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The future of diets and hunger in South East Asia under climate change and alternative investment scenarios

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Technical report based on IMPACT model results

CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)

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Abstract

Despite enjoying strong economic growth in the last few decades, Southeast Asia still faces challenges to food security, with high levels of stunting across countries in the region. Agricultural production is likely to see large impacts from climate change, including sea-level rise, droughts, and floods. The climate threat compounds pressures onto the food systems coming from the rapid demographic and income trends. Population across the region may grow by 25% between 2010 and 2050, and average income per capita may see a fourfold increase in the same period. In absence of climate impacts, growth in agricultural productivity is estimated to bring about an increase in production of over 50% between 2020 and 2050, with positive effects on the availability of kilocalories, and increased consumption of animal products. However, the projected climate impacts are expected to hit most of the crops in the region, especially cereals. Per capita income in 2050 may be negatively affected compared to a scenario without climate shocks. The resulting decrease in total calories availability translates into an increase in population at risk of hunger across the region and by country. We show that enhanced investments in public international agricultural R&D have the potential to improve yields despite the long-term negative effects of climate shocks, and when combined with increased research efficiency they may even offset climate impacts on food security across the region.

Keywords

Southeast Asia, climate change, diets, food security, R&D investments

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Contents

Acronyms

AllC	all crops
CER	cereals
F&V	fruit and vegetables
OLS	oils
PUL	pulses
R&T	roots and tubers
SGC	sugars
SEA	South East Asia

Introduction

South East Asia has been enjoying strong economic growth in the recent decades. Improvements in agricultural productivity and output have supported a stronger export industry; the ensuing benefits to food availability and incomes have led to significant advances in food security. Diet composition has been shifting, from one made mostly of staple grains to one richer in vegetables and fruits, as well as livestock products and processed foods. Between 1990 and 2014 southeast Asia has seen the largest declines in undernourishment compared to any other region (OECD 2017).

Despite the fall in the number of undernourished, the region still faces major challenges to food security. Data reported in 2017 shows that in some countries the share of the population living on less than 2 USD per day was over 40%, and 60 million people remained undernourished. Regional levels of stunting are still high across countries in the region and there are concerns that some of food security numbers may reflect improved conditions that are transitory rather than permanent (OECD 2017). Resilience is low for some population, and their risk of undernourishment increases significantly in case of such temporary shocks as changes in income or increasing prices of food items.

Inserted in this context, climate change represents a significant risk to the future food security of the region. The geographical location of Southeast Asia countries, and the large coastal areas and river deltas expose the agricultural sector across these countries to large climate impacts. Production is impacted by sea-level rise, extreme weather events, droughts, floods and soil erosion. The climate threat compounds pressures onto the food systems coming from the rapid demographic and income changes (Fauziyyah and Duasa 2021).

This study uses data from IFPRI's International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) to explore changing demographics, income, and diets in the context of climate change in South East Asia. The report focuses on climate change effects on agricultural productivity and on diets and explores the potential of heightened investments in R&D as adaptation measures across the agriculture sector.

Methodology

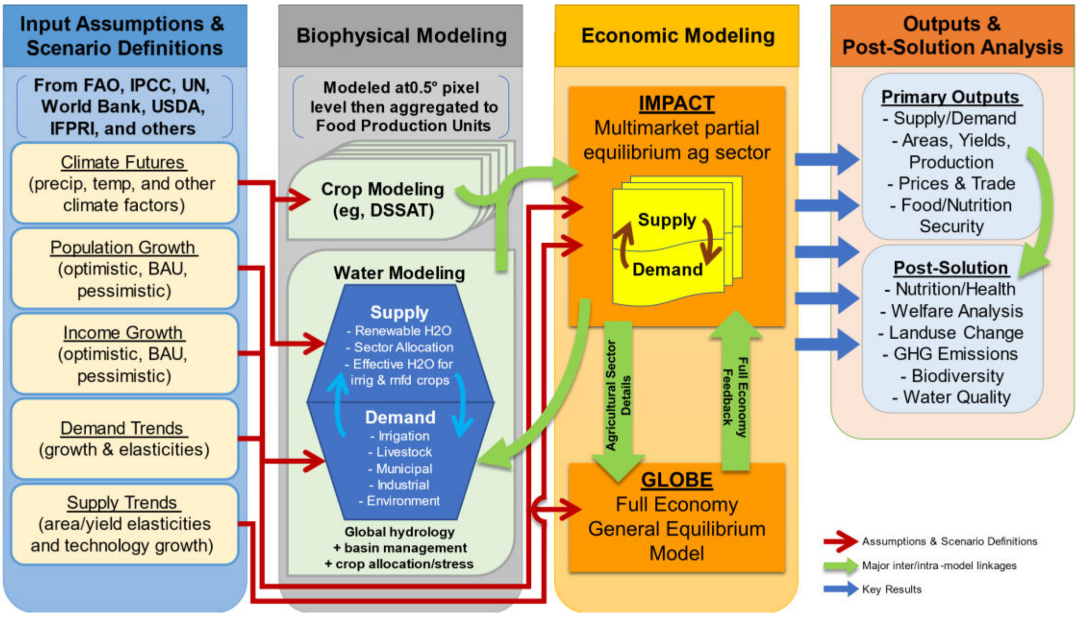
The IMPACT system of models

IMPACT is a partial-equilibrium economic model that simulates national and global markets of agricultural production, demand, and trade associated with 62 agricultural commodities across 159 countries (Robinson et al. 2015).

IMPACT combines projection data for population and income with yield data simulated through crop models, estimates of water availability from water models, and estimates of changes in temperature and precipitation from climate models. Therefore, its outputs reflect changes that come from the interaction of both biophysical and socioeconomic factors.

Simulated changes in yields through the DSSAT crop modeling suite provide IMPACT with an estimate of the effects of temperature-changes on productivity; effects on water availability are captured through linked water models (Figure 1). The IMPACT model receives inputs from three water models (global hydrologic model, water basin management model, and water allocation and stress model), which can reflect the impact of climate change or policy decisions on the hydrology, or water allocation, thereby allowing to simulate changes in water availability for irrigation and their effects on agricultural production. Agricultural production is specified by models of land supply, and by allocation of land (irrigated and rainfed) to crops. Production is modelled at sub-national level, across 320 regions called "food production units" or FPUs. Additionally, it receives information on yield responses from crop simulation models (e.g., DSSAT).

Figure 1. IMPACT modeling framework



The main drivers of the baseline suite of IMPACT scenarios (i.e. BAU scenarios) are GDP, population, and intrinsic agricultural productivity growth rates (IPR). GDP growth rates and population growth are obtained from the SSP database from IIASA. The GDP and population growth rates are applied such that the IMPACT model reproduces the Shared Socioeconomic Pathways (SSP scenarios) adopted by the Intergovernmental Panel on Climate Change Fifth Assessment Report (IPCC AR5). The intrinsic yield growth rates (IPRs) are based on past trends and expert opinion about future trajectories.

For extensive details on the equations at the core of the model, and information on data inputs especially population, GDP and yield growth (IPRs), refer to the IMPACT model documentation (Robinson et al. 2015).

IMPACT has a long record of applications and it has been employed in a wide range of analyses, from assessing the potential effects of climate change on global food production and nutrition, to exploring linkages between agriculture production and food security at the national and regional levels, to interdisciplinary assessments of economic models to evaluating the global effects of biofuels production, to the assessment of economic effects of alternative mitigation policies and the global simulation of technology adoption.

IMPACT is a partial equilibrium model and therefore it does not capture the economy-wide effects of income changes and consequent changes in consumers' purchasing power. Therefore, to assess the effects of changes in the agriculture sector on the wider economy, the modeling system was improved by including macroeconomic feedbacks through coupling the IMPACT PE model with GLOBE-Energy, a CGE model (Rosegrant et al. 2017; Willenbockel et al. 2018). The coupling between IMPACT and Globe essentially translates shocks to the agriculture sector as simulated in IMPACT into corresponding GLOBE agricultural shocks, which can be compared to the calibrated GLOBE baseline scenario. The changes in income from the calibrated baseline scenario can be translated into GDP changes, and are then downscaled from GLOBE's 15 geographical regions to IMPACT's 159. These changes in GDP are then used as an additional data input into IMPACT allowing us to assess how changes in average income may affect agricultural production, demand, natural resource use (water and land), and food security. For more details on GLOBE and the GLOBE-IMPACT coupling please see the GLOBE Discussion Paper (Willenbockel et al. 2018).

IMPACT simulations — reference suite of scenarios

In this study, the reference suite of IMPACT scenarios is comprised of three simulation scenarios:

1. SSP2-NoCC
2. SSP2-Hadgem
3. SSP2-IPSL

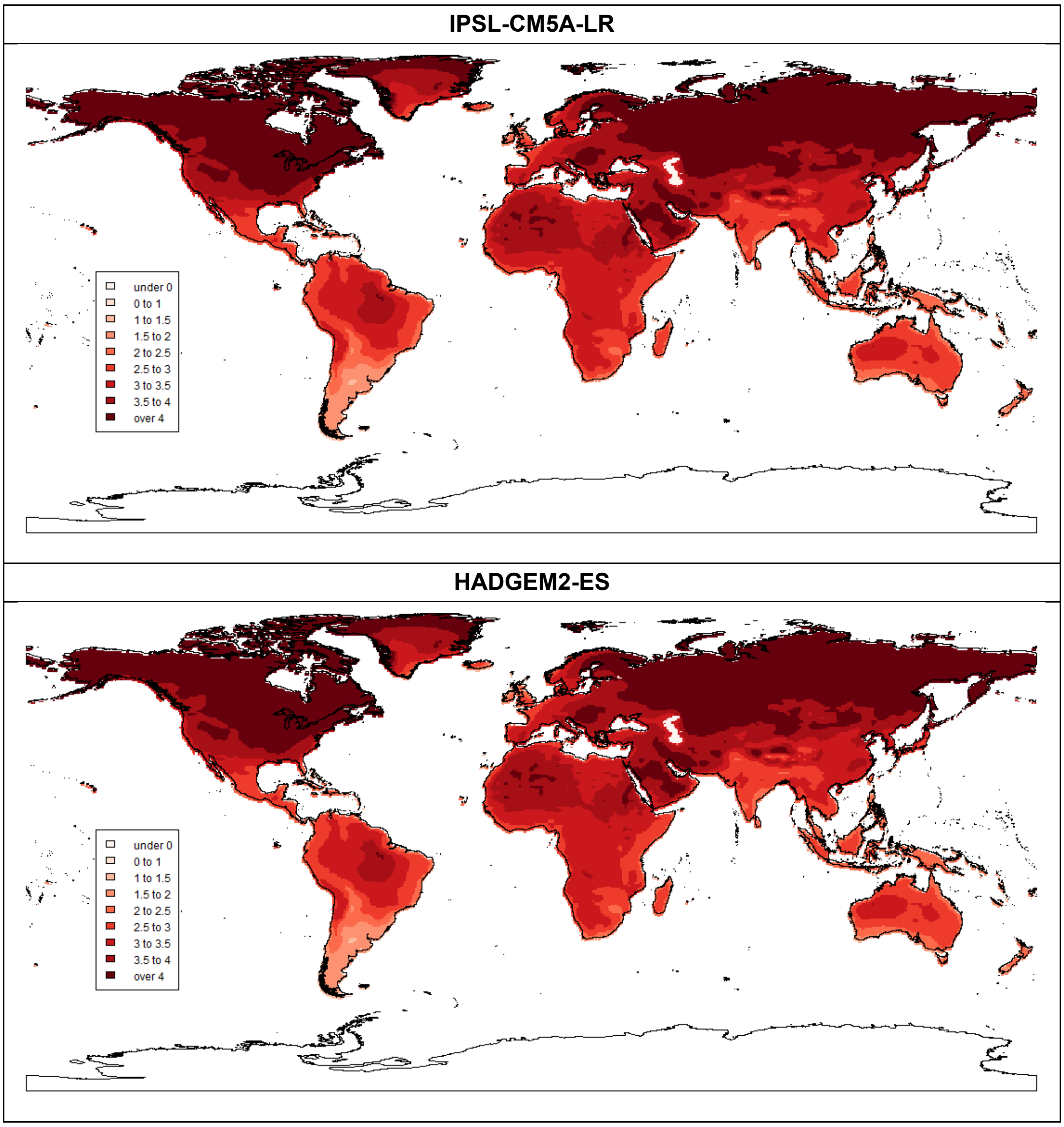
The three scenarios are based on the IPCC middle of the road GDP and population scenario (SSP2) (O'Neill et al. 2014). The first scenario represents a continuation of climate conditions around the year 2000 and maintains the middle of the road projections for population and GDP codified into SSP2 (SSP2-NoCC, the no-Climate Change scenario). To represent some of the uncertainty inherent in climate change projections we chose to use two climate change scenarios that result from running two general circulation models (Hadgem and IPSL) under a Representative Concentration Pathway (RCP) of 8.5 (Riahi et al. 2011).

The two climate models, or Earth System Models (ESMs) as defined by the Intergovernmental Panel on Climate Change 5th Assessment Report (IPCC AR5), are:

1. HADGEM2-ES (Jones et al. 2011)—the Hadley Centre's Global Environment Model, version 2 (http://www.metoffice.gov.uk/research/modelling-systems/unified-model/climate-models/hadgem2)
2. IPSL-CM5A-LR (Dufresne et al. 2013)—the Institute Pierre Simon Laplace's ESM (http://icmc.ipsl.fr/index.php/icmc-models/icmc-ipsl-cm5)

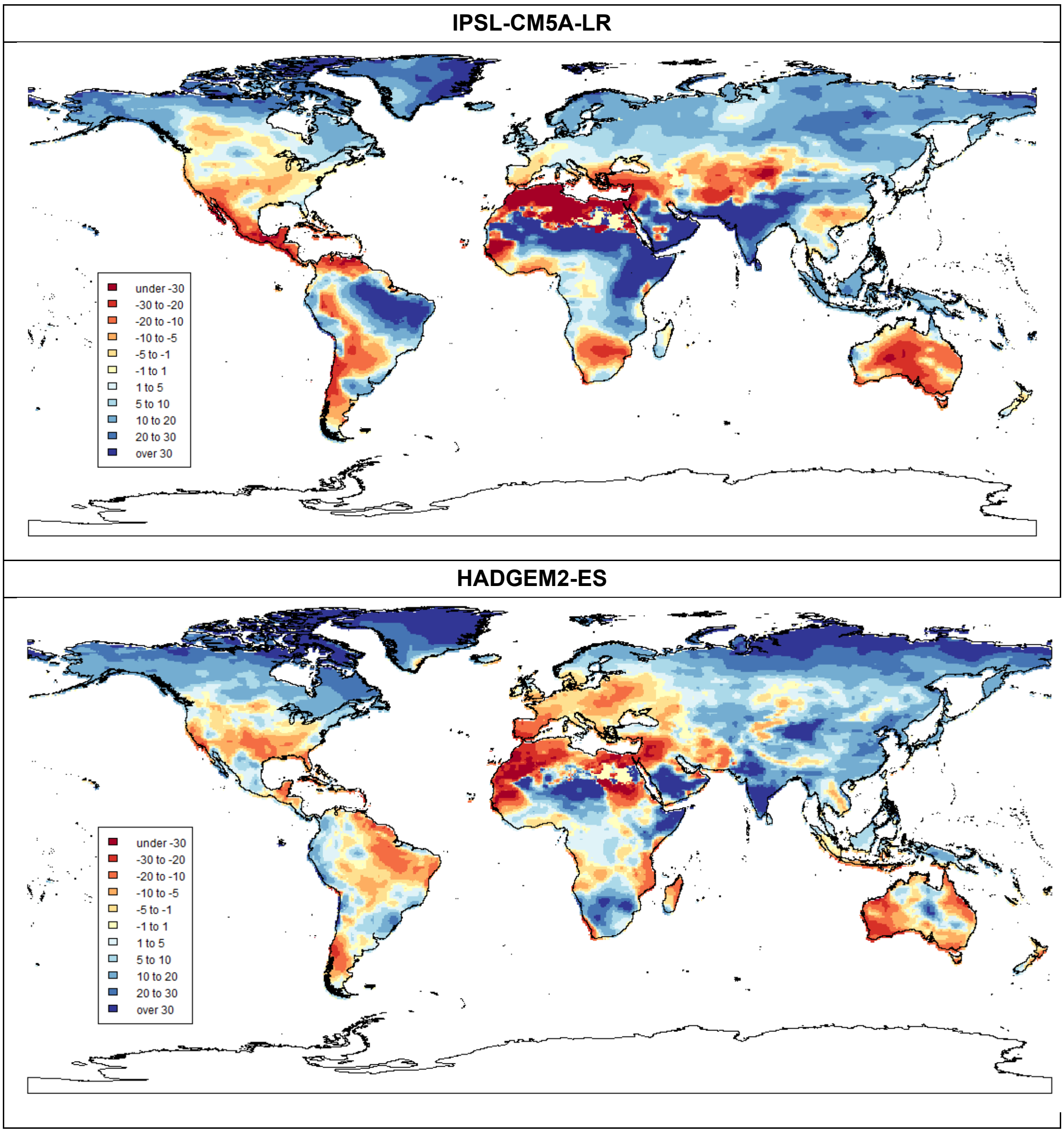
Figure 2 and Figure 3 show respectively the changes in global maximum temperature and annual precipitation estimated according to these two climate scenarios.

Figure 2. Changes in maximum temperature in 2050 compared to 2000 (°C) according to two Earth System Models using Representative Concentration Pathway 8.5



Source: extracted from (Cenacchi et al. 2016)

Figure 3. Changes in annual precipitation in 2050 compared to 2000 (millimeters) according to two Earth System Models using Representative Concentration Pathway 8.5



Source: extracted from (Cenacchi et al. 2016)

IMPACT simulations — Investment scenarios

We include two alternative policy and investment scenarios whose effects are compared against the NoCC and HGEM references mentioned in the previous section (Table 1). The NoCC pathway, which assumes a constant climate after 2005, is included to provide an envelope of potential climate change impacts that has the HGEM-8.5 at the other extreme. This framework allows to better assess the effects of the two alternative investment scenarios.

Table 1. Investments and reference scenarios

Scenario	Options	Abbreviation
Reference	No climate change under SSP2 SSP2 with RCP8.5-HGEM	SSP2- NoCC HGEM
Agricultural R&D	High investments in int'l ag research, implemented under RCP8.5 HiYld with increased research efficiency, implemented under RCP8.5	HiYld HiREFF

Both investment scenarios were developed in collaboration with all 15 CGIAR Centers, which quantified the potential yield gains for their respective mandate commodities in developing countries with increased R&D investment. The HiYld scenario is simulating yield gains accruing over time due to increasing investments in public international agricultural R&D. The HiREFF scenario is still focusing on R&D, but it assumes higher investment levels in combination with increased research efficiency, for example through improved dissemination of new technologies. As a result, the yield impact of R&D investments is 30 percent higher, and the maximum improvement is achieved more rapidly than in the HiYld scenario. More details on the specifications of the scenarios can be found in Rosegrant et al. (2017), and Mason-D'Croz et al. (2019) (Rosegrant et al. 2017; Mason-D'Croz et al. 2019).

The big drivers: population and income futures for South East Asia

Results from the reference scenario without climate change effects (SSP2-NoCC), allow us to focus on the model assumptions regarding shifts in population and GDP, and observe the projected effects of these drivers on the average diet across the SEA region.

Projections under the SSP2-NoCC scenario show an increase in population of 25% for the region between 2010 and 2050. At the country level the largest percentage increases are projected for Timor (+83%) and the Philippines (+60%), but the largest population will remain in Indonesia (287.5 million), followed by the Philippines (149 million) and Vietnam (104.4 million) (Table 2). Large changes are especially evident for GDP, with a four-fold increase in average regional per capita income in 2050 compared to 2010. Some countries like Cambodia, Laos, and Indonesia may see close to a six-fold increase in income (Table 3).

Table 2. Population projections (millions). Years 2030 and 2050

Region	2030	2050
Cambodia	16.7	17.6
Indonesia	277.4	287.5
Laos	7.8	8.6
Malaysia	37.2	43.3
Myanmar	51.1	48.6
Philippines	125.4	149
Thailand	75	73.6
Timor L'Este	1.7	2.1
Vietnam	102	104.4
Other Southeast Asia	6.6	7.2
South-East Asia	700.7	741.8

Source: SSP population from the SSP database (IIASA 2013)

Table 3. Per capita income (2010 = 1.0)

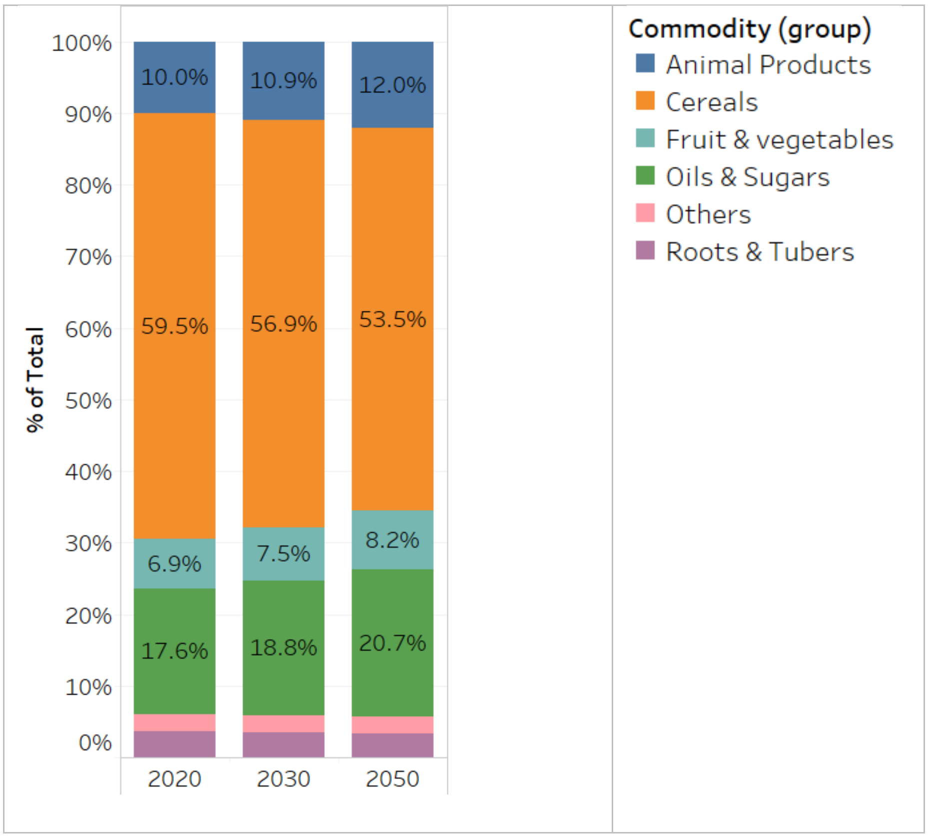
Region	2050
Cambodia	5.9
Indonesia	5.7
Laos	6.0
Malaysia	2.9
Myanmar	4.3
Philippines	3.4
Thailand	4.2
Timor L'Este	3.7
Vietnam	5.4
Other Southeast Asia	1.7
South-East Asia	4.3

Source: GDP per capita from the SSP database (IIASA 2013)

Overall agriculture production is estimated to grow by 56% between 2020 and 2050 under the SSP2-NoCC reference scenario. This expansion mainly originates from productivity growth (+34% across the agriculture sector), rather than expansion of cropland (+14%). As production and incomes grow, total kilocalories per capita per day are estimated to grow

14% between 2020 and 2050, from 2,551 Kcal to 2,905. Consistent with economic theory1, IMPACT results show that as calories grow, the share of consumption of staples like cereals decreases and diets become richer in animal products and higher value and processed foods, represented by oils and sugars in Figure 3. The increases in both production and income contribute to reducing the population at risk of hunger in the region by over 26 million people by 2050, or a 42% reduction compared to 2020 (Table 4).

Figure 4. Evolution of diet in the South East Asia region. Changes in composition as a share of the total Kilocalories per person per day



Source: The authors based on IMPACT version 3.

[1] IMPACT projections of food demand follow empirical patterns. One of these is Bennet's law. Bennett's Law states that as income increases, the share of expenditure on staples (cereals, and starchy roots and tubers) declines, such that the share of total calories coming from staples declines with diets diversifying and becoming richer.

Table 4. Change in population at risk of hunger between 2020 and 2050

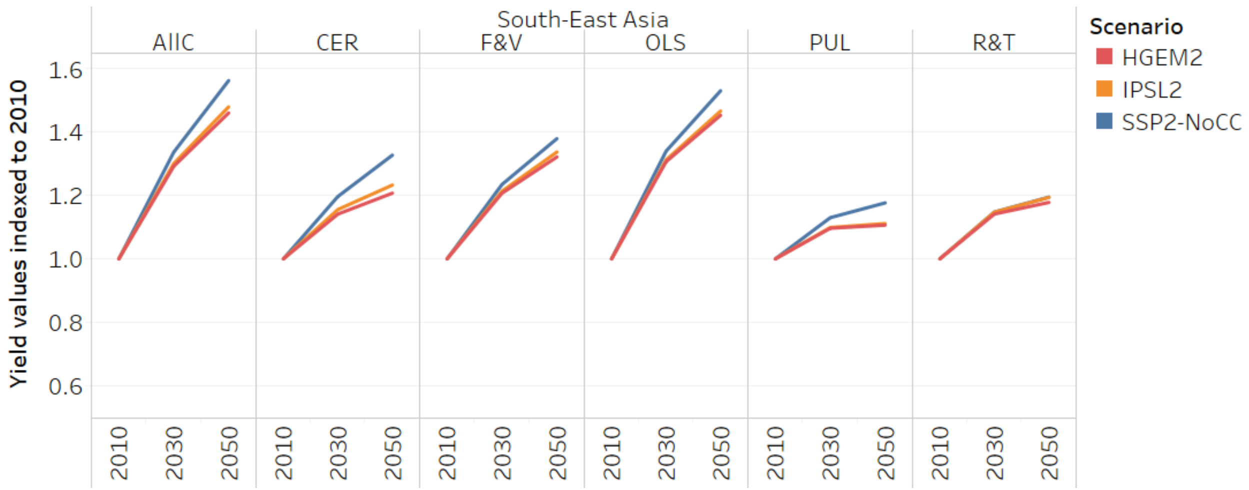
	Difference from 2020 (Million)	Percent change from 2020
South East Asia	-26.6	-42.3%
Indonesia	-13.8	-65.8%
Philippines	-1.6	-12.5%
Vietnam	-4.2	-36.5%
Myanmar	-3.6	-42.5%
Thailand	-2.9	-61.3%
Cambodia	-0.6	-29.4%
Laos	-0.1	-8.5%
Malaysia	0.2	31.3%
Other Southeast Asia	0.1	28.3%
Timor L'Este	-0.1	-33.5%

Source: The authors based on IMPACT version 3.

Impact of climate change on agricultural production, diets, and food security

Climate change is projected to impact all the main crop groups in South East Asia (Figure 5). Cereals may be the most affected, with a decrease in average yields of between 7 and 9% compared to the NoCC scenario in 2050 (respectively for the IPSL and HGEM scenarios). Lower production will follow across all groups especially cereals and pulses, but with lower or no impact on roots and tubers (Table 5). Knock-on effects can also be observed on the output of animal products, as crops used for feed are impacted by climate.

Figure 5. South East Asia - aggregated yields trends for selected crop groups



Source: IMPACT simulations

Notes: AllC= all crops; CER= cereals; F&V= fruit and vegetables; OLS= oils; PUL= pulses; R&T= roots and tubers

Table 5. Change in production for major commodity groups in 2050 compared to NoCC

Commodity (group)	HGEM2	IPSL2
Animal Products	-0.8%	-0.7%
Cereals	-7.7%	-5.8%
Fruit & vegetables	-4.0%	-3.3%
Oils & Sugars	-4.4%	-3.7%
Others (including pulses)	-5.7%	-4.4%
Roots & Tubers	-0.8%	0.4%

Source: IMPACT simulations

Rice, maize, oil palm, cassava, and sugarcane are major crops in SEA, both in terms of production and harvested area (FAO 2020a), and they represent 63% of the daily per capita Kcalories intake across the region, with most of this share coming from rice (45%) (FAO 2020b). As an aggregate across the region, maize and sugarcane yields are projected to see the most declines from changes in temperature and precipitation, but all of these major crops appear to be affected, with the possible exception of cassava, depending on the climate model (Table 6). Production of rice will be especially affected in Cambodia and Thailand, both of which will also see maize and sugarcane production substantially lowered (Figure 6). Cassava production may generally see some improvements under climate change, but in Cambodia and Thailand the results are in different directions depending on the climate scenario (HGEM or IPSL).

Table 6. Percent change in yields for major crops in 2050 compared to noCC scenario

Commodity	HGEM2	IPSL2
CER-Maize	-23.4%	-21.5%
SGC-Sugarcane	-16.7%	-13.7%
CER- All cereals	-9.1%	-7.1%
All Crops	-6.5%	-5.3%
CER-Rice	-5.2%	-3.2%
OLS-Palm Fruit	-5.0%	-4.0%
R&T-Cassava	-0.3%	1.29%

Source: IMPACT simulations

Figure 6. Percent change in production for major crops, across countries. 2050 compared to NoCC

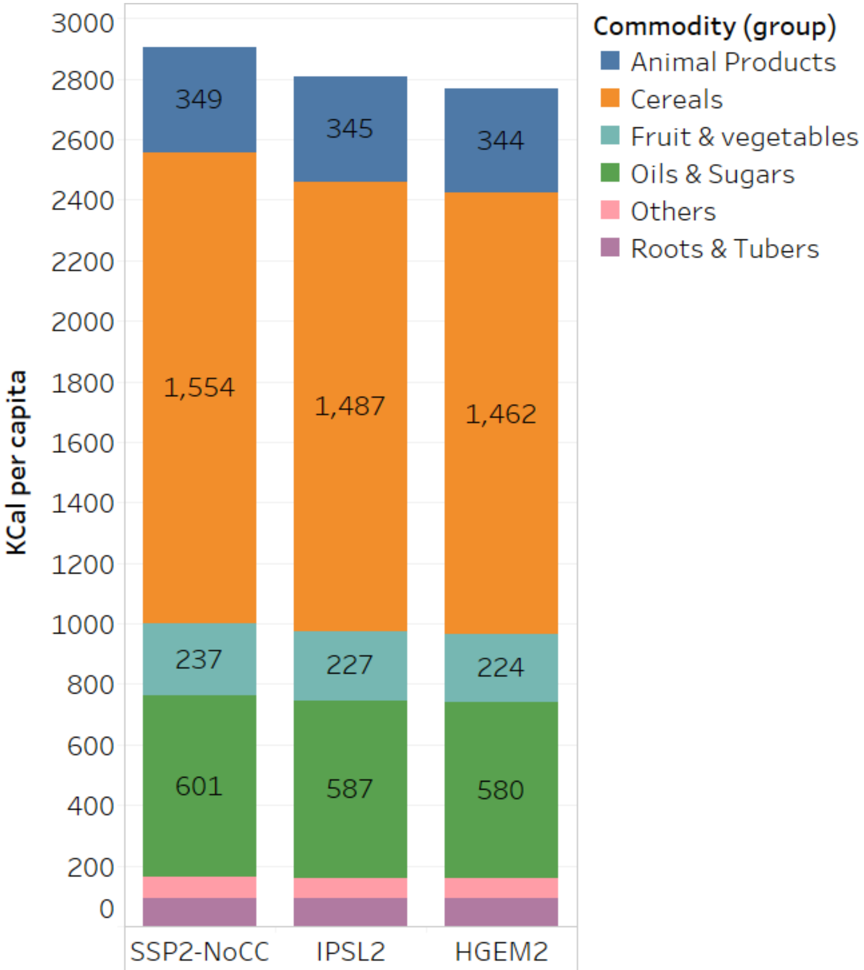
	CER-Maize		CER-Rice		OLS-Palm Fruit		SGC-Sugarcane		R&T-Cassava	
Region	HGEM2	IPSL2	HGEM2	IPSL2	HGEM2	IPSL2	HGEM2	IPSL2	HGEM2	IPSL2
Cambodia	-49.6%	-38.9%	-13.9%	-8.5%			-15.0%	-11.2%	-3.8%	0.8%
Indonesia	-19.8%	-12.5%	3.4%	7.1%	1.6%	2.2%	-2.2%	-4.1%	2.7%	6.4%
Laos	-19.2%	-23.0%	-8.2%	-5.6%			-2.6%	-6.8%	0.4%	1.5%
Malaysia	-23.0%	-16.9%	-7.0%	-6.6%	-4.6%	-4.3%	-6.3%	-8.4%	1.6%	4.6%
Myanmar	-21.5%	-23.2%	0.5%	-2.2%			-4.8%	-7.2%	1.1%	0.2%
Other Southeast Asia			-19.6%	-11.2%					-3.5%	-2.1%
Philippines	-14.3%	-18.7%	-1.8%	-3.0%	-4.6%	-4.6%	-6.4%	-6.5%	2.0%	4.5%
Thailand	-47.9%	-40.2%	-13.9%	-7.8%	-10.8%	-5.6%	-19.6%	-15.4%	0.6%	-1.1%
Timor L'Este	11.1%	2.2%	-18.8%	3.3%					0.5%	4.9%
Vietnam	-13.7%	-22.3%	-12.0%	-8.7%			-7.4%	-8.1%	-4.3%	-4.7%

% Difference in..
-49.6% 11.1%

Source: IMPACT simulations

Using the link to the GLOBE model, we can simulate the changes in income which can be expected when the impacts of climate change on the agricultural sector are transmitted to the wider economy. The estimates are for a 2 to 3% decrease in per capita income in 2050 compared to a scenario without climate shocks. These GDP numbers are used as exogenous input data into IMPACT and affect the projections for agricultural demand, production and ultimately food security. Taking into consideration both changes in supply and income, Figure 7 shows the diet composition under NoCC and under climate change in 2050, illustrating the decrease in total calories availability and the change by crop group. Table 7 shows how this decreasing availability translates into an increase in population at risk of hunger across the region and by country.

Figure 7. Diet composition by commodity group in 2050 (raw Kilocalories), NoCC compared to climate change scenarios



Source: IMPACT simulations

Table 7. Increase in population at risk of hunger in the region and by country. Climate change scenarios compared to NoCC in 2050 (Million people and percentage change)

Region	HGEM2		IPSL2	
	Millions	% change	Millions	% change
South-East Asia	12.0	33%	9.3	26%
Philippines	2.3	21%	1.6	15%
Indonesia	4.2	58%	3.8	53%
Vietnam	2.7	38%	1.9	26%
Myanmar	1.1	23%	0.8	17%
Thailand	0.5	29%	0.4	19%
Cambodia	0.6	36%	0.4	27%
Laos	0.4	31%	0.3	24%
Malaysia	0	0%	0	0%
Other Southeast Asia	0.1	29%	0.1	19%
Timor L'Este	0	28%	0	20%

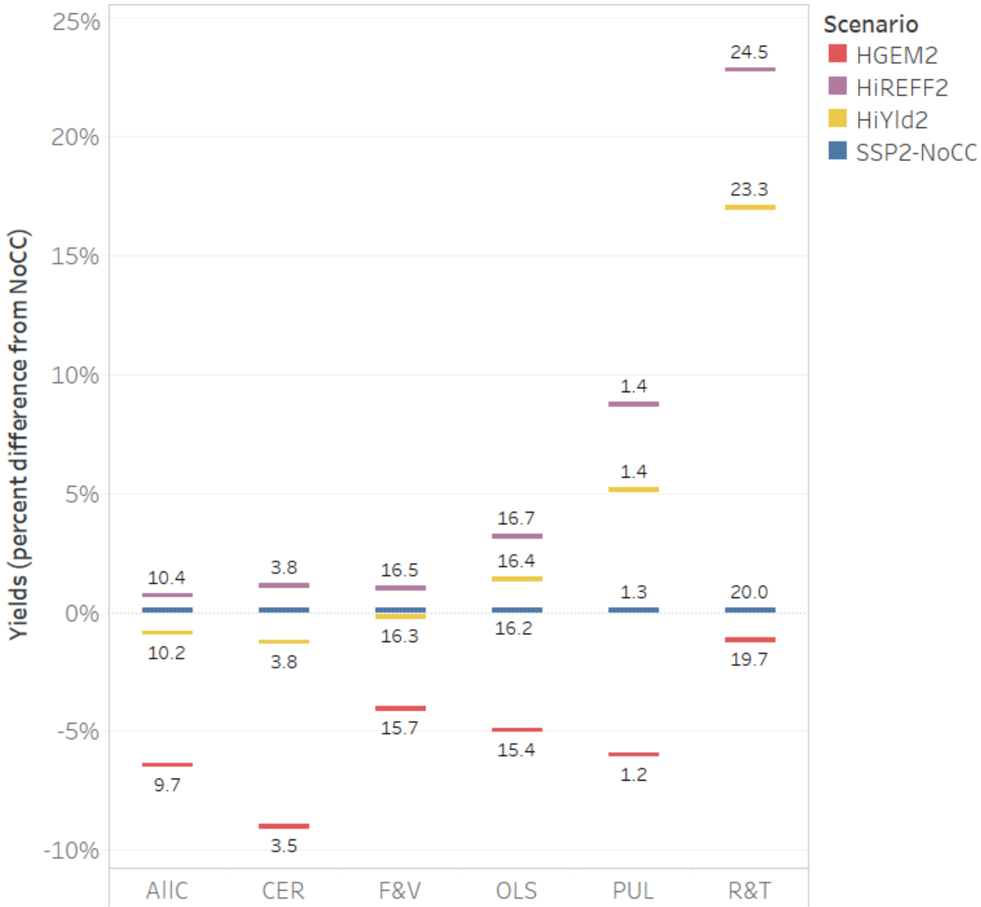
Source: IMPACT simulations

Adaptation to climate change: investments scenarios

As observed from the results above, climate change is projected to have different magnitude effects on the yields of key crop groups, with potential negative consequences on production, food availability, and the overall nutritional and food security status of the population across southeast Asia.

Enhanced investments in R&D show the potential to improve yields despite the long-term negative effects of climate shocks (Figure 8). In fact, R&D improvements with increased efficiency (HiREFF2) may more than offset the impacts of CC for all crop groups. In the case of roots and tubers, which is already marginally impacted by climate shocks, funding additional R&D and improving efficiency may bring about an increase in yields of over 20% compared to NoCC. A more conservative approach only focusing on investing in R&D (HiYld2) can still offset climate impacts for most groups, except for Cereals and Fruit & vegetables.

Figure 8. Total yields for all crops (AllC) and for crop groups. Percent difference from the NoCC scenario in 2050



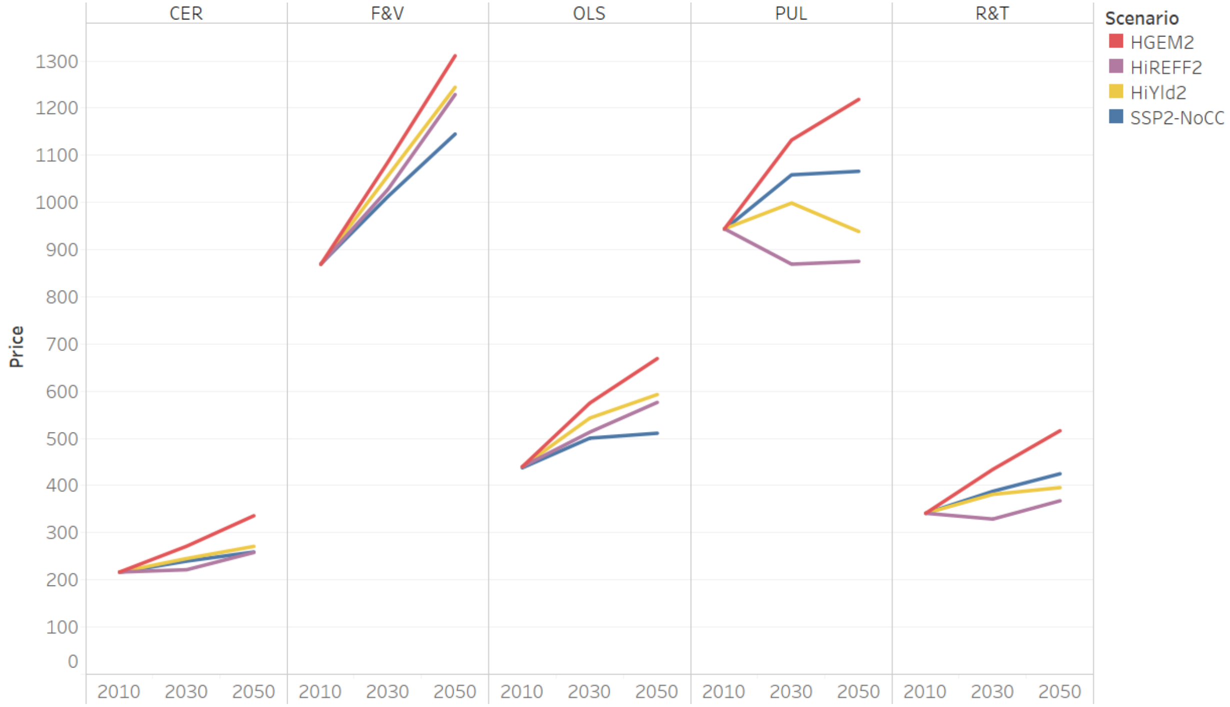
Source: IMPACT simulations

Notes: AllC= all crops; CER= cereals, F&V= fruit and vegetables; OLS= oils; PUL= pulses; R&T= roots and tubers

In the reference scenarios without climate change, prices for all commodities increase to 2050 following the increase in population and income (Figure 9); for some items price growth slows by 2050 as population (and thus demand) begins to decline in some regions. Climate shocks dampen global production, and in combination with growing demand they cause a substantial increase in world prices (Hgem in Figure 9). Increased investment in agricultural R&D (HiYld) and accelerated adoption of new technologies (HiREFF) generate large increases in production and consequent reductions in prices compared to Hgem; in some cases, they offset the changes induced by climate change, and even bring down prices compared to the business-as-usual case without climate change (see Pulses and R&T in

Figure 9). In general, the investment scenario with the largest impacts on production are also those with the largest impacts in terms of price reduction on the prices.

Figure 9. Price of aggregated crop groups in 2010, 2030 and 2050 across the two reference scenarios and the two investment scenarios



Source: IMPACT simulations

Notes: CER= cereals, F&V= fruit and vegetables; OLS= oils; PUL= pulses; R&T= roots and tubers

By 2050, climate shocks left unchallenged may bring about a 5% reduction in total kcalories per person per day compared to NoCC. The more conservative R&D approach (HiYld), implemented under climate change conditions, may almost offset the climate impacts on the diet of an average citizen of south east Asia. Broader investments (HIREFF2) may further increase total kcalories by about half a percentage point compared to NoCC (Figure 10). The result of such an increase would be a total recovery, from potentially 12 more million people at risk of hunger due to climate change across the entire region, to 1 million fewer people at risk, compared to NoCC (Table 8), therefore more than offsetting the impacts of climate on food security. Notably, investments in R&D coupled with increased research efficiency would offset climate shocks not only as an average across the region, but for each single country, with the sole exception of Thailand.

Figure 10. Diet composition by commodity group in 2050 (raw Kilocalories), NoCC compared to climate change and investment scenarios

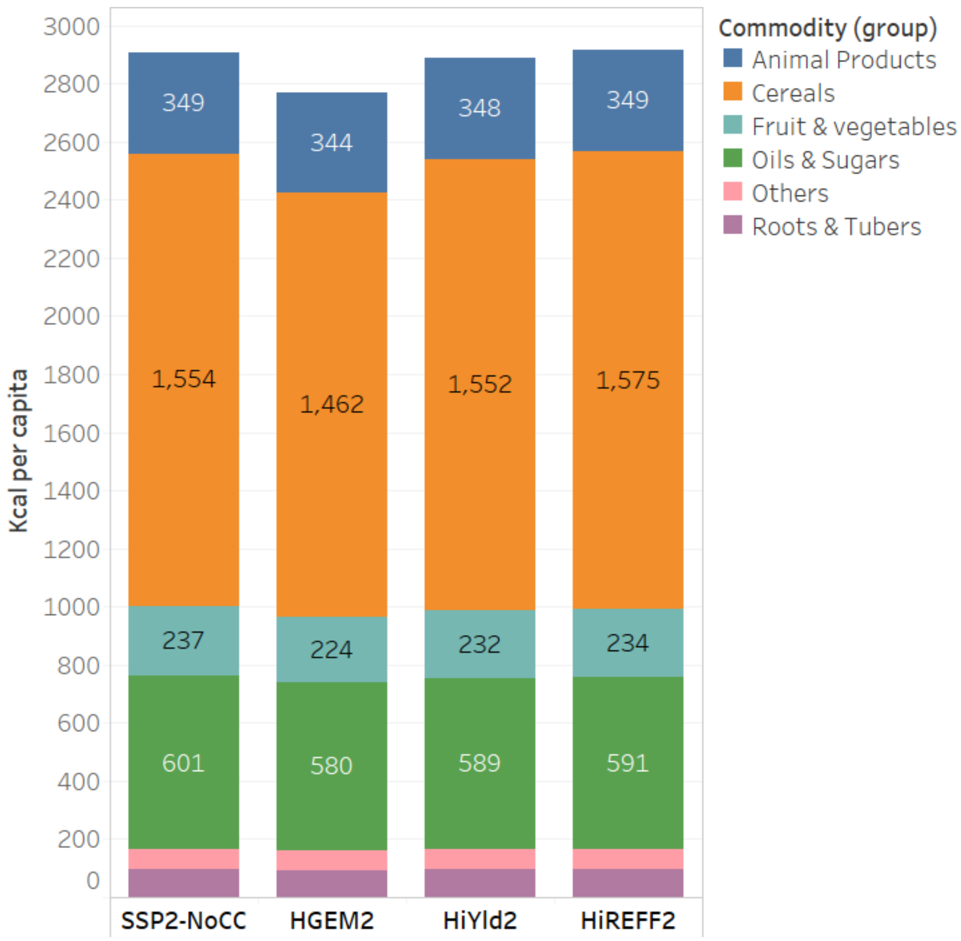


Table 8. Change in population at risk of hunger in the region and by country. HGEM Climate change scenario and Investment scenarios compared to NoCC in 2050 (Million people)

Region	HGEM2	HiYld2	HiREFF2
SEA	12.0	0.6	-1.0
Indonesia	4.2	-0.0	-0.0
Vietnam	2.7	0.3	-0.2
Philippines	2.3	0.1	-0.4
Myanmar	1.1	0.0	-0.2
Cambodia	0.6	0.0	-0.1
Thailand	0.5	0.1	0.1
Laos	0.4	0.0	-0.1
Other Southeast Asia	0.1	-0.0	-0.0
Timor L'Este	0.0	0.0	-0.0
Malaysia	-0.0	-0.0	-0.0

Conclusions

By 2050 South-east Asia may see a decrease in the population at risk of hunger of over 26 million (-46%) compared to 2020, even considering a projected increase in population of close to 88 million. The improvement in food security would result from the rise in income per capita coupled with an estimated 50% potential increase in agriculture production.

This is the picture the region may have enjoyed in the absence of climate change. But impacts of climate change on the productive potential of the region are expected to lower yields of all crops by an aggregate 6% relative to the no-climate-change case in 2050, including impacts on all the most important staple crops (with perhaps the exception of cassava). Maize, rice, and sugarcane may be especially affected, thus diminishing some of the key sources of dietary calories for the region. Impacts on the agricultural sector will also transmit through the whole economy, thus potentially reducing the growth in per capita income across South-East Asia. At the same time, climate change shocks across the global food systems are projected to also increase the price of some of these staple crops. Therefore, the combination of lower purchasing power, slower agricultural production and higher prices is expected to cut almost by half the food security progress in the region compared to the NoCC scenario2. Impacts of extreme events (not considered in this analysis) are likely to slow progress even further.

The scale of the climate impacts highlights the importance of policies and investments to help producers adapt to climate change, and support measures to help vulnerable consumers. Increasing investments in public international agricultural R&D shows significant promise for the region. In particular, investments that also promote greater research efficiency, appear to offset climate change impacts on diets not just as an average across the region, but for each single country, with perhaps the exception of Thailand.

It follows that investments in agricultural R&D may be particularly effective in achieving multiple SDG targets because, by definition, they focus on identifying ways to use resources

[2] BY 2050 under noCC the region may see 26 million fewer people at risk of hunger. With climate change impacts 12 million people would need to be subtracted.

more efficiently. Investment in agricultural R&D faces a trade-off because time lags between initial investments and eventual adoption of new technologies can be significant, but the pace of innovation is itself accelerating, and can be complemented by investment in extension and advisory services to enhance the speed and extent of dissemination.

However, challenges as pervasive as those of climate change require interventions at multiple levels and scales. Key adaptation options such as climate services, risk management mechanisms, and digital technologies will require the full support of governments and extension services, and collaboration with the private sector.

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