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THE RUSSIAN INVASION OF UKRAINE, FERTILIZER PRICES, AND FOOD SECURITY

EVIDENCE FROM RICE-PRODUCING ECONOMIES IN ASIA

Ashok K. Mishra, Harold Glenn A. Valera, Takashi Yamano, and Valerien O. Pede

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ABSTRACT

This study assesses the impact of increased fertilizer prices under different scenarios on rice production, consumption, trade and prices. Using a global rice model based on a partial equilibrium framework, the simulation results show that a 30% to 100% increase in fertilizer prices would reduce rice yields by 0.45% to 1.33%, but increase world rice prices by 7% to 23% between 2022 and 2025. As the world market price for rice increases significantly, rice trade and rice consumption will decrease accordingly, estimated at 1.7% to 7.0% and 0.27% to 0.78%, respectively. The simulation results also show that retail prices for rice would increase significantly in all rice-consuming countries. The impact of higher fertilizer prices would vary widely in the major rice-producing countries.

Keywords: rice, world prices, Asia, rice trade, food security, partial equilibrium model

JEL codes: Q17, Q18, F51

1. Introduction

Fertilizer, especially nitrogen, is one of the primary inputs for rice production (Kousonsavath and Sacklokham 2020), especially for high-yielding rice varieties. About 16% of the world's nitrogen fertilizer is used for rice production (Heffer, Gruere, and Roberts 2017). Nitrogen is essential for plant growth (plant size, leaf width, and number of panicles). The critical period for nitrogen application in the plant life cycle is 21 days after seedling sowing. Farmers need to know the optimal nitrogen application rate because excessive use of nitrogen fertilizer could lead to excessive plant growth and provide a haven for pests. Phosphorus, another critical element in fertilizers, is essential for strong root growth. Finally, potassium, another component of fertilizer, contributes to pest resistance, plant durability and thickness, and panicle formation. Natural gas is a major input used in fertilizer production. Because of the export restrictions resulting from the Russian invasion of Ukraine, increased natural gas prices have led to higher fertilizer prices and reduced supply on the world market (FAO 2022; Glauber and Laborde 2022; World Bank Group 2022; Mottaleb, Kruseman, and Snapp 2022).

Russian forces invaded Ukraine on 24 February 2022. The Russian Federation is a major supplier of oil and natural gas to the world market. The world has imposed significant restrictions on Russian oil and natural gas exports. With no end in sight, the invasion seems to fuel the rising oil and natural gas costs. The Russian Federation is the world's largest exporter of oil and fertilizer (nitrogen) and the second largest exporter of potash and phosphorus fertilizer. Since the invasion, the Russian Federation has suspended fertilizer exports to other countries, putting upward pressure on fertilizer prices. Oil and fertilizer are critical to the global food system. In rice farming, depending

on the country in developing and emerging economies (DEEs), fertilizer expenditures account for 21% to 30% of total production costs (Chau and Ahamed 2022). The Russian invasion of Ukraine has led to severe international sanctions against the Russian Federation. As a result, the global economy is facing a significant increase in oil prices, shortages of fertilizers, and price volatility. One can argue that fertilizer markets will continue to depend on energy markets and geopolitical events.

Volatility in food prices affects consumers. On one hand, the Russian invasion of Ukraine has increased food price volatility, inflation, and logistics. Higher inflation could lead to higher prices, such as labor wages and fuel prices, and lower incomes. The linkages between food–energy and the food–stock market provide important explanations for rising costs (Serra 2011; Lahiani, Nguyen, and Vo 2013). Energy prices influence feedstock markets, especially crude oil prices (Tyner 2010; Zhang et al. 2010; Serra 2011; Vacha et al. 2013; Saghaian et al. 2018; Janda and Kristoufek 2019). Furthermore, crude oil explains post-crisis price volatility, a net transmitter of return spillovers. On the other hand, crops such as wheat and soybeans are net recipients of volatility (Hassen and El Bilali 2022; Wang et al. 2022). Indeed, farming costs have been affected by restrictions on Russian fertilizer exports (Adekoya et al. 2022; Bongou and Yatié 2022; Umar et al. 2022). A number of blog reports from the International Food Policy Research Institute (IFPRI) have documented the rise in fertilizer prices and the uncertain availability of prices for farmers in DEEs (Hebebrand and Laborde 2022a). The blogs point out that smallholder farmers will have difficulty paying for essential inputs, which could affect food

security in many countries around the world,[1] including Bangladesh (Mamun, Glauber, and Laborde 2022), Egypt (Abay et al. 2022), Kenya (Breisinger et al. 2022), Nigeria (Balana et al. 2022), and Malawi (De Weerdt and Duchoslav 2022).

On the other hand, rising fuel costs are also problematic for fertilizer production. Natural gas is an input in the synthetic fertilizers used in many parts of the world. Agricultural production, including rice crops, consumes large amounts of fertilizers. As mentioned earlier, farmers apply large amounts of nitrogen fertilizer in rice cultivation to maximize yield. Most developing countries (India, Bangladesh, Thailand, Viet Nam, the Philippines, and the People's Republic of China [PRC]) produce rice as a staple food and rely heavily on imported fertilizers and oil. For DEEs, the problem is compounded because their budgets are stretched by fertilizer subsidies, price support, and increased inflationary pressures. For example, in DEEs with rice as a staple, policymakers have subsidized fertilizer to increase yield and food security for millions of low-income rural households. India, for example, relies on imported fertilizers and spends about $14 billion annually. As fertilizer prices rise, spending on imported fertilizer is bound to increase. Recently, Verma, Bhardwaj, and Ahmed (2022) reported that India will spend about $40 billion on food and fertilizer subsidies. About $18 billion will be spent on fertilizer subsidies. Ultimately, all of this has a significant impact on the livelihoods of farmers and rural populations and increases food insecurity for millions of people in Asia and around the world. Thus, it is of paramount importance to investigate the current and future effects of increased fertilizer prices on rice production, yields, farm-gate prices, and consumption.

[1] According to recent data from international agencies, such as FAO et al. (2020), about 8.0% of the world's population suffers from hunger. von Gremer et al. (2021) note that about 77 million people are severely food insecure due to wars and conflicts.

This study examines the impact of increased fertilizer prices under different scenarios on rice production area, yield, consumption, trade, and farm-gate prices. We use a modified version of the International Rice Research Institute (IRRI) Global Rice Model (IGRM). Specifically, we illustrate the impact of fertilizer price increases on the rice sector using three scenarios: a 30%, 50%, and 100% increase in fertilizer prices. This study assesses the impact on the world rice market and rice-producing countries such as the PRC, India, the Philippines, Viet Nam, and Thailand.

This study contributes to the literature in two ways. First, it adds to the literature on the effects of the Russian invasion of Ukraine on global food security, particularly in the rice sector. Second, the study contributes to the understanding of the effects of higher fertilizer prices on rice production, consumption, trade, and farm-gate and retail prices in major Asian rice-producing countries.

2. Background

Rice is a valuable crop for more than 4 billion people worldwide. Globally, rice provides 21% of per capita energy and 15% of per capita protein (United Nations 2017). Rice provides 27% of the calories in less developed and emerging economies. The South Asia and Southeast Asia region is the world's leading rice producer, accounting for 58% of global rice production in 2021 (USDA-ERS 2022). However, rice production and consumption vary by region (Mishra et al. 2022). Rice farming is associated with poverty in many areas. About 900 million of the world's poor people depend on rice as producers or consumers. In the first decade of the 21st century, growth in rice area, output, production, and productivity has slowed worldwide. With rising population growth, climate

change, income growth, and less land for farming, innovations in rice farming are critical to meet consumer demand and provide a source of income for smallholder farmers.

The Green Revolution of the 1960s introduced new crop production technologies for major cereals such as rice and helped reduce food insecurity in the world. Rice is the only crop that has benefited from the genetic improvements of the Green Revolution. Rice is one of the central essential food crops in many DEEs. It is grown in diverse agroecosystems in South Asia, Southeast Asia, Africa, and Latin America. Mishra et al. (2022) note that about 400 million poor and malnourished people are engaged in rice-based farming systems, mostly on less than 2 hectares (ha) of land. Finally, the authors note that about 144 million farm households (usually small farms) grow rice for subsistence and employment. Therefore, an abundant and stable supply of affordable rice is critical to reducing poverty and hunger in DEEs.

Rice production has increased significantly over the past five decades with the efforts of international research centers and national governments. Rice is an important crop in Asia (including the PRC, India, Thailand, Viet Nam, and the Philippines),[2] covering 85% of the arable land. Asians consume 84% of the world's rice. We note that rice production and consumption vary by region (FAO 2021; USDA Foreign Agricultural Service 2021). Asian gross domestic product (GDP) per capita income has increased from 1970 to 2018 (Table 1). For example, the share of rice as the primary source of income has decreased from 26% in 1970 to 13% in 2018. Studies by Pandey et al. (2010) and Emerick (2018) find that the shift of labor to nonfarm sectors was the primary reason.

[2] The world's leading rice exporters are Thailand and Viet Nam (which account for 50% of exports to the world market). The world's top rice importers include Indonesia, Malaysia, and the Philippines (all accounting for 10% of global imports).

Despite several changes in the Asian rice sector, rice consumption as GDP per capita has grown rapidly in South America and Africa (Table 1). For example, although the share of rice production in Africa is small, demand for rice as food increased from 11 kilograms (kg)/capita/year in 1970 to 34 kg/capita/year in 2018. The same is true in South America, where rice consumption increased from 27 kg/capita/year in 1970 to 45 kg/capita/year in 2018.

In addition to prices of inputs such as fertilizer, seed, and labor, ongoing demographic transformation in Asia is expected to affect future rice production (Bhandari and Mishra 2018).[3] Several factors are likely to drive the supply response. On the supply side, the major factors are growth in cultivated area, input prices, rice cropping intensity, rice yields from the adoption of high-yielding varieties, aging of farmers, out-migration, and off-farm income opportunities.

Table 1: Importance of Rice as a Source of Food and Income by Region

Type	**GDP per Capita Income** ($) (value of $ per capita)	**Rice for Domestic Consumption** (million tons)[a]	**Food Supply** (kg/capita/year)[c]	**Rice Production Milled** (million tons)[a]	**Percentage of Value of Rice in the Total Value of Agriculture**[b]
			Africa		
1970	320.87	5.11	10.85	4.83	2.86
1980	1,283.62	7.53	14.88	5.27	2.91
1990	937.62	11.15	16.75	7.76	3.09
2000	1,912.15	16.08	18.76	11.15	4.60
2018	1,858.78	37.64	34.26	33.48	3.27

Continued on the next page

[3] The Asian population is projected to reach 4.6 billion in 2050.

Type	GDP per Capita Income ($) (value of $ per capita)	Rice for Domestic Consumption (million tons)[a]	Food Supply (kg/capita/year)[c]	Rice Production Milled (million tons)[a]	Percentage of Value of Rice in the Total Value of Agriculture[b]
South America					
1970	606.89	6.07	26.98	5.43	3.09
1980	1,977.40	9.28	29.47	8.96	3.36
1990	2,588.92	10.87	31.58	10.13	2.57
2000	9,804.27	12.89	30.43	12.84	3.09
2018	6,944.07	14.89	44.74	23.74	2.07
Asia					
1970	245.51	191.70	77.45	195.90	26.63
1980	967.01	241.90	77.20	244.94	24.34
1990	1,699.57	308.36	82.40	321.71	22.24
2000	4,901.91	346.68	78.62	362.53	18.48
2018	8,786.51	407.41	112.99	662.93	12.83
World					
1970	922.94	209.88	47.61	213.01	11.99
1980	2,759.64	270.19	49.71	269.91	11.47
1990	4,316.57	343.81	54.22	351.37	11.89
2000	9,548.35	393.68	53.69	399.19	10.64
2018	11,244.09	444.12	78.46	742.05	7.93

GDP = gross domestic product, kg = kilogram.
[a] Asia consists of South Asia, Southeast Asia, and East Asia, while Africa is composed of the countries in sub-Saharan Africa and North Africa.
[b] Gross value of production (constant 2014–2016 in $'000).
[c] For 2018, estimates include rice and products as compared with earlier estimates of milled rice.
Sources: FAO (2021) and USDA Foreign Agricultural Service (2021).

(Bhandari and Mishra 2018). The out-migration of people from rural areas affects rice farming by decreasing the farming population, the supply of farm labor, and by shifting the demand for rice from rural to urban areas. Thus, growth in rice production has been largely accomplished by adopting new technologies (seeds and fertilizers) and sustainable farming practices, improving access to credit, increasing investment in agricultural research and development, and redesigning national and international trade policies.

However, recent uncertainties in fertilizer prices due to the Russian invasion of Ukraine could increase food insecurity (output and income) for smallholder rice producers[4] and drive up consumer prices. Recent IFPRI reports conclude that the Russian invasion of Ukraine has led to higher fertilizer prices, which in turn threatens global food security (Hebebrand and Laborde 2022b; Glauber and Laborde 2022).

3. Methodology

3.1. Global rice trade modeling

We use the IRRI Global Rice Model (IGRM) to model the impact of different scenarios of fertilizer price increases on the rice sector. The IGRM is documented in Balié and Valera (2020). The supply-side component of a representative country model in IGRM comprises production, beginning stocks and imports, while demand includes domestic consumption, ending stocks and exports. In this study, the impact of increased fertilizer prices on the rice sector is modeled through the supply-side component of the IGRM. Specifically, rice yield is specified as a function of fertilizer use and technological change. Fertilizer use is

[4] Higher input prices result in high production cost, low farm income, low resource use efficiency, and consequently, rice supply shortages.

specified in the IGRM as a function of the ratio of the concurrent world urea price and the lagged farm-gate prices for rice and the lagged yield of rice. The world urea price is then linked to the world oil price. The world reference price in IGRM is the Thai FOB 5% broken rice price.

3.2. Rice and fertilizer use under three scenarios

Rice is the staple food for about 67% of people worldwide. The food security of millions of people and smallholder farmers depends on rice production. The Green Revolution has given the world a much-needed boost in production of rice, wheat, and maize. High-yielding crops like rice and wheat use far more chemical fertilizers than traditional varieties. Chemical fertilizers are the primary input for high-yielding rice crops worldwide. Nitrogen is the primary nutrient and is in demand by major rice-producing countries. Nitrogen is applied every cropping season. The absence of nitrogen often limits rice production and reduces crop yield. Naher et al. (2019) note that nitrogen, phosphorus, and potassium are the most commonly used nutrients for rice production. Chemical fertilizer production relies on natural gas and has significantly affected yield growth in the United States (US) and other countries worldwide. The top buyers of fertilizers (urea, ammonium nitrate, and potash) are Brazil, the PRC,[5] India, and the US. According to Morgan Stanley, the Russian Federation and Ukraine export 28% of the fertilizer produced from nitrogen, phosphorus, and potassium (Schnitkey et al. 2022). Because of sanctions and the Russian invasion of Ukraine, disruptions will affect fertilizer prices, crop area, yields, and farm-gate prices, and change the crop mix.

[5] The PRC uses the largest amount of chemical fertilizers in Asia (Naher et al. 2019).

The aforementioned effects of increases in fertilizer prices will be short term until farmers and the industry find other ways to deal with the disruptions and higher fertilizer prices. Recently, Welsh (2022) found that fertilizer prices (including ammonia, nitrogen, nitrates, phosphates, potash, and sulfates) have increased 30% since January 2022. Thus, we simulate three scenarios for increased fertilizer prices for the rice sector. First, **scenario 1** uses a 30% increase in fertilizer prices and the IGRM to simulate the effects on rice production area, yield, consumption, trade, and farm-gate and retail prices. Second, **scenario 2** uses a 50% increase in fertilizer prices. Finally, **scenario 3** uses a 100% increase in fertilizer prices to assess the impact on the rice sector.

4. Results and Discussion

4.1 Impact on Africa, Asia, the Americas, and the world[6]

This section presents the impact of a 30%, 50%, and 100% increase in fertilizer prices due to the Russian invasion of Ukraine from 2022 to 2026. Simulation results in Table 2 predicted that a 30% increase in fertilizer prices decreases world rice production by 0.45% in 2022.[7] As expected, the estimated decline in production in 2022 is more pronounced with 0.68% and 1.12% decrease under scenario 2 and scenario 3, respectively. A 50% increase in fertilizer prices reduces rice production by 0.37% from 2023 to 2025. Finally, doubling fertilizer prices decreases rice production by 0.61%. However, the effect of increased fertilizer prices in 2026 would dissipate and rice production would increase by

[6] **Africa** includes Cote d'Ivoire, Egypt, Kenya, Mozambique, Nigeria, South Africa, Rest of Africa. **Asia** includes Bangladesh; Cambodia; the PRC; India; Indonesia; Japan; Malaysia; Nepal; Pakistan; the Philippines; the Republic of Korea; Sri Lanka; Thailand; Viet Nam; Rest of Asia. **Americas** include Brazil, Uruguay, United States, Rest of America. **Rest of the world** includes EU and Rest of the world.

[7] Note that the results reported here are modelling outcomes and the model was estimated in July 2023.

0.21% to 0.51%. This reversal in trend could be attributed to many factors, including increased use of modern technology, substitution of inorganic fertilizer for organic fertilizer, and more sustainable production in the long run.

Table 2: Simulated Effects of Changes in Fertilizer Prices on World Rice Production, Yield, Consumption, Trade, and Prices (Relative to Baseline), 2022–2026

	2022	2023	2024	2025	2026
Production					
Baseline (1,000 MT)	744,017	747,278	748,831	754,590	759,122
Scenario 1	740,685	745,578	746,922	752,644	760,705
Scenario 2	738,969	744,724	745,956	751,659	761,505
Scenario 3	735,708	743,130	744,145	749,813	763,005
			(In percent)		
Scenario 1	-0.45	-0.23	-0.25	-0.26	0.21
Scenario 2	-0.68	-0.34	-0.38	-0.39	0.31
Scenario 3	-1.12	-0.56	-0.63	-0.63	0.51
Yield					
Baseline (MT/ha)	4.65	4.67	4.69	4.70	4.72
Scenario 1	4.63	4.64	4.66	4.68	4.72
Scenario 2	4.62	4.63	4.65	4.66	4.72
Scenario 3	4.59	4.60	4.63	4.64	4.71
			(In percent)		
Scenario 1	-0.45	-0.55	-0.53	-0.54	-0.09
Scenario 2	-0.68	-0.82	-0.80	-0.82	-0.13
Scenario 3	-1.12	-1.35	-1.30	-1.33	-0.22
Consumption					
Baseline (1,000 MT)	507,680	511,985	513,497	516,119	518,994
Scenario 1	506,089	510,664	512,154	514,741	519,310
Scenario 2	505,269	509,993	511,473	514,043	519,470
Scenario 3	503,708	508,731	510,194	512,734	519,774
			(In percent)		
Scenario 1	-0.31	-0.26	-0.26	-0.27	0.06
Scenario 2	-0.47	-0.39	-0.39	-0.40	0.09
Scenario 3	-0.78	-0.64	-0.64	-0.66	0.15

Continued on the next page

	2022	2023	2024	2025	2026
Net trade					
Baseline (1,000 MT)	37,048	38,212	38,615	38,485	38,477
Scenario 1	36,433	37,297	37,557	37,398	38,026
Scenario 2	36,106	36,824	37,013	36,841	37,797
Scenario 3	35,460	35,912	35,972	35,779	37,367
			(In percent)		
Scenario 1	-1.66	-2.39	-2.74	-2.82	-1.17
Scenario 2	-2.54	-3.63	-4.15	-4.27	-1.77
Scenario 3	-4.29	-6.02	-6.85	-7.03	-2.89
Thai 5% broken rice price					
Baseline ($/MT)	444	441	507	543	566
Scenario 1	484	475	543	579	558
Scenario 2	505	493	561	598	553
Scenario 3	544	525	594	633	545
			(In percent)		
Scenario 1	9.12	7.76	6.96	6.77	-1.49
Scenario 2	13.82	11.69	10.49	10.20	-2.25
Scenario 3	22.76	19.11	17.12	16.64	-3.69

ha = hectare, MT = metric ton.
Note: Scenario 1 is a 30% increase in fertilizer prices, scenario 2 is a 50% increase in fertilizer prices, and scenario 3 is a 100% increase in fertilizer prices.
Source: IRRI Global Rice Model simulations, July 10, 2023.

Rice yield would decrease by 0.45% in 2022, and there would be no decrease in 2026 if fertilizer prices increased by 30% (see second panel of Table 2). If fertilizer prices increase by 50%, rice yield will immediately decrease by 0.68% in 2022, reach a high of 0.82% in 2025, and decrease by 0.13% in 2026. However, when fertilizer prices double, it shows a more pronounced decline in rice yield. For example, rice yield reduces by 1.35% in 2023, followed by a 1.33% reduction in 2025, but the decline in rice yield slows down in 2026 (only 0.22%). On the consumption side, rice consumption decreases under each scenario with increasing fertilizer prices from 2022 to 2025 (third panel of Table 2). The decrease in rice consumption (percentage change) is immediately large under all three scenarios. The reduction in rice consumption is even larger in percentage terms when fertilizer prices double. However, we find that rice consumption in 2026 will increase

only modestly by 0.06% when fertilizer prices increase by 30% and by about 0.15% when fertilizer prices double. Thus, the above analysis shows that consumption rebounds or increases modestly to the original level (before the Russian invasion of Ukraine).

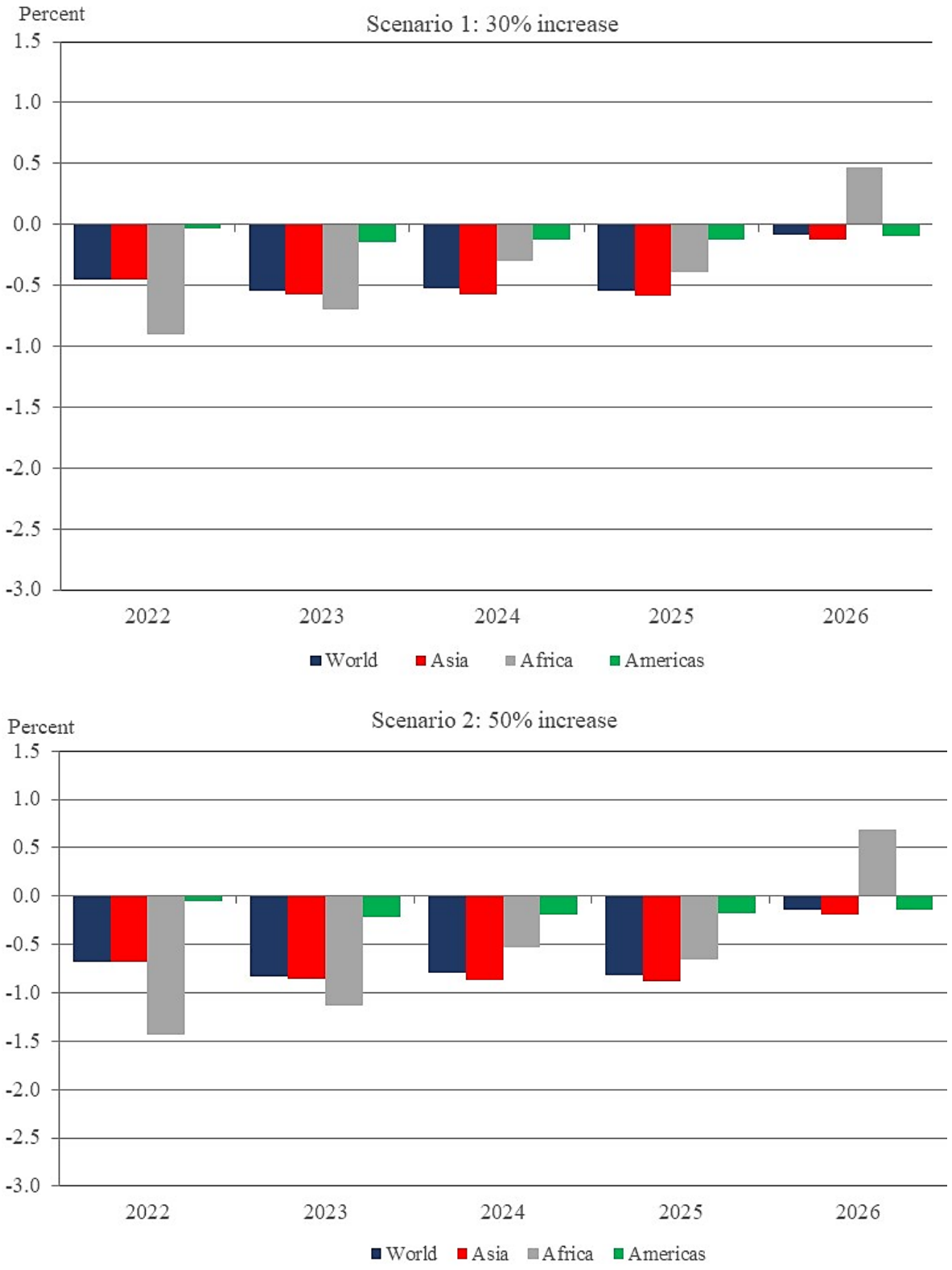
Global rice trade noticeably declines due to fertilizer price increases in all three scenarios (fourth panel of Table 2). This is also to be expected as countries will export less and try to meet their country's needs before exporting rice. The percentage decline in rice trade is smaller for a 30% increase in fertilizer prices—from 1.66% in 2022 to 2.82% in 2025. The largest impact on the rice trade occurs when fertilizer prices double. Rice trade may decline by 4.29% in 2022 to 7.03% in 2025. Indeed, a significant reduction in rice trade can have far-reaching implications for food security in many DEEs. In all fertilizer price increase scenarios, the impact on net trade drops to the lowest level from 1.17% to 2.89% for a 30% and 100% increase in fertilizer prices, respectively. Finally, the last panel of Table 2 reports the effect on Thai 5% broken price of an increase in fertilizer prices under the three scenarios. Specifically, Thai 5% prices would increase by about 9% in 2022 and 7% in 2025 under scenario 1. If fertilizer prices increase by 50%, Thai 5% broken prices would increase by about 14% in 2022 and decrease by about 10% in 2025. If fertilizer prices doubled, Thai 5% broken rice prices would increase by about 23% in 2023 and by about 16% in 2025. However, in all three scenarios for the increase in fertilizer prices in 2026, a decrease in Thai 5% broken prices can be observed—from 1.49% to 3.69%.

In the case of Africa, the simulation results suggest that for 30%, 50%, and 100% increases in fertilizer price scenarios, the rice area would remain unchanged in 2022. However, rice area during the period 2023–2026 increased on average by 0.45%, 0.70%,

and 1.16%, with a 30%, 50%, and 100% increase in fertilizer prices, respectively. In terms of rice yields in Africa, our estimates show a larger decline in the 2022 and 2023 rice-growing seasons under the three scenarios of fertilizer price increases. The decline in rice yields decreases from 2024 to 2025 (Figure 1). Incidentally, we see a trend reversal in 2026, for which our estimates show a modest increase in rice yields (from 0.46% to 1.09%) with a 30% and 100% increase in fertilizer prices, respectively. These findings suggest that farmers adopt a different technology that uses less fertilizer due to the increase in fertilizer prices, or that smallholder farmers expect the effects of the invasion to moderate or disappear altogether in later years.

Next, in all three scenarios of fertilizer price increases, African rice imports in 2022 increases from 0.82% to 1.42% (Appendix Table). The decline in imports increases with the scenarios for increased fertilizer prices. Perhaps African countries would need to import much of the rice from Asia and the rest of the world (the US and others) to meet consumer demand. However, because of the invasion, the Americas and Asia face a similar decline in output and consumption if fertilizer prices increase. Thus, the net effect of increased fertilizer prices will be significant for the food security of rice farmers and consumers in Africa.

Figure 1: Changes in Rice Yield, Globally and by Region, 2022–2026



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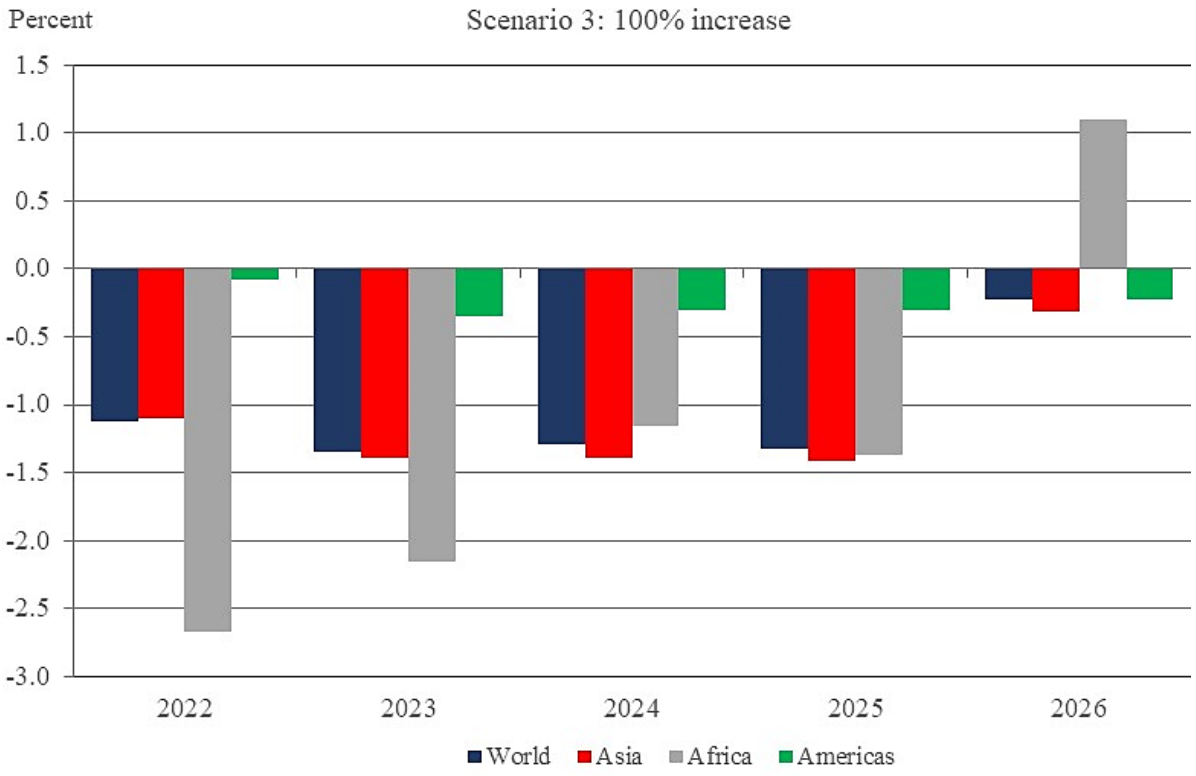


Note: The vertical axis represents the percentage change in rice yield.
Source: International Rice Research Institute Global Rice Model simulations, July 10, 2023.

The results for Asia differ significantly from those for Africa, as Asia is the largest producer and consumer of rice. For example, the US Department of Agriculture (USDA) recently reported that 503.17 metric tons (MT) of rice is produced globally, of which 29.5% is produced in the PRC, followed by India (23.8%), Bangladesh (7.0%), Indonesia (6.9%), Viet Nam (5.4%), and Thailand (3.7%). Figure 1 shows that the area under rice cultivation will only increase slightly from 2022 to 2026. The percentage increase in rice area in Asia is lower than in Africa. Given the increasing population and urbanization in Asian countries, these figures are not surprising. The impact of fertilizer price increases on rice yields in Asia shows that we will have a higher decline in rice yields in the 2023 and 2024 rice-growing seasons under the three scenarios of fertilizer price increases. Unlike for

Africa, we do not see a reversal in rice yield trends due to rising fertilizer prices in 2026. However, the decline in rice yields will be much smaller in 2026.

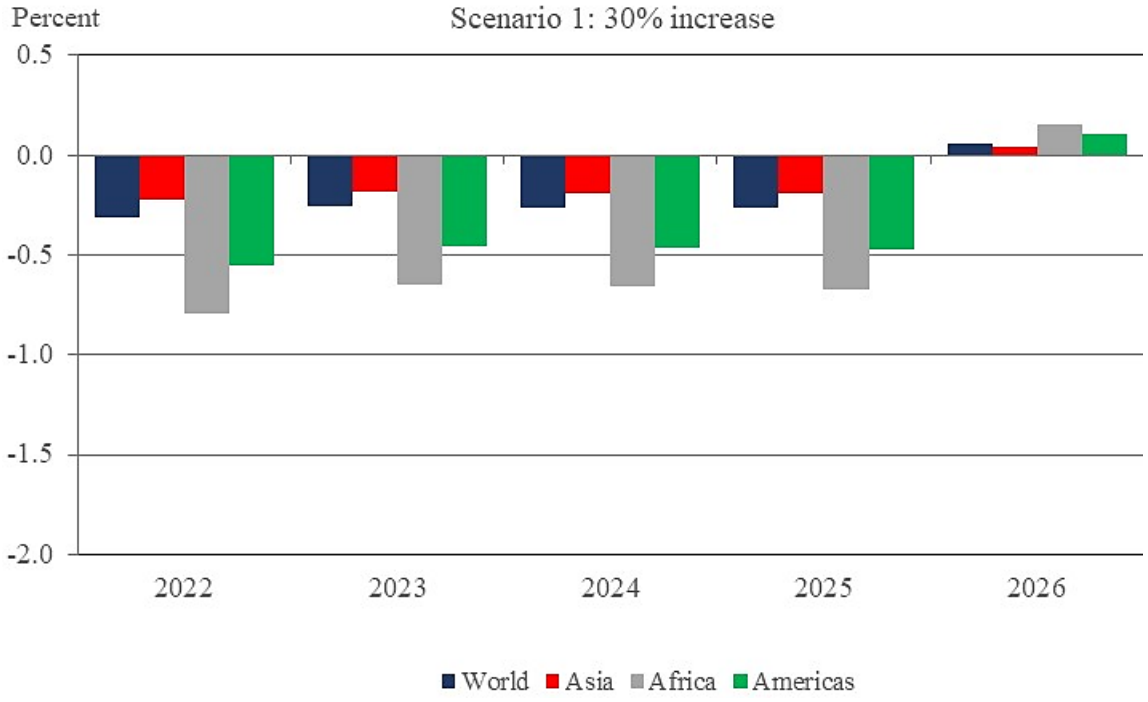
Our estimates reveal that Asian countries' rice consumption will be reduced from 2022 to 2025. The percentage decrease in rice consumption from 2022 to 2025 ranges from 0.20% to 0.47%, depending on the increase in fertilizer prices. However, rice consumption would increase slightly in 2026 from 0.04% to 0.11%. Our estimates show a significant decrease in rice exports for the rice trade. Recall that in Asia, major rice-producing and exporting countries such as India, Thailand, and Viet Nam are all affected by increased input costs. Under all three scenarios for fertilizer price increases, rice exports will decline significantly in 2022 and peak in 2025. After that, the effect of increased fertilizer prices on rice exports decreases, regardless of the scenario used.

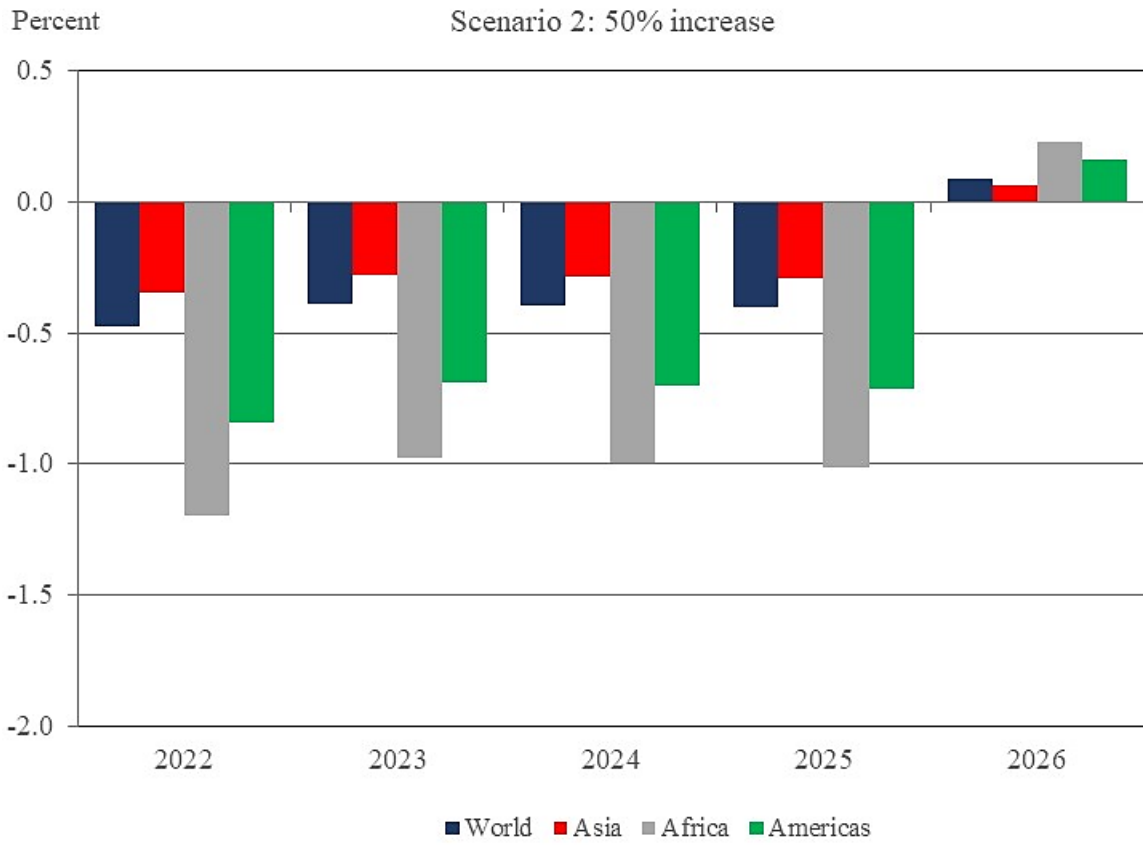
Finally, we estimated the effect of fertilizer price increases on area, yield, consumption, and trade for the Americas. As in Africa and Asia, fertilizer price increases have no impact on rice areas in 2022. However, compared to Asia and Africa, we see that the rice area in the Americas increases much more, from 0.93% with a 30% increase in fertilizer prices to 1.40% for a 100% increase. According to Mishra et al. (2022), the average growth rate of rice yields from 2008 to 2019 in Latin America was 2.5%, the highest compared to other regions (Africa and Asia). In Latin America, farms tend to be large and farmers are concerned about environmental sustainability, climate change adaptation, and competitiveness in global markets. Investments in improved rice varieties yielded a return of 13.2% per year (Labarta et al. 2015). Nevertheless, our estimates of the impact of fertilizer price increases on rice yields are negative in the Americas but to a

lesser extent than in Asia and Africa. The decline in rice yields is felt throughout the 2022–2026 period.

On the consumption side, Figure 2 shows that rice consumption declines under each fertilizer price increase scenario from 2022 to 2025. The decline in rice consumption and intensity (percentage change) is larger in 2022 under all three scenarios. The reduction in rice consumption (percentage change) is larger under a doubling of fertilizer prices. However, we find that rice consumption in 2026 increases slightly by 0.11% in 2026 when fertilizer prices increase by 30% and by 0.26% when fertilizer prices double. Thus, the above analysis shows that American consumption rebounds to the original level (before the invasion) or increases slightly. As for the rice trade, our estimates reveal that America's rice exports would decrease significantly with increased fertilizer prices (30%, 50%, and 100%) due to the Russian invasion of Ukraine. Under all three scenarios of fertilizer price increases, the results show that rice exports would decline starting in 2022 and continue to drop through 2025. In 2026, we find a smaller decrease in exports. The decline in the share of rice exports increases with the increased fertilizer prices (30%, 50%, and 100%) due to the Russian invasion of Ukraine.

Figure 2: Changes in Rice Consumption, Globally and by Region, 2022–2026





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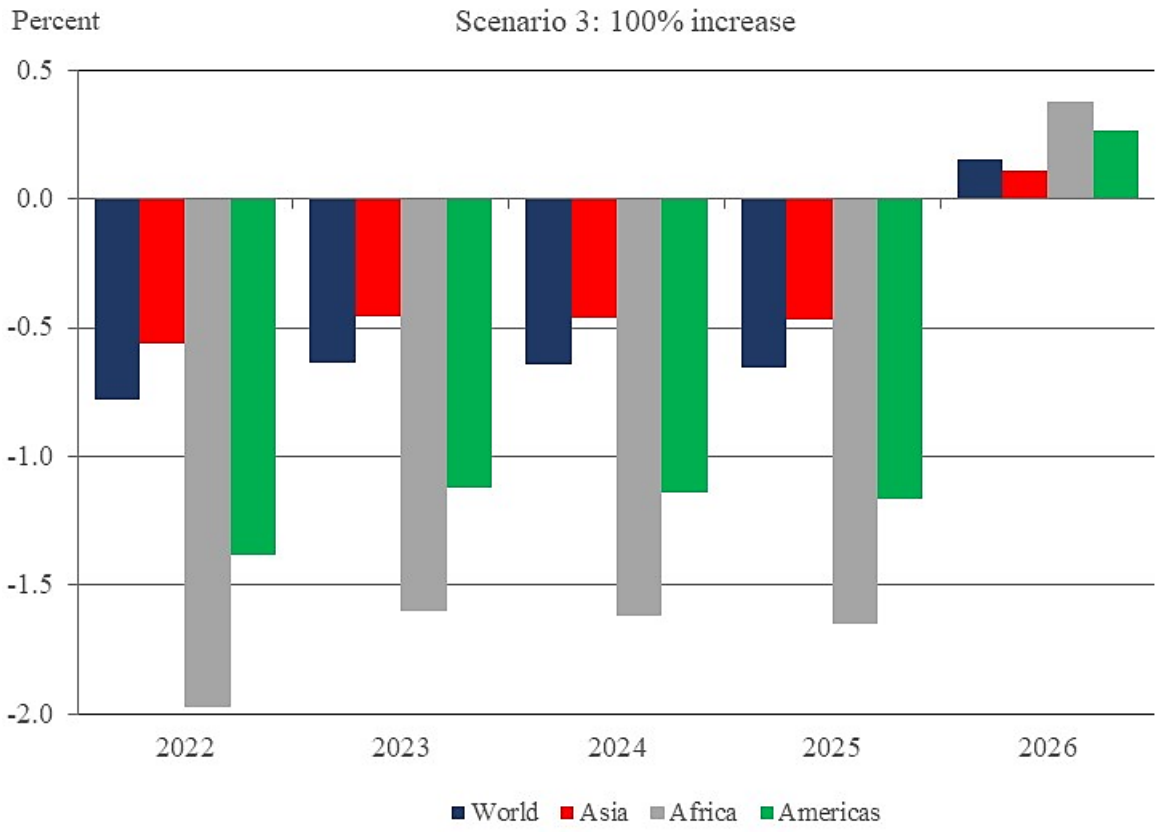

IRRI = International Rice Research Institute.
Note: The vertical axis represents the percentage change in rice consumption.
Source: IRRI Global Rice Model simulations, July 10, 2023.

4.2 Impact on production, yields, and consumption in selected Asian economies

We also analyzed the impact of fertilizer price increases in selected Asian countries (see Table 3). These countries are major rice producers, exporters, and consumers (about 74% of global trade). Table 3 shows the changes in rice production under the three fertilizer price increase scenarios for each year and country. Column 1 of Table 3 shows the year and country distribution, and column 2 shows the baseline (in 1,000 MT) used to calculate the changes. In contrast, columns 3–5 show the percentage change in rice production when fertilizer prices are increased by 30%, 50%, and 100%. The top panel of Table 3 shows an immediate effect on rice production in 2022. Indeed, if fertilizer prices

increase, farmers may be forced to buy less and apply less fertilizer. Table 3 shows that India's largest decrease in rice production in 2022 is due to rising fertilizer prices. In 2022, rice production in India could decline from 1.09% to 2.66% if fertilizer prices increase by 30% or double. In contrast, the result shows a smaller reduction in rice production in the PRC, Thailand, and Viet Nam. During 2022–2026, rice area allocation in the PRC appears stagnant.

Table 3: Simulated Effects of Changes in Fertilizer Prices on Production, by Country, Relative to Baseline, 2022–2026

Year/Country	Baseline (1,000 MT)	Scenario 1 (30%)	Scenario 2 (50%)	Scenario 3 (100%)
2022			*(In percent)*	
PRC	213,214.27	-0.09	-0.13	-0.22
India	186,523.26	-1.09	-1.64	-2.66
Thailand	29,223.33	-0.04	-0.05	-0.09
Viet Nam	44,005.89	-0.02	-0.04	-0.06
Philippines	19,709.83	-0.11	-0.17	-0.28
2023			*(In percent)*	
PRC	213,965.07	-0.09	-0.13	-0.22
India	187,313.44	-1.27	-1.91	-3.07
Thailand	29,488.52	1.62	2.45	4.04
Viet Nam	44,005.89	0.34	0.51	0.85
Philippines	20,035.58	0.60	0.91	1.50
2024			*(In percent)*	
PRC	213,755.89	-0.09	-0.13	-0.22
India	188,317.78	-1.32	-1.98	-3.17
Thailand	29,133.62	1.27	1.91	3.12
Viet Nam	44,178.35	0.28	0.42	0.68
Philippines	20,191.13	0.46	0.70	1.14
2025			*(In percent)*	
PRC	213,578.24	-0.09	-0.13	-0.22
India	189,388.77	-1.34	-2.01	-3.22
Thailand	29,933.39	1.26	1.90	3.10
Viet Nam	44,613.46	0.28	0.42	0.67
Philippines	20,570.04	0.45	0.68	1.10
2026			*(In percent)*	
PRC	213,392.83	0.00	0.00	0.01
India	190,380.04	-0.24	-0.36	-0.59
Thailand	30,378.21	1.32	1.99	3.25

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Year/Country	Baseline (1,000 MT)	Scenario 1 (30%)	Scenario 2 (50%)	Scenario 3 (100%)
Viet Nam	44,922.01	0.30	0.46	0.74
Philippines	20,832.35	0.57	0.86	1.39

MT = metric ton, PRC = People's Republic of China.
Note: Scenario 1 is a 30% increase in fertilizer prices, scenario 2 is a 50% increase in fertilizer prices, and scenario 3 is a 100% increase in fertilizer prices.
Source: IRRI Global Rice Model simulations, July 10, 2023.

Interestingly, we see a couple of trends starting in 2023. First, the percentage decline in the PRC's rice production remains the same in 2023–2025. However, in 2026, the trend reverses to positive and rice production barely increases. Second, the percentage decline in India's rice output continues to grow due to higher fertilizer prices and increases in magnitude until 2025. Then, in 2026, we observe a smaller decrease in rice output. This is plausible since India's rice area allocation would increase at a modest rate of 0.03% and 0.07% over the same period. For 2023–2026, the simulation results show that Thailand, Viet Nam, and the Philippines will have positive rice output. In Thailand, our estimates show a significant increase in rice area.

Table 4 shows the changes in rice yields under the three scenarios for fertilizer price increases and for year and country. Column 1 of Table 4 shows the year and country distribution and column 2 shows the baseline yield (in MT/ha) used to calculate the changes. In contrast, columns 3–5 show the percentage change in rice yield when fertilizer prices increase by 30%, 50%, and 100%. The simulation results show that the immediate impact of higher fertilizer prices could result in lower rice yield. For example, from 2022 to 2025, rice yield in the PRC could decrease from 0.09% to 0.22% if fertilizer prices increase by 30% or double. However, estimates for 2023 suggest that rice yields in the PRC will return to pre-invasion levels. On the other hand, the results reveal that

rice yields in India would decline significantly as higher fertilizer prices could lead to lower rice yields. In 2022, rice yield in India could decrease from 1.09% to 2.26% if fertilizer prices increase by 30% or double. From 2023 to 2025, rice yield in India could drop by 1.30% to 3.29% if fertilizer prices increase by 30% or 100%, respectively. Recall that the Government of India subsidizes fertilizer for farmers to stimulate agricultural production and achieve food self-sufficiency.[8]

Table 4: Simulated Effects of Changes in Fertilizer Prices on Rice Yield by Country, Relative to Baseline, 2022–2026

Year/Country	Baseline (MT/ha)	Scenario 1 (30%)	Scenario 2 (50%)	Scenario 3 (100%)
2022			*(In percent)*	
PRC	7.14	-0.09	-0.13	-0.22
India	4.15	-1.09	-1.64	-2.66
Thailand	2.83	-0.04	-0.05	-0.09
Viet Nam	5.92	-0.02	-0.04	-0.06
Philippines	4.15	-0.11	-0.17	-0.28
2023			*(In percent)*	
PRC	7.14	-0.09	-0.14	-0.23
India	4.17	-1.30	-1.95	-3.14
Thailand	2.84	0.07	0.11	0.17
Viet Nam	5.95	-0.02	-0.04	-0.06
Philippines	4.18	-0.09	-0.14	-0.23
2024			*(In percent)*	
PRC	7.14	-0.09	-0.14	-0.23
India	4.19	-1.35	-2.02	-3.24
Thailand	2.86	0.05	0.08	0.12
Viet Nam	5.97	-0.02	-0.04	-0.06
Philippines	4.20	-0.10	-0.14	-0.24

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[8] Subsidies tend to lower the price of fertilizers and encourage their overuse. The Indian government has introduced a bill that would subsidize fertilizer prices by 55%. Thus, the price of urea and diammonium phosphate in India is significantly lower than in countries such as the US, the PRC, and Brazil.

Year/Country	Baseline (MT/ha)	Scenario 1 (30%)	Scenario 2 (50%)	Scenario 3 (100%)
2025		*(In percent)*		
PRC	7.15	-0.09	-0.14	-0.23
India	4.21	-1.37	-2.05	-3.29
Thailand	2.88	0.05	0.07	0.11
Viet Nam	5.99	-0.02	-0.04	-0.06
Philippines	4.23	-0.10	-0.15	-0.24
2026		*(In percent)*		
PRC	7.15	0.00	0.00	0.00
India	4.23	-0.27	-0.40	-0.66
Thailand	2.89	0.09	0.13	0.21
Viet Nam	6.02	0.00	0.00	0.00
Philippines	4.26	0.02	0.03	0.05

MT = metric ton, PRC = People's Republic of China.
Note: Scenario 1 is a 30% increase in fertilizer prices, scenario 2 is a 50% increase in fertilizer prices, and scenario 3 is a 100% increase in fertilizer prices.
Source: IRRI Global Rice Model simulations, July 10, 2023.

Higher fertilizer prices could reduce rice yields in Viet Nam and the Philippines. The results show that Viet Nam should expect a 0.02% decline in rice yields from 2022 to 2025. At the other extreme, doubling fertilizer prices in the Philippines would lead to a 0.24% to 0.28% decline in rice yields from 2022 to 2025. Finally, there was a reversal in rice yields (positive rice yields) in Viet Nam and the Philippines. One bright spot in this analysis is Thailand. Interestingly, higher fertilizer prices in Thailand could lead to a decline in rice yields for only in 2022—from 0.04% to 0.09% with a 30% increase or a doubling of fertilizer prices. However, Thailand would revert to positive rice yield in 2026. Thailand's rice yield would increase by 0.05%, 0.08%, and 0.12% if fertilizer prices were increased by 30%, 50%, and 100%, respectively.

Let us now turn to the effects on rice consumption reported in Table 5. The results show a decrease in rice consumption for 2022–2025 for the PRC, India, Thailand, Viet Nam, and the Philippines. However, all countries would revert to higher rice consumption

in 2026. In fact, rice consumption would increase by 0.01% in India and 0.33% in the Philippines. Second, we note that the initial increases (in 2022) in fertilizer prices reduce rice consumption by 0.18% in the PRC to 0.69% in Thailand (with a 30% increase in fertilizer prices).

Table 5: Simulated Effects of Changes in Fertilizer Prices on Rice Consumption by Country, Relative to Baseline, 2022–2026

Year/ Country	Baseline (1,000 MT)	Scenario 1 (30%)	Scenario 2 (50%)	Scenario 3 (100%)
2022			*(In percent)*	
PRC	153,565.05	-0.18	-0.27	-0.45
India	102,208.95	-0.06	-0.09	-0.15
Thailand	12,896.58	-0.69	-1.04	-1.71
Viet Nam	21,625.44	-0.25	-0.37	-0.61
Philippines	14,644.72	-0.65	-0.99	-1.63
2023			*(In percent)*	
PRC	153,955.26	-0.15	-0.22	-0.37
India	103,143.37	-0.05	-0.07	-0.12
Thailand	12,984.02	-0.53	-0.80	-1.30
Viet Nam	21,779.54	-0.20	-0.30	-0.50
Philippines	14,850.23	-0.53	-0.80	-1.30
2024			*(In percent)*	
PRC	153,825.96	-0.15	-0.23	-0.37
India	103,951.84	-0.05	-0.07	-0.12
Thailand	12,860.15	-0.54	-0.82	-1.34
Viet Nam	21,838.07	-0.20	-0.31	-0.50
Philippines	14,905.91	-0.53	-0.80	-1.30
2025			*(In percent)*	
PRC	153,868.18	-0.15	-0.23	-0.37
India	104,780.00	-0.05	-0.07	-0.12
Thailand	12,797.97	-0.56	-0.84	-1.37
Viet Nam	21,931.85	-0.21	-0.31	-0.51
Philippines	15,037.91	-0.53	-0.80	-1.31
2026			*(In percent)*	
PRC	153,917.53	0.03	0.05	0.08
India	105,605.02	0.01	0.02	0.03
Thailand	12,758.52	0.13	0.19	0.31
Viet Nam	22,029.58	0.05	0.07	0.12
Philippines	15,193.08	0.13	0.20	0.33

MT = metric ton, PRC = People's Republic of China.

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Note: Scenario 1 is a 30% increase in fertilizer prices, scenario 2 is a 50% increase in fertilizer prices, and scenario 3 is a 100% increase in fertilizer prices.
Source: International Rice Research Institute Global Rice Model simulations, July 10, 2023.

However, the decrease in rice consumption is higher, from 0.45% in the PRC to 1.71% in Thailand (with a 100% increase in fertilizer prices). The scenarios with increased fertilizer prices would have a moderate effect (small percentage change) during 2023–2025. Also, rice consumption in selected Asian countries would decrease by 0.15% to 1.37% from 2023 to 2025, with a 30% and 100% increase in fertilizer prices, respectively. Incidentally, the impact of an increase in fertilizer prices on rice consumption would be smaller for India's consumers. Thus, from 2022 to 2025, rice consumption in India would decline by 0.05% to 0.12% if fertilizer prices were to increase by 30% or 100%, respectively. The main reasons for this decline could be rapid income growth in India, dietary change (for example, consumption of more processed foods, refined grains, fried foods, high-sugar drinks, and pre-packaged foods), and migration of labor from rural to urban areas (Pingali 2007; Timmer 2010).

4.3 Impact on rice trade in selected Asian economies

Table 6 reports the changes in net rice trade under the three scenarios for fertilizer price increases, by year and country. The PRC's rice imports would increase from 7.6% in 2022 with a 30% increase in fertilizer prices to about 19% with a doubling of fertilizer prices. Similarly, the net import of rice from the Philippines would increase from 5.2% with a 30% increase in fertilizer prices to about 13% with a doubling of fertilizer prices.[9]

[9] India and the PRC have robust rice sectors (both in area allocated and output of rice) and are major players in the global rice economy.

Table 6: Simulated Effects of Changes in Fertilizer Prices on Net Rice Trade by Country, Relative to Baseline, 2022–2026

Year/ Country	Baseline (1,000 MT)	Scenario 1 (30%)	Scenario 2 (50%)	Scenario 3 (100%)
2022			*(In percent)*	
PRC	2,969.23	-7.60	-11.39	-18.55
India	19,768.08	-5.64	-8.48	-13.73
Thailand	6,320.76	2.33	3.53	5.82
Viet Nam	5,756.45	2.66	4.03	6.63
Philippines	2,057.54	-5.24	-7.94	-13.12
2023			*(In percent)*	
PRC	3,607.05	-2.36	-3.49	-5.50
India	21,744.24	-6.82	-10.21	-16.41
Thailand	6,348.24	5.16	7.81	12.83
Viet Nam	5,685.44	2.32	3.50	5.71
Philippines	2,109.51	-6.73	-10.16	-16.57
2024			*(In percent)*	
PRC	3,797.58	-2.63	-3.90	-6.19
India	21,890.06	-7.27	-10.87	-17.42
Thailand	6,450.38	4.75	7.17	11.71
Viet Nam	5,898.85	2.05	3.09	5.02
Philippines	2,044.29	-6.74	-10.15	-16.57
2025			*(In percent)*	
PRC	4,326.70	-2.38	-3.53	-5.60
India	21,510.06	-7.61	-11.38	-18.23
Thailand	6,918.85	4.60	6.93	11.30
Viet Nam	6,016.27	2.06	3.10	5.04
Philippines	2,072.44	-6.67	-10.05	-16.38
2026			*(In percent)*	
PRC	4521.96	2.82	4.25	6.94
India	21,266.68	-2.32	-3.48	-5.63
Thailand	7,232.02	2.50	3.76	6.13
Viet Nam	6,078.00	-0.57	-0.86	-1.42
Philippines	2,081.00	-1.33	-2.00	-3.24

MT = metric ton, PRC = People's Republic of China.
Notes: Scenario 1 is a 30% increase in fertilizer prices, scenario 2 is a 50% increase in fertilizer prices, and scenario 3 is a 100% increase in fertilizer prices. The PRC and the Philippines are net importers of rice, while India, Thailand, and Viet Nam are net exporters.
Source*:* International Rice Research Institute Global Rice Model simulations, July 10, 2023.

For 2023–2025, the percentage change in India's net exports decreases under the three fertilizer price scenarios. The impact of increased fertilizer prices could lower

exports from 5.6% in 2022 with a 30% increase in fertilizer prices to 13% in 2025 with a doubling of fertilizer prices. Higher fertilizer prices in developing countries such as India would mean higher input subsidies and government expenditure. Finally, the situation in the PRC would improve under the three fertilizer price scenarios, i.e., a declining import rate. In fact, the estimates in Table 6 suggest that the PRC could have a rice surplus in 2026 under the three fertilizer price scenarios. A USDA report notes that the PRC increased its exports substantially in 2017 and became a major exporter again in 2018 (USDA-ERS 2022).

Remember that Thailand and Viet Nam are two of the six major rice exporters. Thailand's rice exports in 2022 could increase from 2.3% if fertilizer prices increase by 30% to 5.8% if fertilizer prices double. Similarly, Viet Nam's rice exports could increase from 2.6% with a 30% increase in fertilizer prices to 6.6% with a doubling of fertilizer prices. Thailand and Viet Nam will remain relevant in the global rice market during 2022–2026, but Viet Nam may experience a decrease in rice exports in 2026.

4.4 Impact on farm-gate and retail prices in selected Asian economies

Increased fertilizer prices would ultimately affect rice farmers through farm-gate prices and consumers through retail prices. The impact of the higher fertilizer price scenarios on rice farm-gate prices from the perspective of rice producers is shown in Table 7. Farm-gate prices would increase for all countries, although the magnitude depends on the country and the percentage increase in fertilizer prices over the 2022–2025 period. For example, farm-gate prices of rice in the PRC could increase from 0.45% to 1.12% in 2022

if fertilizer prices increase by 30% or double. However, farm-gate prices would decrease by 0.08% to 0.21% in 2026.

Table 7: Simulated Effects of Changes in Fertilizer Prices on Farm-Gate Price, by Country, Relative to Baseline, 2022–2026

Year/Country	Baseline (LCU/kg)	Scenario 1 (30%)	Scenario 2 (50%)	Scenario 3 (100%)
2022			*(In percent)*	
PRC	2.15	0.45	0.68	1.12
India	334.26	2.35	3.56	5.86
Thailand	11.72	6.08	9.22	15.18
Viet Nam	4,210.40	0.79	1.19	1.95
Philippines	17.39	4.02	6.09	10.03
2023			*(In percent)*	
PRC	2.15	0.37	0.56	0.91
India	330.26	1.90	2.86	4.68
Thailand	11.01	5.01	7.55	12.34
Viet Nam	4,196.39	0.78	1.18	1.93
Philippines	17.33	3.26	4.92	8.04
2024			*(In percent)*	
PRC	2.16	0.37	0.56	0.91
India	338.62	1.81	2.72	4.44
Thailand	11.97	4.69	7.07	11.54
Viet Nam	4,247.79	0.78	1.18	1.95
Philippines	18.33	3.06	4.61	7.52
2025			*(In percent)*	
PRC	2.16	0.37	0.56	0.91
India	338.65	1.77	2.67	4.36
Thailand	12.40	4.64	6.99	11.40
Viet Nam	4,268.57	0.79	1.19	1.19
Philippines	18.75	3.30	4.52	7.37
2026			*(In percent)*	
PRC	2.17	-0.08	-0.13	-0.21
India	338.28	-0.39	-0.58	-0.96
Thailand	12.62	-1.03	-1.56	-2.55
Viet Nam	4,279.27	-0.18	-0.27	-0.44
Philippines	18.98	-0.74	-1.11	-1.82

LCU/kg = local currency unit per kilogram, PRC = People's Republic of China.
Note: Scenario 1 is a 30% increase in fertilizer prices, scenario 2 is a 50% increase in fertilizer prices, and scenario 3 is a 100% increase in fertilizer prices.
Source*:* International Rice Research Institute Global Rice Model simulations, July 10, 2023.

Table 7 also reports significant farm-gate rice prices in India, Thailand, and the Philippines due to higher fertilizer prices. The magnitude of the increase in farm-gate

prices increases as fertilizer prices increase. For example, farm-gate prices for rice in Thailand could increase by 6.08%, 9.22%, and 15.18% in 2022 if fertilizer prices increase by 30%, 50%, and 100%, respectively. Similarly, farm-gate rice prices in the Philippines could increase by 4.02%, 6.09%, and 10.03% in 2022 if fertilizer prices increase by 30%, 50%, and 100%, respectively. The impact of higher fertilizer prices on farm-gate prices, irrespective of the country, slowly begins to decline during the 2023–2025 period. Thailand and the Philippines will see the largest decreases in rice farm-gate prices. Farm-gate prices in Thailand (the Philippines) could fall from 1.03% to 2.55% (–0.74% to 1.82%), with a 30% increase and a doubling of fertilizer prices.

Finally, let us turn to the retail prices of rice. The effects of the scenarios with increased fertilizer prices (30%, 50%, and 100%) on retail rice prices are shown in Table 8. Column 1 of Table 8 shows the distribution by year and country. Column 2 shows the baseline price of retail rice in local currency units per kilogram used to calculate the changes. In contrast, columns 3–5 show the percentage change in retail rice prices for a 30%, 50%, and 100% increase in fertilizer prices. Retail rice prices would increase for all countries in 2022, and from 2023 onward, the percentage increase in retail prices will be slower. Again, the increase in retail rice prices depends on the country and the percentage increase in fertilizer prices during 2022–2025.

Table 8: Simulated Effects of Changes in Fertilizer Prices on Retail Price, by Country, Relative to Baseline, 2022–2026

Year/Country	Baseline (LCU/kg)	Scenario 1 (30%)	Scenario 2 (50%)	Scenario 3 (100%)
2022			*(In percent)*	
PRC	3.66	2.13	3.23	5.32
India	21.26	1.45	2.19	3.61
Thailand	11.96	9.59	14.53	23.94
Viet Nam	8,167.41	2.84	4.30	7.08
Philippines	36.64	4.66	7.06	11.63
2023			*(In percent)*	
PRC	3.64	1.77	2.66	4.35
India	2.17	1.17	1.76	2.88
Thailand	10.81	8.20	12.36	20.20
Viet Nam	8,086.76	2.36	3.56	5.81
Philippines	32.50	3.79	5.71	9.33
2024			*(In percent)*	
PRC	3.74	1.73	2.60	4.25
India	21.57	1.13	1.70	2.77
Thailand	12.36	7.31	11.01	17.97
Viet Nam	8,382.62	2.29	3.45	5.62
Philippines	34.68	3.52	5.31	8.66
2025			*(In percent)*	
PRC	3.77	1.73	2.61	4.25
India	21.75	1.11	1.67	2.73
Thailand	13.05	7.09	10.69	17.43
Viet Nam	8,502.18	2.29	3.45	5.62
Philippines	35.59	3.44	5.18	8.45
2026			*(In percent)*	
PRC	3.79	-0.39	-0.58	-0.96
India	21.84	-0.24	-0.37	-0.60
Thailand	13.40	-1.56	-2.36	-3.86
Viet Nam	8,563.80	-0.51	-0.77	-1.26
Philippines	36.10	-0.84	-1.27	-2.08

LCU/kg = local currency unit per kilogram, PRC = People's Republic of China.
Note: Scenario 1 is a 30% increase in fertilizer prices, scenario 2 is a 50% increase in fertilizer prices, and scenario 3 is a 100% increase in fertilizer prices.
Source: International Rice Research Institute Global Rice Model simulations, July 10, 2023.

For consumers in Thailand and the Philippines, retail rice prices could increase more than for consumers in the PRC, India, and Viet Nam. For example, retail rice prices in Thailand could increase by 9.59%, 14.53%, and 23.94% in 2022 if fertilizer prices

increase by 30%, 50%, and 100%, respectively. Similarly, retail rice prices in the Philippines could increase by 4.66%, 7.06%, and 11.63% in 2022 if fertilizer prices increase by 30%, 50%, and 100%, respectively. For Thai and Filipino consumers, retail prices would be higher than for consumers from the PRC, India, and Viet Nam during 2022–2025. Overall, we observe a decreasing trend in the percentage increase in retail rice prices for all countries from 2023 to 2025. Table 8 (bottom panel) shows that the impact of higher fertilizer prices on retail rice prices starts decreasing from 2026 onward, regardless of country. In this case, we also find that Thailand and the Philippines could significantly reduce retail rice prices. Retail rice prices in Thailand (and the Philippines) could decrease from 1.56% to 3.86% (–0.84% to –2.08%), with a 30% increase and a doubling of fertilizer prices.

5. Conclusion and Policy Implications

World population is projected to reach more than 9 billion by 2050 (Rosegrant et al. 2017). At the same time, agriculture faces significant problems. The agricultural economy, subsistence-oriented production, low productivity, low farm income, high food prices, and low labor productivity due to increased labor density in agriculture cause persistent poverty and hunger in developing countries. Food security remains fragile despite economic progress over the past 4 decades. The 2008 world food crisis and the recent COVID-19 pandemic emphasize the need to ensure a stable, affordable, high-quality, and sustainable food supply for poor people. More recently, the Russian invasion of Ukraine has unleashed a significant reduction in oil and natural gas supplies on the world market. Indeed, many researchers (see Abay et al. 2022; Balana et al. 2022; Mamun, Glauber, and Laborde (2022) have echoed the severe impact of the invasion on the food security

of millions of poor people around the world. In addition, the Russian invasion of Ukraine has restricted the amount of fuel and fertilizer available to farmers. This invasion has increased the price of fertilizer and the uncertainty in fertilizer supply for many smallholder rice farmers worldwide, especially poor smallholders in South Asia and Southeast Asia. Thus, farm families in low- and middle-income countries are vulnerable to unsustainable rice production and lack of food security.

The main objective of this study is to assess the impact of the rapid increase in fertilizer prices resulting from the Russian invasion of Ukraine on the rice sector in the major Asian rice-producing economies. The Russian Federation and Ukraine are major exporters of urea and fertilizer (FAO 2022; Mottaleb, Kruseman, and Snapp 2022). The Russian Federation supplies significant amounts of natural gas and oil used to manufacture inorganic fertilizer, and oil is used in farm machinery. The simulation results indicate that the Russian invasion of Ukraine could affect rice output, consumption, trade, and prices (farm gate and retail). However, the magnitude of production and yield declines varies depending on the location and duration of the invasion. The rice trade would be significantly affected. In the near term (2022–2025), rice production and consumption will also suffer. However, markets will adjust to rising prices beyond 2025 with the global rice economy returning to pre-invasion levels of output, yield, area allocated to rice, consumption, and prices.

Our estimates show that rice consumption would decrease in all major Asian rice economies such as the PRC, India, Thailand, Viet Nam, and the Philippines. In India, rice output would drop significantly. Rice yields in India, Viet Nam, and the Philippines would decline significantly, depending on the scenarios with higher fertilizer prices. The PRC’s

rice sector appears to be less affected by the increase in fertilizer prices. The impact of higher fertilizer prices on rice exports of India, Thailand, and Viet Nam is quite different. Our estimates reveal that India will reduce its exports under all three price increase scenarios. However, Thailand and Viet Nam will continue to be key rice exporters during 2022–2025. Finally, farm-gate prices would increase in India, the PRC, Thailand, and the Philippines. For consumers in Thailand and the Philippines, the increase in retail rice prices could be higher than for consumers in the PRC, India, and Viet Nam.

Regarding policy implications, this study underscores the importance of governments and organizations in rice farming in Asian economies. For example, in times of crisis or disaster, governments could strengthen existing domestic support for rice production, promote crop diversification, and reduce dependence on imports as much as possible. Regarding domestic support for rice production, the results underscore the importance of continuing to invest in and implement policies aimed at making rice production more price-sensitive, such as the continued use of technology for higher productivity and strengthening farmer organizations. Farmer organizations can improve the welfare of rice farmers by increasing access to markets, information, and production. Finally, governments should promote improved agronomic and sustainable production systems that rely on reduced chemical use. Finally, in the long term, policymakers could explore the possibility of expanding cultivated areas and/or developing new technologies to avoid the consequences of disasters and wars in the future, for example, by increasing rice areas in Latin American countries (Mishra et al. 2022). Other policy actions include supporting staples like millets (small-grained, annual, warm-weather cereals and staple crops of the semiarid tropics). To that end, the United Nations, at the behest of the

Government of India, declared 2023 the International Year Millets (IYM) to increase awareness, consumption, and production.

This study provides a big picture of the consequences of the Russian invasion of Ukraine. However, to fully understand the impact of the invasion, it is necessary to assess the impact at the country or farm level through household surveys. Future studies could also include climate risks, war, and disputes that affect production and resource allocation in rice production and other key commodities such as wheat, maize, and barley.

Appendix Table: Change in Rice Area, Yield, Consumption, and Net Trade, IGRM Model, 2022–2026

		2022	2023	2024	2025	2026
World						
Area (ha)	**Baseline**	**160,117.62**	**160,128.44**	**159,754.51**	**160,439.81**	**160,775.32**
	30% increase	0.00%	0.32%	0.28%	0.29%	0.30%
	50% increase	0.00%	0.49%	0.42%	0.43%	0.45%
	100% increase	0.00%	0.80%	0.68%	0.70%	0.73%
Yield (MT/ha)	**Baseline**	**4.65**	**4.67**	**4.69**	**4.70**	**4.72**
	30% increase	-0.45%	-0.55%	-0.53%	-0.54%	-0.09%
	50% increase	-0.68%	-0.82%	-0.80%	-0.82%	-0.13%
	100% increase	-1.12%	-1.35%	-1.30%	-1.33%	-0.22%
Consumption (1,000 MT)	**Baseline**	**507,680.24**	**511,984.65**	**513,497.16**	**516,118.67**	**518,993.62**
	30% increase	-0.31%	-0.26%	-0.26%	-0.27%	0.06%
	50% increase	-0.47%	-0.39%	-0.39%	-0.40%	0.09%
	100% increase	-0.78%	-0.64%	-0.64%	-0.66%	0.15%
Net Trade (1,000 MT)	**Baseline**	**37,048.23**	**38,211.65**	**38,615.17**	**38,484.55**	**38,476.81**
	30% increase	-1.66%	-2.39%	-2.74%	-2.82%	-1.17%
	50% increase	-2.54%	-3.63%	-4.15%	-4.27%	-1.77%
	100% increase	-4.29%	-6.02%	-6.85%	-7.03%	-2.89%
Asia		**2022**	**2023**	**2024**	**2025**	**2026**
Area (ha)	**Baseline**	**137,888.14**	**138,147.97**	**137,947.02**	**138,490.55**	**138,774.45**
	30% increase	0.00%	0.28%	0.24%	0.24%	0.26%
	50% increase	0.00%	0.42%	0.35%	0.37%	0.38%
	100% increase	0.00%	0.69%	0.58%	0.60%	0.63%
Yield (MT/ha)	**Baseline**	**4.81**	**4.82**	**4.84**	**4.85**	**4.86**
	30% increase	-0.45%	-0.57%	-0.58%	-0.59%	-0.13%
	50% increase	-0.68%	-0. 86%	-0.87%	-0.88%	-0.20%
	100% increase	-1.10%	-1.39%	-1.39%	-1.42%	-0.32%
Consumption (1,000 MT)	**Baseline**	**425,863.76**	**428,604.69**	**429,605.37**	**431,233.90**	**432,935.78**
	30% increase	-0.23%	-0.19%	-0.19%	-0.19%	0.04%
	50% increase	-0.34%	-0.28%	-0.28%	-0.29%	0.07%
	100% increase	-0.56%	-0.46%	-0.46%	-0.47%	0.11%
Exports (1,000 MT)	**Baseline**	**17,240.37**	**18,908.65**	**19,137.53**	**19,065.72**	**19,174.13**
	30% increase	-2.43%	-3.22%	-3.83%	-3.85%	-1.45%
	50% increase	-3.58%	-4.75%	-5.68%	-5.70%	-2.17%
	100% increase	-5.49%	-7.38%	-8.88%	-8.89%	-3.50%

Continued on the next page

Africa		**2022**	**2023**	**2024**	**2025**	**2026**
Area (ha)	**Baseline**	**15,174.11**	**15,037.10**	**14,946.27**	**15,017.48**	**15,068.94**
	30% increase	0.00%	0.49%	0.44%	0.46%	0.48%
	50% increase	0.00%	0.74%	0.66%	0.69%	0.73%
	100% increase	0.00%	1.23%	1.08%	1.13%	1.19%
Yield (MT/ha)	**Baseline**	**2.42**	**2.45**	**2.50**	**2.55**	**2.62**
	30% increase	-0.90%	-0.70%	-0.30%	-0.39%	0.46%
	50% increase	-1.44%	-1.13%	-0.53%	-0.66%	0.69%
	100% increase	-2.67%	-2.15%	-1.16%	-1.37%	1.09%
Consumption (1,000 MT)	**Baseline**	**41,302.19**	**42,442.06**	**43,050.68**	**43,922.55**	**44,896.11**
	30% increase	-0.79%	-0.65%	-0.66%	-0.67%	0.15%
	50% increase	-1.20%	-0.98%	-0.99%	-1.01%	0.23%
	100% increase	-1.97%	-1.60%	-1.62%	-1.65%	0.37%
Imports (1,000 MT)	**Baseline**	**17,281.86**	**18,320.50**	**18,658.95**	**18,932.29**	**19,178.40**
	30% increase	-0.82%	-1.14%	-1.65%	-1.62%	-0.71%
	50% increase	-1.13%	-1.61%	-2.39%	-2.33%	-1.06%
	100% increase	-1.42%	-2.21%	-3.47%	-3.38%	-1.70%
Americas		**2022**	**2023**	**2024**	**2025**	**2026**
Area (ha)	**Baseline**	**5,520.04**	**5,479.61**	**5,447.05**	**5,551.69**	**5,575.42**
	30% increase	0.00%	1.09%	0.91%	0.91%	0.93%
	50% increase	0.00%	1.65%	1.37%	1.37%	1.40%
	100% increase	0.00%	2.72%	2.24%	2.24%	2.29%
Yield (MT/ha)	**Baseline**	**6.38**	**6.42**	**6.47**	**6.50**	**6.54**
	30% increase	-0.03%	-0.14%	-0.12%	-0.12%	-0.09%
	50% increase	-0.05%	-0.22%	-0.19%	-0.18%	-0.14%
	100% increase	-0.08%	-0.35%	-0.31%	-0.30%	-0.23%
Consumption (1,000 MT)	**Baseline**	**24,968.13**	**25,201.05**	**25,190.88**	**25,277.76**	**25,397.95**
	30% increase	-0.55%	-0.45%	-0.46%	-0.47%	0.11%
	50% increase	-0.84%	-0.69%	-0.70%	-0.71%	0.16%
	100% increase	-1.38%	-1.12%	-1.14%	-1.16%	0.26%
Imports (1,000 MT)	**Baseline**	**867.69**	**1,286.63**	**1,131.70**	**776.84**	**614.60**
	30% increase	-23.20%	-23.17%	-27.21%	-40.07%	-17.01%
	50% increase	-35.15%	-35.00%	-41.02%	-60.34%	-25.60%
	100% increase	-57.92%	-57.36%	-66.97%	-98.36%	-41.63%

ha = hectare, IRRI = International Rice Research Institute, IGRM = IRRI Global Rice Model, MT = metric ton.
Note: 30%, 50%, and 100% increase in fertilizer prices.
Source: IRRI Global Rice Model simulations, July 10, 2023.

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The Russian Invasion of Ukraine, Fertilizer Prices, and Food Security

Evidence from Rice-Producing Economies in Asia

Rice is a valuable crop for more than four billion people worldwide. Asia is the world's leading rice producer. Rice cultivation depends largely on fertilizer use. The Russian invasion of Ukraine has led to a shortage of fertilizers and increased prices. The major rice-producing economies could therefore face a decline in output and higher rice prices. This study assesses the impact of higher fertilizer prices on rice production, consumption, trade and prices, and discusses the implications for major rice-producing economies in Asia.

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