AGRICULTURAL GROWTH AND CLIMATE RESILIENCE IN THE PHILIPPINES:

Subnational Impacts of Selected Investment Strategies and Policies

Timothy S. Thomas, Angga Pradesha and Nicostrato Perez

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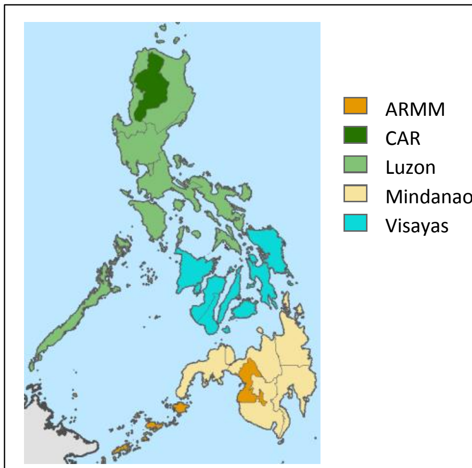
Being a nation of many islands spanning a considerable range of latitudes, the Philippines is noted for its climatic and ecological diversity. Significant climate differences exist, not least due to the country's extensive coastal exposure and mountainous areas. For these reasons, the impacts of climate change on agriculture are likely to differ significantly across the country. Apart from the more well-known phenomenon of cyclones, which have increased in frequency and strength in recent years, what in fact is the impact of climate change on agriculture in the Philippines? Will it be wholly negative, or might some parts of the country actually be positively affected? And if the impact on agriculture will be positive in some areas and negative in others, could identifying these differences ahead of time help people to adapt in locations projected to be negatively affected? This policy note summarizes the results of biophysical and economic modeling analyses presented in the forthcoming International Food Policy Research Institute (IFPRI) and National Economic and Development Authority (NEDA) manuscript, The Future of Philippine Agriculture: Scenarios, Policies, and Investments under Climate Change, edited by Mark W. Rosegrant, Arsenio Balisacan, and Mercedita Sombilla.

CURRENT DIFFERENCES AMONG REGIONS

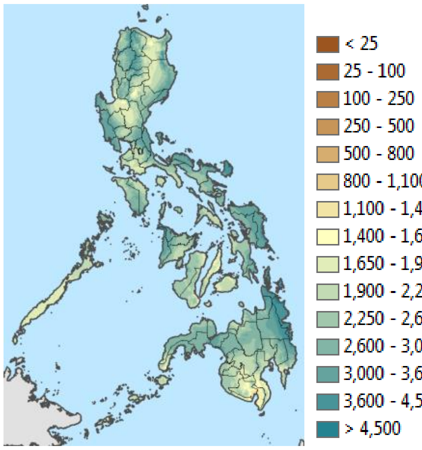
The aggregated regions used in this policy note are presented in Figure 1. The Cordillera Administrative Region (CAR) and Autonomous Region in Muslim Mindanao (ARMM) are treated separately but are also included in the larger groupings in which they fall (Luzon and Mindanao, respectively). The wettest parts of the country appear to be in eastern Mindanao, although high rainfall is also found in eastern Visayas and in the mountains where CAR is located (Figure 2; Table 1). The main agricultural areas of Luzon appear to be among the driest in the nation, but they still have considerable rainfall levels of 1,400 to 1,900 millimeters per year. While it is not universally true that the very driest portions of the other major groups (Visayas and Mindanao) are the most densely cultivated, as a general rule they have relatively low rainfall levels by Philippine standards (which would be considered high in many other countries) and are the preferred areas for agriculture. The rainfall map for the wettest three consecutive months of the year—indicating the approximate rainfall in a growing season—are shown in Figure 3 and are aggregated in Table 2. The general distribution of rainfall in the wettest three months (calculated at each pixel, so the actual three-month period varies) follows a similar geographic distribution to that of yearly rainfall.

Figure 1. Regional groupings underlying the analysis



Source: Constructed by authors based on GADM (2010)

Figure 2. Yearly rainfall, 1950–2000



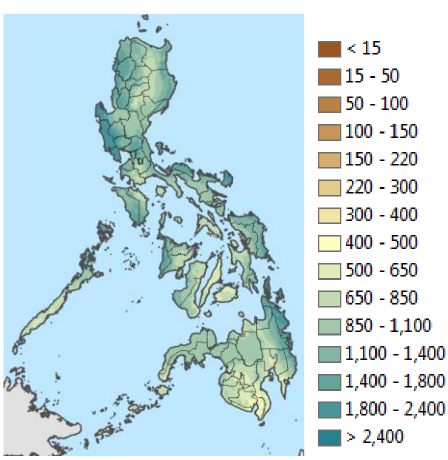
Source: Constructed by authors based on WorldClim version 1.4 (Hijmans et al. 2005).

Table 1. Yearly rainfall by region, 1950–2000

Region	Percentile				
	5th	25th	50th	75th	95th
1. Luzon	1,751	2,060	2,465	2,897	3,367
1.1 Luzon	1,737	2,039	2,432	2,862	3,320
1.2 CAR	1,855	2,246	2,698	3,059	3,545
2. Visayas	1,707	2,133	2,431	2,975	3,466
3. Mindanao	1,667	2,129	2,585	2,863	4,024
3.1 Mindanao	1,636	2,182	2,616	2,904	4,080
3.2 ARMM	1,785	1,979	2,290	2,717	2,923
Total	1,719	2,096	2,491	2,892	3,561

Source: Constructed by authors based on WorldClim version 1.4 (Hijmans et al. 2005).

Figure 3. Rainfall in the wettest three months, 1950–2000



Source: Constructed by authors based on WorldClim version 1.4 (Hijmans et al. 2005).

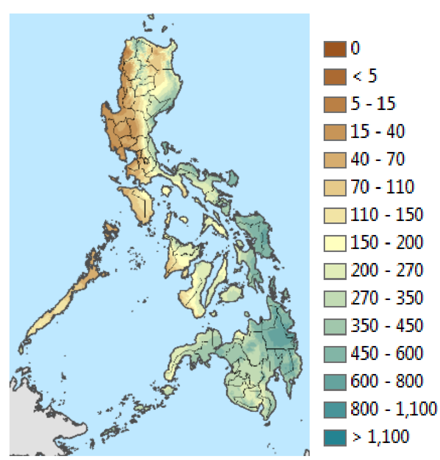
Table 2. Rainfall in the wettest three months by region, 1950–2000

Region	Percentile				
	5th	25th	50th	75th	95th
1. Luzon	692	917	1,134	1,382	1,885
1.1 Luzon	684	916	1,123	1,382	1,925
1.2 CAR	762	935	1,209	1,384	1,614
2. Visayas	611	769	950	1,185	1,469
3. Mindanao	528	697	883	983	1,752
3.1 Mindanao	528	718	888	999	1,784
3.2 ARMM	538	660	783	947	1,008
Total	616	806	982	1,276	1,739

Source: Constructed by authors based on WorldClim version 1.4 (Hijmans et al. 2005).

Rainfall levels in the driest three consecutive months of the year are shown in Figure 4 and are aggregated by major grouping in Table 3. The figure reveals striking differences in rainfall patterns. Mindanao clearly has rainfall throughout the year, but most of Luzon has a distinct dry season, and Visayas fits in between these two extremes. This general trend toward a distinct dry period is most pronounced in the westward sectors of Luzon and Visayas, with the eastern-most area experiencing a fairly high level of rainfall, similar to that noted for most of Mindanao. The mean daily maximum temperature in the warmest month of the year is shown in Figure 5, with the companion data by major grouping shown in Table 4. As expected, higher elevations are much cooler than the lower elevations, but very little difference exists in distribution across major groupings, or in moving from east to west, as was noted with rainfall.

Figure 4. Rainfall in the driest three months, 1950–2000



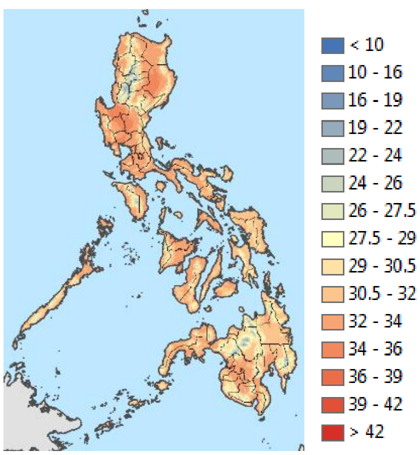
Source: Constructed by authors based on WorldClim version 1.4 (Hijmans et al. 2005).

Table 3. Rainfall in the driest three months by region, 1950–2000

Region	Percentile				
	5th	25th	50th	75th	95th
1. Luzon	27	60	135	244	410
1.1 Luzon	27	55	130	248	416
1.2 CAR	32	106	156	226	326
2. Visayas	110	193	251	444	571
3. Mindanao	235	300	374	473	619
3.1 Mindanao	229	303	386	492	624
3.2 ARMM	257	284	315	388	422
Total	32	129	256	383	562

Source: Constructed by authors based on WorldClim version 1.4 (Hijmans et al. 2005).

Figure 5. Mean daily maximum temperature in the warmest month, 1950–2000



Source: Constructed by authors based on WorldClim version 1.4 (Hijmans et al. 2005).

Table 4. Mean daily maximum temperature in the warmest month by region, 1950–2000

Region	Percentile				
	5th	25th	50th	75th	95th
1. Luzon	25.3	28.7	30.2	30.7	31.5
1.1 Luzon	26.5	29.2	30.3	30.8	31.5
1.2 CAR	21.4	24.5	27.6	29.9	30.8
2. Visayas	27.9	29.5	30.2	30.6	31.3
3. Mindanao	25.5	28.4	30.0	30.8	31.8
3.1 Mindanao	25.6	28.4	30.0	30.7	31.7
3.2 ARMM	25.2	28.1	30.5	31.5	32.1
Total	25.7	28.9	30.1	30.7	31.5

Source: Constructed by authors based on WorldClim version 1.4 (Hijmans et al. 2005).

PROJECTED DIFFERENCES AMONG REGIONS UNDER CLIMATE CHANGE

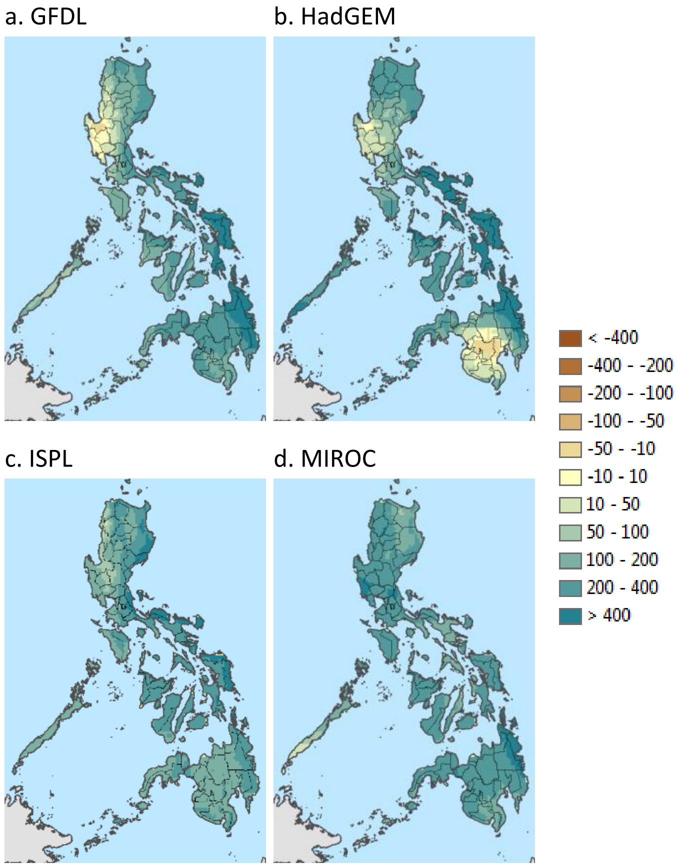
General circulation models (GCMs), also known as global climate models, are developed by climate scientists to determine how climate might change in response to greenhouse gas (GHG) accumulation in the upper atmosphere. The Intergovernmental Panel on Climate Change (IPCC) has a process by which teams submit models for use in IPCC assessment reports. Assessment Report 4 (AR4) incorporated 24 models, whereas Assessment Report 5 (AR5) included 61 models. The analysis presented in this policy note is based on the following four AR5 models:

1. GFDL-ESM2M, which was developed by the National Oceanographic and Atmosphere Administration's General Fluid Dynamics Laboratory (GFDL) (Dunne et al. 2012, 2013)
2. HadGEM2-ES, the Hadley Centre Global Environmental Model (HadGEM), from the Met Office Hadley Centre (Collins et al. 2011; Martin et al. 2011)
3. IPSL-CM5A-LR, generated by Institut Pierre-Simon Laplace (IPSL) (Dufresne et al. 2013)
4. MIROC-ESM-CHEM, (MIROC), from the Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (University of Tokyo), and National Institute for Environmental Studies (Sakamoto et al. 2012)

In AR5, each of the above-named models employed five different assumptions about GHG emissions, but the analysis in this policy note is limited to the assumption of the highest GHG emissions—Representative Concentration Pathway (RCP) 8.5—which is most commonly used by researchers. Projected changes in yearly precipitation from the 1950–2000 baseline period to the climate in 2050 are shown in Figure 6, and are quantified by regional grouping in Table 5. All of the models indicate that the Philippines will generally receive more rainfall; the median amount averaged across the nation is 256 millimeters.

While the averages from the climate models do not differ greatly for the country as a whole, regional differences are substantial. The most obvious of these are the significantly drier portion of CAR and western Luzon under the GFDL model, and the significantly drier portion of Mindanao (most of central and south) and ARMM under the HadGEM model (which also has a modestly drier portion in western Luzon). It should be noted that these significantly drier areas are likely to influence the model results in their respective areas.

Figure 6. Change in mean yearly precipitation based on four general circulation models, 2000–2050



Source: Constructed by authors based on the Agricultural Model Intercomparison Project (AgMIP), as part of Phase 5 of the Coupled Model Intercomparison (CMIP5), for Representative Concentration Pathway 8.5.

Notes: GFDL = General Fluid Dynamics Laboratory; HadGEM = Hadley Centre Global Environmental Model; IPSL = Institut Pierre-Simon Laplace; MIROC = Model for Interdisciplinary Research on Climate.

Table 5. Change in yearly rainfall based on four general circulation models, 2000–2050

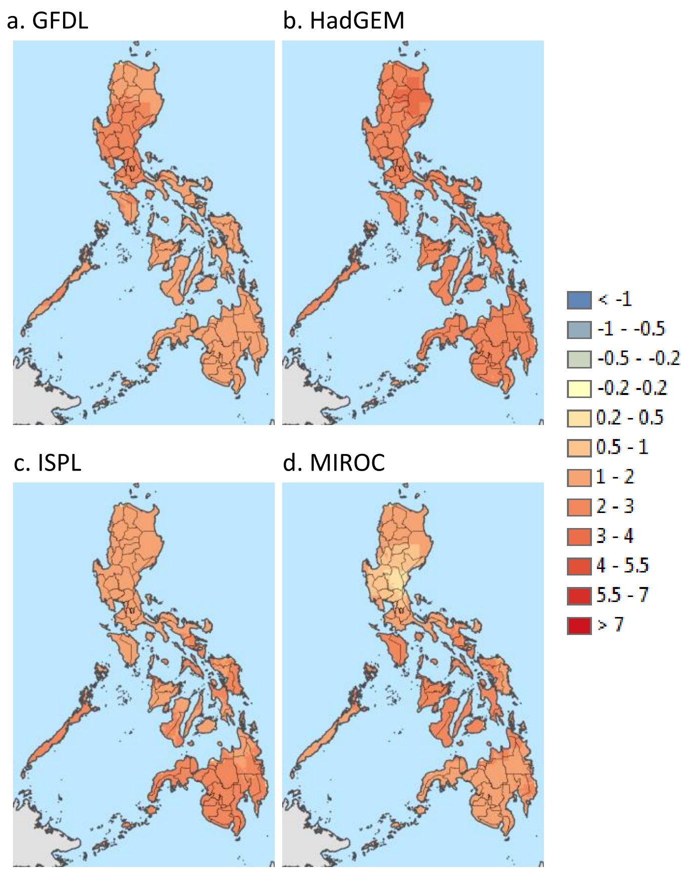
Region	GFDL	HadGEM	IPSL	MIROC
	Millimeters (mm)			
1. Luzon	167	252	235	250
1.1 Luzon	172	253	240	245
1.2 CAR	133	248	204	280
2. Visayas	309	531	297	261
3. Mindanao	329	240	200	290
3.1 Mindanao	346	262	203	295
3.2 ARMM	210	86	181	254
Total	247	298	235	265

Source: Constructed by authors based on WorldClim version 1.4 (Hijmans et al. 2005).

Notes: GFDL = General Fluid Dynamics Laboratory; HadGEM = Hadley Centre Global Environmental Model; IPSL = Institut Pierre-Simon Laplace; MIROC = Model for Interdisciplinary Research on Climate.

Changes projected in the mean daily maximum temperature in the warmest month of the year are shown in Figure 7 and are aggregated in Table 6. The HadGEM model predicts the largest temperature changes of the four GCMs, and it does so reasonably consistently across the country, although northern Luzon has noticeably higher temperature changes than the other regions. An area of low temperature increase in Central Luzon using MIROC model was observed. Overall, the temperature increases in the MIROC and GFDL models are modest. It might be expected that the increased temperature indicated by the IPSL model could lead to lower crop yields compared with the other models (due to heat stress).

Figure 7. Changes in mean daily maximum temperature in the warmest month based on four general circulation models, 2000–2050



Source: Constructed by authors based on the Agricultural Model Intercomparison Project (AgMIP), as part of Phase 5 of the Coupled Model Intercomparison (CMIP5), for Representative Concentration Pathway 8.5.

Notes: GFDL = General Fluid Dynamics Laboratory; HadGEM = Hadley Centre Global Environmental Model; IPSL = Institut Pierre-Simon Laplace; MIROC = Model for Interdisciplinary Research on Climate.

Table 6. Change in mean daily maximum temperature in the warmest month based on four general circulation models, 2000–2050

Region	GFDL	HadGEM	IPSL	MIROC
	Degrees Celsius (°C)			
1. Luzon	1.96	2.58	1.86	1.43
1.1 Luzon	1.95	2.53	1.86	1.45
1.2 CAR	1.98	2.90	1.84	1.25
2. Visayas	1.77	2.31	1.95	2.16
3. Mindanao	1.46	2.30	2.10	1.75
3.1 Mindanao	1.47	2.30	2.10	1.77
3.2 ARMM	1.43	2.31	2.13	1.57
Total	1.76	2.44	1.96	1.67

Source: Constructed by authors based on WorldClim version 1.4 (Hijmans et al. 2005).

Notes: GFDL = General Fluid Dynamics Laboratory; HadGEM = Hadley Centre Global Environmental Model; IPSL = Institut Pierre-Simon Laplace; MIROC = Model for Interdisciplinary Research on Climate.

A comparison of rainfall in the wettest and driest three months, based on the IPCC's AR5 analysis and RCP 8.5, shows changes to 2050 from the 1950–2000 baseline period (Table 7). Rainfall in both the wet and the dry season increases under all four GCMs. Overall, the HadGEM model suggests the highest wet season rainfall and the lowest increase in dry season rainfall.

Table 7. Comparison of changes in national rainfall levels in the dry and wet seasons based on four general circulation models, 2000–2050

Rainfall	GFDL	HadGEM	IPSL	MIROC
	Millimeters (mm)			
Change in the wettest three months	142	176	105	102
Change in the driest three months	27	17	31	36

Source: Constructed by authors based on the Agricultural Model Intercomparison Project (AgMIP), as part of Phase 5 of the Coupled Model Intercomparison (CMIP5), for Representative Concentration Pathway 8.5.

Notes: GFDL = General Fluid Dynamics Laboratory; HadGEM = Hadley Centre Global Environmental Model; IPSL = Institut Pierre-Simon Laplace; MIROC = Model for Interdisciplinary Research on Climate.

The country's five leading crops by harvested area are rice, coconuts, maize, vegetables, and bananas. Apart from maize, area harvested increased for all these crops between 2001 and 2012, but bananas expanded more rapidly than rice and coconuts. While maize area did not expand during that period, maize yields increased by a little more than 50 percent. The increase in the productivity of bananas was even higher, at just under 60 percent; rice productivity rose by just over 20 percent; and coconut productivity expanded by just under 9 percent.

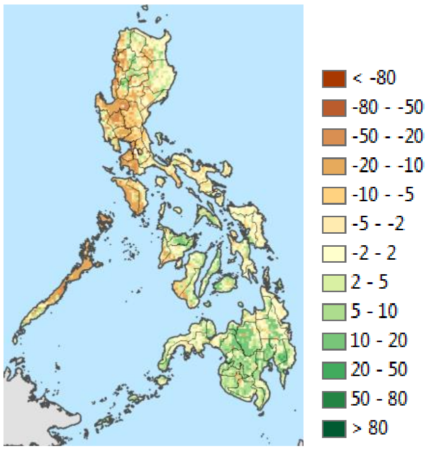
DIRECT IMPACTS OF CLIMATE CHANGE ON AGRICULTURE

To determine the impact of climate change on yields, the crop models were used in combination with the Decision Support System for Agrotechnology Transfer (DSSAT), which is a software package comprising multiple mathematical models that "grow" the crop in daily time increments. This enabled yields to be predicted for every five arc-minute grid-cell (approximately 9 or 10 kilometers), the results of which were then averaged across the major regional groupings, weighted by crop area.

The impact on rainfed rice with low fertilizer use in Luzon is highly negative in many locations, sometimes exceeding 20 percent (Figure 8). While yield changes in the Cagayan Valley are projected to be minimal and mostly positive, Central Luzon and MIMAROPA[1] are likely to experience large, negative impacts. On the other hand, Mindanao is likely to experience yield increases under climate change, with some areas having up to 20 percent higher productivity. Visayas is projected to experience mostly neutral climate impacts on rainfed rice, with areas of increase being offset by areas of decrease. Results for rainfed rice and rainfed sugarcane generally show modest negative impacts (Table 8), with Luzon projected to experience the greatest impact, followed by Visayas, and then Mindanao.

[1] MIMAROPA stands for Mindoro Occidental, Mindoro Oriental, Marinduque, Romblon and Palawan. These are five provinces under Region IV-B in Luzon.

Figure 8. Median projected changes in rainfed rice yields with low fertilizer use, 2000–2050



Source: Constructed by authors based on DSSAT model simulation results

THE FULL EFFECT OF CLIMATE CHANGE ON AGRICULTURE

Direct productivity effects are only one aspect of the impact of climate change, which also catalyzes indirect impacts across the globe. If climate change reduces the supply of an agricultural commodity, for example, prices will rise. For this reason, the effect of reduced production and productivity on the accessibility of agricultural commodities is not trivial. Under climate change, the prices of agricultural food commodities are projected to be considerably higher in 2030 and 2050 than they otherwise would be. Unsurprisingly, the impact of higher food prices is disproportionately higher on poor people.

Analyses based on the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) project substantial consumer price increases by 2050 for cereals (38 percent), roots and tubers (34 percent), and fruits and vegetables (27 percent) compared with baseline values. Similarly, meat prices are projected to increase by 4 percent despite only a 0.7 percent decline in production. Among cereals, the prices of corn, rice, and wheat are projected to increase by 45, 26, and 15 percent, respectively. Depending on the climate model used, the impact of climate change on the productivity of rice ranges from a decline of 0.9–2.2 percent in 2030 to a decline of 2.2–4.3 percent in 2050. The negative impact on corn yields is even wider, ranging from a decline of 0.1– 12.6 percent in 2030 to decline of 3.2–23.8 percent in 2050.

ADAPTATION STRATEGIES

Rosegrant et al. (2014) studied the potential benefits of developing a variety of agricultural technologies based on a global analysis at a half-degree resolution using a similar methodology to GCM crop modeling already discussed, but using two models from IPCC's AR4—from Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO) and MIROC—using the A1B scenario, which represents high-emissions, but not as high as under RCP 8.5. The results are useful not only in illustrating the magnitude of potential benefits of various technology interventions, but also in highlighting regional differences in those benefits. One limitation of their analysis, however, is that, although they calculated each technology's benefits, they did not calculate the costs, which makes it difficult to determine the overall economic benefit of any one technology over any other.

The technology that provided the highest projected increase in maize productivity was integrated soil fertility management (ISFM), at just over 32 percent nationwide (Table 9). The second-highest increase resulted from no-till agriculture, at just over 24 percent. ISFM includes the use of both organic inputs and synthetic fertilizers to maximize soil fertility. Both technologies ultimately increase soil organic matter, which in turn enhances other soil fertility indicators, such as nutrient and water retention (Rosegrant et al. 2014).

Unlike the case for rainfed maize, nitrogen-efficient varieties seem to offer large potential benefits for irrigated rice (Table 10). The projected increase in productivity was 53 percent nationally, and 61 percent for CAR. It should be noted, however, that—although this is a very encouraging result— the simulation was based on the potential to develop a crop that is not currently cultivated in the Philippines, so investment decisions should not be based on that statistic alone.

Table 8. Summary of projected changes in major crop yields due to climate change, 2000–2050

Region	Rice				Maize		Sugarcane		Bananas	Coconuts
	Rainfed		Irrigated		Rainfed		Rainfed	Irrigated	Rainfed	Rainfed
	Low	High	Low	High	Low	High	–	–	–	–
	Percent (%)									
1. Luzon	−7.4	−7.7	−0.2	−0.1	−18.9	−20.6	−8.6	−3.6	−11.2	1.4
1.1 Luzon	−7.5	−7.8	−0.2	−0.2	−19.1	−20.7	−8.7	−3.6	−11.1	1.4
1.2 CAR	−6.7	−6.7	0.2	2.0	−16.6	−18.6	−6.6	−2.2	−12.3	−1.7
2. Visayas	−4.1	−3.9	−1.1	−0.6	−22.8	−25.0	−5.8	−5.6	−4.8	0.9
3. Mindanao	−0.5	−0.6	−0.8	0.7	−18.7	−21.2	−0.5	−1.2	−1.4	2.5
3.1 Mindanao	−0.4	−0.5	−0.8	1.0	−18.1	−20.6	−0.4	−1.2	−1.6	2.4
3.2 ARMM	−0.8	−1.0	−0.9	−1.5	−21.3	−24.1	−3.9	−0.4	−0.1	2.8
Total	−4.5	−4.5	−0.4	0.0	−19.3	−21.6	−4.7	−4.3	−3.7	1.7

Source: Calculated by authors based on DSSAT model simulation results.

Notes: Grid-cell values were calculated using weights from MapSPAM 2005 (You et al. 2014). “Low” and “High” refer to levels of fertilizer (30 and 90 kilograms of nitrogen per hectare, respectively). Because the sugarcane model did not respond to changing nitrogen levels, the fertilizer variable was omitted.

Table 9. Projected improvements in rainfed maize yields from various technologies, 2050

Region	Drought-tolerant varieties	Heat-tolerant varieties	Nitrogen-efficient varieties	No-till agricul-ture	Crop-disease protection	Pest protec-tion	Weed protec-tion	Integrated soil fertility management	Water harvesting
	Percent (%)								
1. Luzon	5.1	13.2	11.9	25.4	11.3	16.3	12.5	34.7	0.5
1.1 Luzon	5.3	16.2	10.8	26.4	11.4	16.4	12.8	32.6	0.7
1.2 CAR	4.6	2.9	15.7	21.9	11.2	15.7	11.3	42.1	0.1
2. Visayas	4.1	11.3	12.7	24.7	10.0	13.1	10.7	32.1	0.0
3. Mindanao	2.6	8.2	14.2	23.7	12.4	17.1	14.4	31.8	0.9
3.1 Mindanao	2.9	8.2	14.2	24.6	12.2	17.1	14.1	31.4	1.1
3.2 ARMM	1.1	8.2	13.9	19.1	13.5	17.3	16.3	34.2	0.2
Total	3.2	9.4	13.7	24.1	12.0	16.7	13.9	32.4	0.8

Source: Calculated by authors based on data from Rosegrant et al. (2014).

Table 10. Projected improvements in irrigated rice from various technologies, 2050

Region	Heat-tolerant varieties	Nitrogen-efficient vari-eties	Precision agriculture	Crop-disease protection	Pest protection	Weed protection	Integrated soil fertility management
	Percent (%)						
1. Luzon	1.8	52.1	22.6	10.2	8.1	5.1	24.4
1.1 Luzon	1.7	51.3	21.5	10.2	8.1	5.1	22.8
1.2 CAR	2.7	61.1	35.0	10.3	7.2	4.7	40.5
2. Visayas	1.7	49.1	31.9	8.9	10.4	7.3	33.7
3. Mindanao	1.5	56.7	32.8	11.7	9.6	7.6	34.4
3.1 Mindanao	1.7	56.4	32.0	11.6	9.5	7.5	33.6
3.2 ARMM	0.1	59.0	39.1	11.9	10.2	8.4	40.6
Total	1.7	53.1	25.6	10.6	8.6	5.8	27.4

Source: Calculated by authors based on data from Rosegrant et al. (2014).

The potential for improvement in rainfed rice is much more limited than for irrigated rice or rainfed maize (Table 11). As for irrigated rice, nitrogen-efficient varieties show the most potential across the country, but the gain is limited to 12 percent—much less than the 53 percent for irrigated varieties. It is not clear why there should be such a large difference, but it may have to do with the variety chosen within the crop modeling software, and the variety's ability to use the nitrogen.

THE FULL IMPACT OF CLIMATE CHANGE ON ECONOMIC GROWTH AND INCOME DISTRIBUTION

The dynamic computable general equilibrium model of the Philippines (Phil-DCGE) was developed for this study for the purpose of assessing the economy-wide impacts of climate change in the agricultural sector and to explore policy options to offset these effects. Between 2011 and 2050, the share of agricultural labor is projected to fall from 33.6 to 23.5 percent, reflecting a reduction in the importance of agriculture to the Philippine economy. Nevertheless, 23.5 percent is still a significant proportion of the population, and many of these people will be among the nation's poorest. As a result, agriculture will continue to provide an important source of both employment and food security among a highly vulnerable segment of the society.

At the sector level, the largest quantitative economic impact of climate change is on agriculture—and, surprisingly, the net effect is positive (Table 12). The direct effect of climate change, through productivity, is negative, but the indirect effect, through prices and trade, is positive because the higher global prices of agricultural commodities is projected to induce Philippine farmers to produce more. Higher food and agricultural prices will still present challenges for the Philippine economy, however, because the country is a net food importer. Higher prices also present significant challenges for poor people given that a disproportionate amount of their household budgets are spent on food.

Table 12. Climate impact on value-added growth by sector and exchange rate, 2011–2050

Sectors	Climate shock (yearly change from baseline) Productivity effect	Global trade effect	Total effect
	Percent (%)		
Agriculture	–0.02	0.13	0.12
Industry	–0.01	–0.05	–0.06
Service	0.00	–0.01	–0.01
Total gross domestic product	0.00	–0.01	–0.02
Real exchange rate	–0.01	–0.03	–0.04

Source: Calculated by authors based on Phil-DCGE model simulations results

For all regions, the direct effect of climate change is negative (Table 13), although it is least negative in Mindanao. Once global price changes from climate change are accounted for, a large regional disparity in the impact on the agricultural sector remains, with Mindanao gaining greatly, Visayas receiving a small gain, and Luzon experiencing relatively small losses. Mindanao, however, experiences the most negative impact of the three major regions for staple crops, primarily through the global price and trade pathway, given that all three regions are projected to be affected by comparable staple crop productivity losses through the direct impact of

TABLE 11. Projected improvements in rainfed rice yields from various technologies, 2050

Region	Drought-tolerant varieties	Heat-tolerant varieties	Nitrogen-efficient varieties	Precision agriculture	Crop-disease protection	Pest protection	Weed protection	Integrated soil fertility management
	Percent (%)							
1. Luzon	1.8	1.9	11.2	3.0	9.8	8.1	5.4	8.0
1.1 Luzon	1.9	2.0	11.0	3.2	9.9	8.2	5.5	8.1
1.2 CAR	1.5	1.2	11.9	2.4	9.3	7.9	5.0	7.8
2. Visayas	1.2	0.4	13.3	2.2	9.8	9.5	5.9	6.8
3. Mindanao	1.3	0.4	11.6	0.6	11.6	9.7	7.8	4.9
3.1 Mindanao	1.4	0.3	11.2	0.5	11.3	9.5	7.4	3.9
3.2 ARMM	0.6	1.0	13.4	0.8	12.8	10.5	9.5	9.0
Total	1.4	0.9	12.0	1.9	10.4	9.1	6.4	6.6

Source: Calculated by authors based on data from Rosegrant et al. (2014).

climate change. In terms of export crops, all three regions are projected to have sizeable gains, but Mindanao is projected to grow almost twice as fast as the other two regions.

Table 13. Climate impact on agricultural production by region, 2011–2050

Commodities	Climate shock (yearly change from baseline)		
	Productivity effect	Global trade effect	Total effect
	Percent (%)		
Total agriculture	*–0.02*	*0.16*	*0.15*
Luzon	–0.03	0.01	–0.02
Visayas	–0.03	0.06	0.04
Mindanao	–0.01	0.39	0.39
Staple crops	*–0.04*	*–0.02*	*–0.06*
Luzon	–0.04	–0.01	–0.04
Visayas	–0.04	–0.03	–0.07
Mindanao	–0.04	–0.06	–0.10
Export crops	*–0.01*	*0.93*	*0.95*
Luzon	–0.02	0.60	0.59
Visayas	–0.02	0.46	0.45
Mindanao	0.00	1.13	1.16
Other crops	*0.02*	*–0.01*	*0.01*
Luzon	0.01	0.08	0.09
Visayas	0.01	0.04	0.05
Mindanao	0.02	–0.04	–0.02
Livestock	*–0.02*	*–0.07*	*–0.10*
Luzon	–0.02	–0.07	–0.10
Visayas	–0.02	–0.07	–0.10
Mindanao	–0.02	–0.07	–0.10

Source: Calculated by authors based on Phil-DCGE simulations results.
Note: Staple crops comprise rice and corn; export crops comprise bananas, coconuts, coffee, sugar, and other fruits.

This may suggest the country should develop a strategy to expand the export crop sector, and develop ways for poorer smallholder farmers to participate. Luzon has a comparative advantage in the category of "other crops" based on a positive overall climate change impact of almost twice the magnitude of the gain for Visayas; Mindanao, on the other hand, is projected to experience net losses in the productivity of other crops. Finally, livestock is projected to record losses across the country, both through direct declines in productivity and through the effects of global prices and trade.

The impact of climate change on income distribution is reflected in changes in "factor returns," (that is, income, share for major types of production inputs. The factors for this study were differentiated as labor, land, livestock, agricultural capital and non-agricultural capital. Changes in the wage rate for labor have more influence in driving the income levels of poor people, the majority of whom earn their income by providing unskilled labor. Climate change is projected to have positive effects on the wages of unskilled agricultural workers—that is, those having either no education or only a primary school education (Table 14). This positive trend is mainly generated through global climate effects, whereby higher international agricultural prices stimulate agricultural production, which in turn increases the demand for agricultural inputs (with the apparent exception of capital).

Table 14. Climate impact on factor returns, 2011–2050

Input factors		Climate Shock (yearly change from baseline)		
		Productivity effect	Global trade effect	Total effect
		Percent (%)		
Labor	No education	0.01	0.09	0.09
	Primary education	0.00	0.06	0.06
	Secondary education	–0.01	–0.04	–0.05
	Tertiary education	–0.01	–0.05	–0.06
Land	Luzon	0.03	0.21	0.24
	Visayas	0.03	0.24	0.27
	Mindanao	0.02	0.33	0.35
Livestock	Luzon	0.02	0.10	0.12
	Visayas	0.02	0.10	0.12
	Mindanao	0.02	0.10	0.12
Capital	Agricultural	–0.01	–0.03	–0.04
	Nonagricultural	–0.01	–0.04	–0.06

Source: Calculated by authors based on Phil-DCGE simulations results

Wage levels for skilled labor are projected to fall slightly as a result of climate change, which is mainly driven by lower production in both the industry and service sectors due to lower (real) exchange rates. Returns to land and livestock, mainly owned by nonpoor rural households, also increase under climate change, and to an even greater level than the returns to unskilled labor. Higher return on unskilled labor and land are likely to cause income increases across all rural households in all regions, with landowners in Mindanao benefiting the most (from increased land prices). Hence, because the gains to land are higher than the gains to labor, rural people who also own land benefit more than those who don't.

Results for income changes among urban households are mixed. The negative effect for upper-income urban households can be explained by the reduced return on skilled labor and capital, whereas for lower-income urban household, the higher return on low-skilled labor slightly improves their overall income levels. Nevertheless, rural households benefit more than the urban household across comparable income levels.

POLICY IMPLICATIONS

Crop Modeling Analyses of Direct Climate Impacts

The direct impact of climate change on irrigated crops is less than the impact on rainfed crops, at least in regard to the two irrigated crops examined for this study. Climate change is projected to have large, negative impacts on maize, and the impacts are fairly uniform across the country—with the exception of Visayas, where the impact is slightly more negative. Careful analysis of monthly rainfall and temperature patterns with and without climate change indicates that these results are consistent with documented yield impacts of higher temperatures on maize. Because maize is such an important crop in the Philippines, results suggest that careful consideration should be given to adaptation strategies targeting maize, in particular. Furthermore, because yield losses are reasonably high for both rainfed rice and rainfed sugarcane in Luzon, and all major crops are projected to be affected, adaptation strategies in that region will require particular attention. This also limits the strategies for maize adaptation in Luzon because one of them, relevant in the rest of the country, is to cultivate alternative crops, such as rice or sugarcane.

There are still possibilities for adaptation, however. Investment in agricultural research could result in heat-tolerant varieties of maize, rice, and sugarcane. The Rosegrant et al. (2014) study suggested that heat-tolerant varieties would only provide modest benefits, but that study used the AR4 climate models, and so perhaps did not project the same kind of losses resulting from this more recent analysis with the newer AR5 models. One possible alternative to heat-tolerant varieties that would nonetheless help with losses due to hotter temperatures would be the development of shorter-duration varieties that would allow farmers to plant in cooler months, and yet not miss out on months with sufficient rainfall for a good yield. Rosegrant et al. (2014) showed that no-till cultivation of maize could lead to much higher yields, as could improved pest protection, and—best of all—integrated soil fertility management.

For farmers who currently under-utilize fertilizer, increased use could be an effective means of adapting to climate change. This would especially be the case in the presence of rising food prices, which could in fact rise faster than fertilizer prices. Of course this does not necessarily mean the use of chemical fertilizers. Better use of manure or nitrogen-fixing plants—either as cover crops, through inter-cropping, or in rotation—might be an effective solution.

In irrigated areas, slightly shifting the growing season for rainfed crops to avoid the hottest months is a potential strategy, as is supplementing rainfed crops with irrigation while still using irrigation for the off-season crops. Such a strategy will often require careful consideration of the impact on both crops. The use of shorter-duration varieties for both crops may also be of great benefit in enhancing the success of this adaptation strategy. In areas that do not currently have irrigation but have that potential, investment in irrigation may be highly beneficial in overcoming the limitations of rainfed agriculture, under which some farmers may otherwise be forced to plant in the hottest (albeit wettest) months. Finally, Rosegrant et al. (2014) noted reasonably large potential improvements in irrigated rice productivity from the implementation of precision agriculture.

Policy Insights from the Phil-DCGE Model

In a simulation experiment, the Phil-DCGE model was used to evaluate a couple of policies that would potentially assist the Philippines in adapting to climate change. These results are presented in more detail in Project Policy Note 1, but are worth reiterating here. The first was to evaluate the results of investment in agricultural research for the purpose of increasing rice productivity and close the yield gap by about 30 percent. The second experiment was to explore a policy of reduced trade barriers on agriculture and food commodities to minimize the increasing domestic commodity price in the event of climate change.

The results are similar for the two policies, with the exception of staple crops, including rice (Table 15). Rice benefits more through direct investment in increasing rice productivity. Rice production is also much higher with the National Food Authority (NFA) subsidy, but export crop production is considerably higher without it. The NFA rice subsidy appears to have the unintended consequence of diverting production from higher to lower value crops. Overall, with the NFA subsidy in effect, the cost of climate change is reduced by only 17 billion pesos per year for rice productivity, and the cost actually increases by 0.2 billion pesos per year with a tariff reduction strategy (Table 16). The total cost of the NFA subsidy is around 41.6 billion pesos per year, which would more than compensate for the anticipated 26.2 billion pesos per year cost of climate change. The benefit of removing the NFA subsidy also results in higher private consumption and investment, with a slight increase in government consumption.

Table 15. Impact on macroeconomic variables of policy response to climate change, 2011–2050

Sectors	Yearly change from baseline				
	Total climate effect	With National Food Authority subsidy		Without National Food Authority subsidy	
		Increased rice productivity	Agricultural tariff reduction	Increased rice productivity	Agricultural tariff reduction
	Percent (%)				
Agriculture	0.12	0.18	0.13	0.18	0.12
Staple crops	–0.06	0.05	–0.07	–0.14	–0.29
Export crops	0.95	1.07	1.01	1.22	1.21
Other crops	0.01	0.04	–0.03	0.07	0.01
Livestock	–0.10	–0.07	–0.09	–0.05	–0.07
Industry	–0.06	–0.05	–0.06	–0.04	–0.05
Service	–0.01	–0.01	–0.02	0.01	0.01
Gross domestic product	–0.02	0.00	–0.02	0.01	0.00

Source: Calculated by authors based on Phil-DCGE simulations results.

Table 16. Benefit or cost of policy response on total absorption in yearly net present value, 2011–2050

Variable	Total climate effect	With National Food Authority subsidy		Without National Food Authority subsidy		Mean cost of National Food Authority subsidy
		Increase rice productivity	Agriculture tariff reduction	Increase rice productivity	Agriculture tariff reduction	
	Php billion					
Yearly absorption	–26.2	–9.3	–26.4	30.0	17.2	41.6
Private consumption	–21.5	–7.0	–20.8	13.9	4.4	22.8
Investment	–5.8	–3.5	–6.3	12.0	9.5	16.0
Government consumption	1.1	1.3	0.7	4.0	3.3	2.7

Source: Calculated by authors based on Phil-DCGE simulations results

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Timothy Thomas**, **Angga Pradesha and ***Nicostrato Perez**, are, respectively, research fellow, research analyst and senior scientist in the Environment and Production Technology Division of the International Food Policy Research Institute, Washington, DC, USA.*

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE
A member of the CGIAR Consortium | A world free of hunger and malnutrition
2033 K Street, NW | Washington, DC 20006-1002 USA
T: +1.202.862.5600 | F: +1.202.467.4439
Email: ifpri@cgiar.org | www.ifpri.org

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