially among vulnerable Asian farmers, and building their climate resilience.

Major obstacles remain for assessing weather-related damage. Lessons can be drawn from the successful implementation of crop insurance systems in some economies. Spatial information systems, for example, are helping insurance programs in the PRC and India rapidly assess crop damage and expedite settlement claims. Imaging technologies such as drones, low Earth orbits, and remote-sensing satellites can capture high resolution images for assessing crop damage. The PRC is using low Earth orbits to capture images of vegetation for monitoring crop growth around the world. In the United States, drones are used to gather data for crop insurance claims. Spatial crop stress maps provide crop insurance programs with timely information, allowing them to expedite claim processing. The map in Figure 2.3.2, for example, was generated for the Indian state of Madhya Pradesh for the period 15–30 October, indicating crop stress at the district level. Similar maps are generated twice a month for Indian states that are covered by crop insurance programs.

Figure 2.3.2 Madhya Pradesh state crop stress map

Spatial information systems can help insurance programs rapidly assess crop damage and expedite settlement claims.



Note: The crop stress map for Madhya Pradesh state on 30 October 2020 shows crop stress by district over the past 15 days. "Other LULC/Cloud" means other land use and land cover or unable to identify land use due to heavy cloud. "Cloud (cropland)" means identified as cropland with unspecified crop stress due to heavy cloud.

Source: M. K. Gumma et al. 2019. Mapping Drought-Induced Changes in Rice Area in India. *International Journal of Remote Sensing* 40(21): 8146–8173.

India's past crop insurance schemes have encountered several problems. The problems include lack of transparency, high premiums, delay in conducting crop-cutting experiments to gauge yield, and absent or delayed payment of claims to farmers. Aware of the limitations of its previous crop insurance schemes, the Government of India launched in 2016 a new crop insurance scheme called Pradhan Mantri Fasal Bima Yojana (PMFBY) (Roy et al. 2018). Its establishment was intended to bring greater transparency and effective implementation, particularly in terms of quick and accurate compensation to farmers for the damage incurred.

PMFBY faced several implementation challenges, especially during its first year of implementation. One was delayed submission of yield data, which were unreliable as they were drawn from thousands of crop-cutting experiments. As a result, state government payment of premium subsidies was delayed. Quick processing and payment of insurance claims require quick and reliable assessment of crop damage. Despite its initial problems, PMFBY has succeeded in increasing insurance coverage from fiscal year 2016 to fiscal year 2017: in terms of area by 5.6%, the number of farmers covered by 20.4%, the sum insured by 74%, and premiums paid by 298%.

2.3.3 Value chains evolve as farmers diversify into high-value crops

The production of high-value crops such as fruit and vegetables have expanded to meet growing demand. Fruit and vegetables currently provide 32% of production value in agriculture, while cereal crops provide only 26%. Today, the PRC, India, and Indonesia are in that order the top three producers of fruit and vegetables in developing Asia, but some other economies are catching up. Commercialization and market integration in food systems have accelerated these shifts in agricultural production shares. Food supply chains have shifted away from being local and fragmented toward broader geographic integration. The transformation of value chains has featured the rapid rise of supermarkets, modern cold storage facilities, and the food-processing industry, as well as the formation of commercialized producers using input-intensive, mechanized agriculture. Information technology has likewise been adopted, as discussed below, to facilitate more efficient processing and distribution of food products and to ensure their quality and safety.

Rising volumes of high-value agricultural products have been produced and marketed through contract farming (Otsuka, Nakano, and Takahashi 2016). Contract farming has become a widely used production and procurement arrangement for various crops in Asia (Table 2.3.2). It can benefit both farmers and contractors. A contract with advance agreement on output prices can provide price stability, and the established business relationship facilitates the provision to farmers of technical assistance, access to credit, new technologies, and ultimately new markets. For farmers, contract farming is a step away from subsistence farming toward market integration. For contractors, contract farming helps ensure greater and more stable supplies of a given commodity with better quality than is available from spot-market procurement. Working with several neighboring farmers helps contractors overcome constraints imposed by small individual plots.

Table 2.3.2 Case studies of contract farming in Asia

Economy	Crops	Number of Studies	Notes
PRC	Fruit and vegetables	3	Reduction in transaction cost, price stability, and access to markets attract farmers; mixed evidence on farm size; product quality attracts processors
	Multiple crops	1	Contract enforcement mechanisms influence growers' decisions
India	Fruit and vegetables	4	Mixed evidence on welfare effects; risk perception, irrigation, extension services, and access to formal credit attract farmers
	Rice	3	Contract enforcement mechanisms influence farmer performance
	Commercial crops	2	Access to inputs on credit attracts farmers
	Poultry and dairy	2	Positive effect on farmer welfare
Indonesia	Palm oil	2	Greater participation among large farmers
	Cereal crops	1	Greater participation among large farmers; mixed evidence regarding return on capital
Nepal	Multiple crops	3	Positive effect on income and productivity
Pakistan	Rice	1	Stabilize farmers' income; large farmers prefer spot markets
	Maize and potato	1	Mixed evidence on income effect
Philippines	Tobacco	1	Greater participation among small farmers; positive effect on income
Viet Nam	Rice	1	Output price and profit attract farmers
	Dairy	2	Third-party quality checks effective

PRC = People's Republic of China.
Source: M. Bellemare. 2017. Contract Farming. Background paper for *Asian Development Outlook 2021 Update*. Asian Development Bank.

Contract farming allows product specialization, which boosts productivity and efficiency, benefiting farmers and contractors alike.

Contract farming can be an effective policy instrument for leveraging agricultural development. A review of studies on contract farming in Asia summarizes the types of farmers who participate, what they produce, and the welfare benefits that accrue to them (Bellemare 2021). While participation in contract farming is popularly associated with large farmers, the actual evidence is mixed (Table 2.3.2). A study on contract farming in Punjab, Pakistan, found that contract farming was more prevalent among medium-sized farmers, as larger farmers who are able to manage considerable risk usually found spot markets more attractive (Dhillon and Singh 2006). Another study found that large palm oil farmers tend to participate in contract farming more than small farmers do (Cahyadi and Waibel 2013). Other studies of multiple crops showed mixed evidence on the relationship between contract farming participation and landholding size. Several studies showed that contract farming can increase and stabilize farmers' income and productivity (Table 2.3.2). It should be noted that contract farming studies reviewed here come from only a handful of economies and may not be representative of actual practice in contract farming across developing Asia.

However, contract disputes often occur due to unclear agreements and lack of contract enforcement mechanisms. Studies highlight contract problems arising from noncompliance on both sides. Noncompliance by farmers includes diverting inputs for contracted products to other uses and selling on the side. Under a contract, a contractor may provide inputs to produce the contracted crop. However, when farmers find higher returns from using the inputs for other crops, they may divert their use to these other crops. Side selling happens when farmers find other buyers who offer a higher price for the contracted crop. On the contractor side, noncompliance may occur when they change their contract terms after signing. Output prices may unexpectedly decline, for instance, or food safety requirements in intended export markets may change. In these situations, contractors may refuse to process transactions, leaving farmers with unsold products or not paying for them. Third party quality assessments can yield better results. On contract enforcement for milk production in Viet Nam, an experimental study showed that having independent quality assessments by third parties encourages farmers to use 12% more inputs and increase their output. This finding highlights the positive influence of independent quality assessments on farmers' performance. This is similar to the use of a mobile phone app to assess the quality of shrimps, as discussed in Box 2.2.5.

The capacity of local agencies to monitor contract farming practices, as well as enforce contracts need to be strengthened. Contract disputes between producers and contracting agents, as discussed above, have possible implications for food safety such as chemical residues in agricultural products, and for environmental damage caused by chemical inputs. To realize the full potential of contract farming, better monitoring of contract farming practices is important. COVID-19 lockdowns and the resulting market disruption affecting the marketing of high-value crops in 2020 provide a vivid illustration. Uncertainty caused by market disruption could have been mitigated by contract farming, under which the costs would have been shared by producers and buyers.

2.3.4 Digital technologies to promote inclusive growth

In recent years, digital technologies have helped farmers in remote areas acquire both technical and market information. They provide tools to collect, store, analyze, and share information more quickly. Big data analytics, the Internet of Things, and sensors can collect real-time data and perform advanced analytics on crops to provide farmers and other actors in value chains with insights and access to data to help them make good decisions. Agricultural extension services and private dealers use mobile technologies to connect with farmers and promote new practices and products.

Many mobile phone applications have been developed to help farmers adopt good agricultural practices. Ranging from simple offline advisory videos for farmers to complex systems for precision agriculture and distributed ledger technologies for value chain traceability, digital technologies can help boost technical efficiency and farm profits, enhance climate resilience, and improve environmental sustainability. However, farmers' use of digital technologies is still limited, leaving large potential gains unexploited. Further, access to mobile phone and internet services remains unequal between men and women in low- and middle-income economies, though the gap is narrowing (GSMA 2021).

Data-driven innovation can reduce transaction costs by improving efficiency and transparency (De Clercq, Vats, and Biel 2018). Conventional food supply chains comprise many transactions between different stakeholders including wholesalers and intermediaries for sales of commodities, equipment, and processed goods. These transactions generate costs as every additional player demands a share of the profit, and every additional transaction increases the risk of fraud. Further, digital technologies can improve productivity on the farm by (i) optimizing the use of machinery and equipment, (ii) facilitating the acquisition of the skills and knowledge needed for agricultural production, and (iii) providing accurate, timely, and location-specific information on prices, weather, and agronomic conditions.

Sensor technologies, big data analytics, and blockchain technology are increasingly being used. These technologies can monitor and analyze climate conditions and initiate mitigation measures. Remote sensing, spectral analysis, and blockchain technology help researchers, policy makers, and businesses monitor, analyze, and initiate investment and other action to conserve and manage landscapes and resources such as forests, oceans, and other water resources. Innovators have developed natural capital accounts at the farm or estate level that use information technology to show how farming depends on ecosystem services and affects ecosystems. These services have been developed to inform farmers on the impacts of their farm management on natural capital and on how changing farm management can mitigate these harmful effects. The testing of these services continues.

The digital transformation of food supply chains can overcome information barriers and emerging mobility challenges. Bridging information gaps and equalizing asymmetries between producers and consumers allows stakeholders with different preferences and incentives to work together more effectively, creating opportunities to improve policy for the agro-food sector and opening new market opportunities, particularly for small stakeholders. Asia is witnessing the emergence of innovative digital start-ups focused on transforming food systems.

Digital transformation can help establish more sustainable and resilient agriculture. In the PRC, e-commerce has emerged as a lifeline during the COVID-19 pandemic. E-commerce helped ensure the delivery of food to urban residents in the midst of strict virus-containment restrictions by pairing input suppliers, agricultural producers, and output marketers, and by facilitating logistical support. Beyond enhancing market connectivity and value chain development, digital technologies can be deployed to shrink environmental and climate footprints in food supply chains and strengthen their risk resilience (Box 2.3.2). The safeguarding of consumer health stands to benefit from improved product traceability and integrity, contract certainty, verification of geographic origin, and compliance with sanitary and phytosanitary requirements. Other direct and indirect benefits to consumers are better information on prices and nutritional value and assurances on production practices and environmental and biodiversity impacts.

Box 2.3.1 Stress-tolerant crop varieties

Submergence has been a persistent problem for rainfed lowland rice farmers in South and Southeast Asia. Rice plants have two ways to survive flooding stress: extend their stalks above rising floodwater, or tolerate submergence. Certain rice varieties can survive submergence for several days. In the 1990s, rice scientists examined several rice varieties and identified a single DNA component, named Sub1, that was responsible for submergence tolerance. Sub1 provides tolerance to complete submergence for up to 14 days. Since this discovery, many submergence-tolerant rice varieties have been developed by crossing popular high-yielding rice varieties with Sub1 varieties. Pilot tests have demonstrated benefits from submergence-tolerant rice varieties on farmers' fields in South Asia.

Despite its potential benefits, adoption of submergence-tolerant varieties has been slow. Slow adoption can be explained by their benefit being hidden most of the time. Under normal conditions, farmers observe no additional benefit from submergence-tolerant rice varieties over other popular varieties, these benefits become apparent only after plants are submerged for longer than most varieties can tolerate. A recent study in Bangladesh by Yamano et al. (2018) found that the adoption of submergence-tolerant rice varieties increased among neighbors of early adopters only after flooding occurred in their area. To encourage farmers to adopt submergence-tolerant or other crops with hidden benefits, including nutrition-enhanced crops, campaigns are needed to disseminate this information to farmers.

Avoiding heat can help crops to be tolerant against drought and heat. Many crops for drought-prone areas are bred for early maturity to avoid heat during their growth periods. However, this trait is generally associated with lower grain yield because plants have less time to grow panicles, prompting crop scientists to search for alternative traits and help them to identify one candidate. Rice plants are sensitive to high temperature as they flower. Exposure to high temperature during flowering can greatly decrease pollen viability, which causes yield loss. If rice plants start flowering early in the morning, when the temperature is low, they can avoid reduced pollen viability. Crop scientists have found rice varieties that open flowers early in the morning and identified the DNA components that are responsible for this characteristic (Hirabayashi et al. 2015). Rice varieties that flower early in the morning and have other desired traits such as high yield and good eating quality have been developed and tested in India and Myanmar.

Sources:

Hirabayashi, H. et al. 2015. qEMF3, a Novel QTL for the Early-Morning Flowering Trait from Wild Rice, Oryza Officinalis, to Mitigate Heat Stress Damage at Flowering in Rice, O. Sativa. *Journal of Experimental Botany* 66(5).

Yamano, T. et al. 2018. Neighbors Follow Early Adopters under Stress: Panel Data Analysis of Submergence-Tolerant Rice in Northern Bangladesh. *Agricultural Economics* 49(3).

Box 2.3.2 Agricultural e-commerce in the PRC

The recent development of agricultural e-commerce in the People's Republic of China (PRC) follows three models. The first uses nationwide e-commerce platforms for online sales of fresh agricultural products to consumers, serving as major channels with wide market scope and large transaction volume. These platforms offer a full range of agricultural products suitable for shipping long distances. As the entry barrier for merchants is low and competition is fierce, price remains the main basis of competition. The second model has local governments organizing agriculture e-commerce using third-party platforms. In this model, merchants must obtain government permission to enter the platform, which guarantees to some extent the quality of the agricultural products on offer. The third model uses unofficial social network channels that are active in agricultural e-commerce. Transaction volume is relatively small, but this model has potential for growth because of interpersonal trust and the convenience that social networks offer.

Traditional vegetable supply chains have many weaknesses, both upstream and down. Each intermediary link—connecting producers, farmers' brokers, wholesale markets in production areas, wholesale markets in sales areas, and vendors in the vegetable market—incurs costs that increase final food prices. Because of information asymmetry in traditional vegetable supply chains, farmers often grow produce without good information on market demand. Farmers' brokers must cope with unstable vegetable supply as farmers produce blindly and with fluctuating selling prices to wholesalers. Wholesalers and vegetable vendors bear such logistics expenses as trucking costs, loading and unloading charges, and the labor costs involved. Moreover, wholesalers and vendors pay booth or entry fees for the right to trade in a market.

E-commerce can help vegetable supply chains address their weaknesses. For instance, Songxiaocai, a business-to-business trading platform for vegetables, innovatively tackled supply chain problems. Songxiaocai designed a demand-driven supply chain informed and underpinned by advanced information technology and has positioned itself as a one-stop intermediary connecting producers to final consumers and eliminating some of the middlemen in traditional vegetable supply chains. Small vendors and wholesalers place orders through one of the mobile applications maintained by Songxiaocai. Specific orders from vendors and wholesalers allow producers to prepare accurate deliverables to meet specified demand. Standardized products are packaged and transported directly to end users, thus improving product quality and reducing the lead time required for unpacking shipments and sorting them at various stages along a traditional supply chain. Through Songxiaocai, vendors in the same area may choose to order products from the same supplier and pool their orders. Vendors thus strengthen their bargaining power in price negotiations and stabilize the quality of the produce they buy.

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2.4 Policies need to shift toward transforming agriculture in Asia

Government policies toward agriculture need to evolve to meet new challenges. This chapter has discussed many of the challenges facing agriculture in Asia in its ability to provide nutritious and diverse food, while ensuring environmental sustainability and climate resilience. At the same time, several opportunities have emerged, sometimes with private sector involvement, and with the application of new technologies and practices. Agriculture policy in the region needs to be reoriented to meet these challenges by fully exploiting these new opportunities.

First, subsidies and other producer support programs often distort market incentives and can spur overproduction. Such policies often fail to provide consistent incentives to preserve natural capital or support sustainable production. Subsidies for chemical inputs can lead to pollution of soil and the surrounding environment that can cause health problems for farmers and consumers. Direct support for producers can also distort incentives and encourage misallocation of resources away from more productive use.

Second, resource-intensive agricultural production requires monitoring and better regulation to protect the environment and consumers. Production of livestock and high-value crops requires intensive use of natural resources and chemical inputs. In addition, rice production on irrigated land and livestock production emit high levels of greenhouse gases. The rapid expansion of aquaculture can cause deforestation of mangroves and raises concerns over land and water pollution and food safety. To monitor and reduce adverse environmental effects from resource-intensive agricultural and aquaculture production, policy makers must account for these impacts when crafting agricultural policies. Well-designed regulations, effective monitoring programs on chemical contaminations in soil, water, and agricultural products, and enforcement programs to reduce contamination need to be put in place to safeguard the environment and ensure food safety for consumers.

Third, governments need to modernize agricultural laws and regulations to provide an enabling environment for farmers and business agents. Agricultural processers and traders offer contracts to farmers with advance pricing, technical assistance, and access to markets, which have the potential to benefit both farmers and traders.

However, unclear agreements and contract enforcement mechanisms often lead to contract disputes and prevent farmers and traders from fully benefiting from such services. Agricultural laws and regulations need to be modernized so that agricultural business agents can engage in innovative arrangements that stimulate agricultural development.

Fourth, investments are needed for climate-resilient agricultural infrastructure and support systems to mitigate impacts from weather shocks. Climate-resilient agriculture infrastructure and practices, early warning systems, and crop insurance can all help to mitigate negative impacts of weather shocks at various stages. For example, investments in early warning systems and other complementary programs, such as building cyclone shelters or providing cash assistance to stock emergency goods, can mitigate damage to rural communities. These investments need to increase as more frequent and devastating weather shocks are expected due to climate change. Because they have a public good element—the benefits accrue to a wide range of participants—the public sector has an important role to play in assuring or encouraging adequate provision. But such investments in support systems could be pursued in collaboration with private agents, who may already be providing similar services and who are often more familiar with the latest technological advances. Many private firms are already involved in crop insurance and weather forecasting, for example, and tapping their expertise could be helpful. More generally, agricultural policies need to shift toward support for innovation, market development, and fostering effective business ecosystems with updated regulations.

Finally, instead of direct producer support, economies in developing Asia need to focus more on supporting market-oriented development by encouraging innovation and investing in research and development (R&D). Economies in developing Asia depend on technology transfer from developed economies through public research networks and private companies. However, public research funds from international organizations and other development partners have declined in recent years. Private research funds are oriented toward commercial agricultural products for which demand is high from consumers in developed economies. As discussed above, Asian agriculture faces serious challenges and needs improved technologies. In the last decades, scientists have made many discoveries, such as identifying DNA components associated with drought tolerance. However, it will take further R&D to adapt these scientific discoveries into agricultural technologies that farmers can use. Policy makers in the region need to invest in agricultural R&D to help farmers benefit from such scientific discoveries.

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