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CLIMATE CHANGE POLICY NOTE 2 | NOVEMBER 2016

# Agricultural Growth, Climate Resilience, and Food Security in the Philippines

## Subnational Impacts of Selected Investment Strategies and Policies

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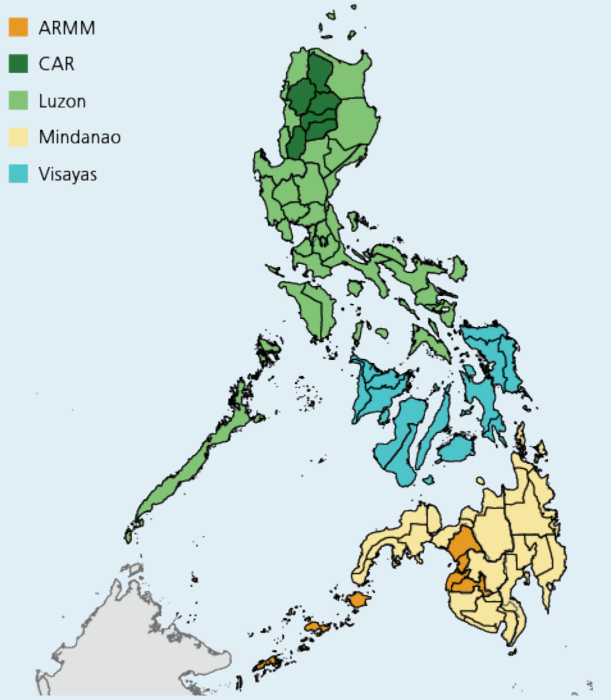
**THE FREQUENCY AND INTENSITY OF TROPICAL CYCLONES IN THE PHILIPPINES HAVE INCREASED IN RECENT years, with detrimental effects for the economy, socioeconomic welfare, and food security.** An archipelago known for its climatic and ecological diversity, the Philippines is strongly affected by the adverse impacts of climate change, especially in the agricultural sector. Yet, apart from extreme events, it remains to be seen whether the climate impact will be unequivocally negative, or whether, on balance, some parts of the country may experience gains. An enhanced understanding of how these dynamics will affect the country's major crops—rice, maize, sugarcane, coconuts, and bananas—is intended to assist Philippine communities in preparing for and adapting to these changes effectively and to assist donors and policy makers in helping them.

This policy note presents results of modeling analyses undertaken for 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 and Mercedita A. Sombilla. The research employed a suite of interlinked climate, crop, and economic modeling software in order to project a range of climate and socioeconomic "futures" simulating the impact of climate change (for more information, see Policy Note 1 in this series). The analyses presented are based on the regional groupings shown in Figure 1. Note that the Cordillera Administrative Region (CAR) and the Autonomous Region in Muslim Mindanao (ARMM) are treated separately, but are also included in the larger regional aggregations (CAR within Luzon, and ARMM within Mindanao).

**FIGURE 1** Regional groupings underlying the analyses

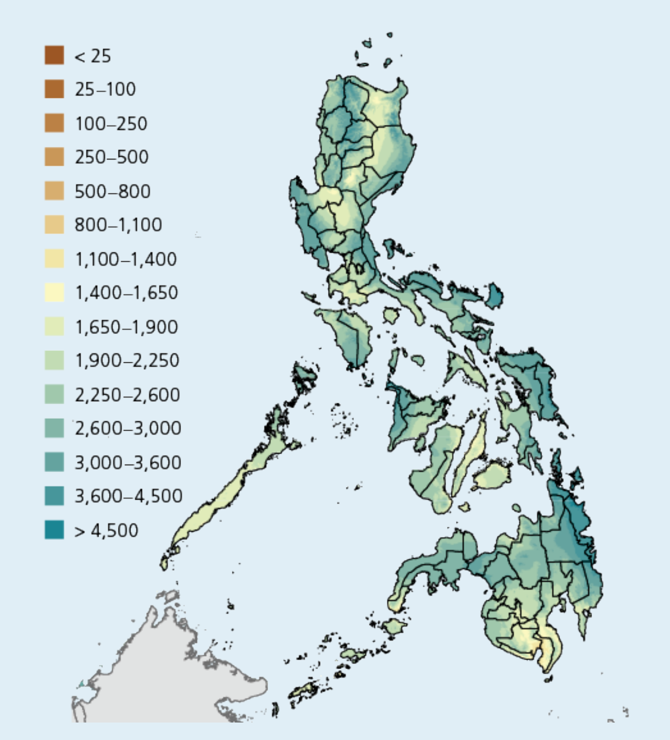


**Source:** Constructed by authors based on GADM (2010).

## CURRENT REGIONAL DIFFERENCES IN CLIMATE

The wettest parts of the country are 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 are among the driest in the region but still have considerable rainfall of 1,400 to 1,900 millimeters per year. While it is not universally true that the driest parts of the other major regions (Visayas and Mind-

**FIGURE 2** Yearly rainfall (mm), 1950–2000



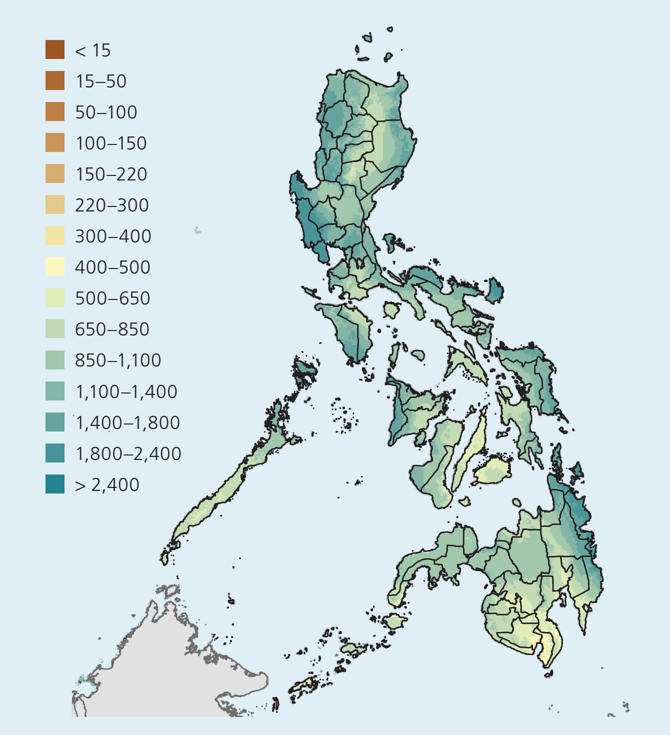
**Source:** WorldClim version 1.4 (Hijmans et al. 2005).

**TABLE 1** Yearly rainfall (mm) by region, 1950–2000

| | Percentile | | | | |
|---|---|---|---|---|---|
| Region | 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:** Calculated by authors from WorldClim version 1.4 (Hijmans et al. 2005).

**FIGURE 3** Rainfall (mm) in the wettest three months, 1950–2000



**Source:** WorldClim version 1.4 (Hijmans et al. 2005).

**TABLE 2** Rainfall (mm) in the wettest three months by region, 1950–2000

| | Percentile | | | | |
|---|---|---|---|---|---|
| Region | 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 |

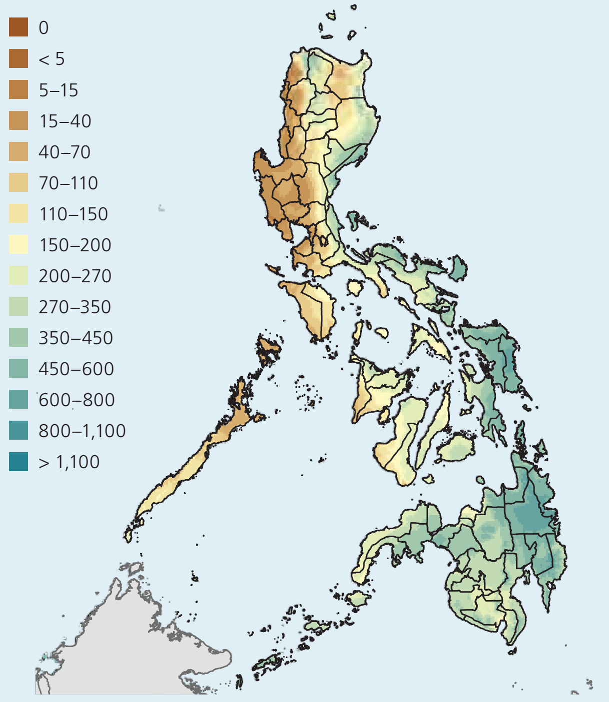
**Source:** Calculated by authors from WorldClim version 1.4 (Hijmans et al. 2005).

anao) are the most densely cultivated, relatively low rainfall levels by Philippine standards are generally preferred for agriculture, although these levels would be considered high in many parts of the world. The general distribution of rainfall in the wettest three consecutive months (calculated at each pixel, so the actual three-month period varies) follows a similar geographic distribution to that of yearly rainfall (Figure 3; Table 2).

While Mindanao clearly receives rainfall throughout the year, most of Luzon has a distinct dry season, and Visayas falls between these two extremes (Figure 4; Table 3). The general trend toward a distinct dry period is most pronounced in the west of each regional group, with the easternmost areas experiencing a higher level of rainfall, similar to that noted for most of Mindanao.

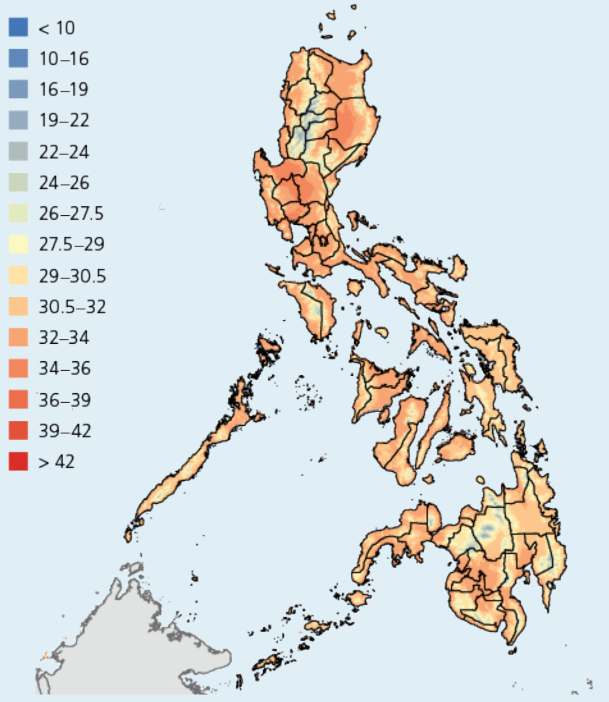
As expected, higher elevations are much cooler than are lower elevations, with little difference in rainfall distribution among major groupings, or north to south, or east to west (Figure 5; Table 4).

**FIGURE 4** Rainfall (mm) in the driest three months, 1950–2000



**Source:** WorldClim version 1.4 (Hijmans et al. 2005).

**FIGURE 5** Mean daily maximum temperature (°C) in the warmest month, 1950–2000



**Source:** WorldClim version 1.4 (Hijmans et al. 2005).

**TABLE 3** Rainfall (mm) in the driest three months by region, 1950–2000

| | Percentile | | | | |
|---|---|---|---|---|---|
| Region | 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:** Calculated by authors from WorldClim version 1.4 (Hijmans et al. 2005).

**TABLE 4** Mean daily maximum temperature (°C) in the warmest month by region, 1950–2000

| | Percentile | | | | |
|---|---|---|---|---|---|
| Region | 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 |

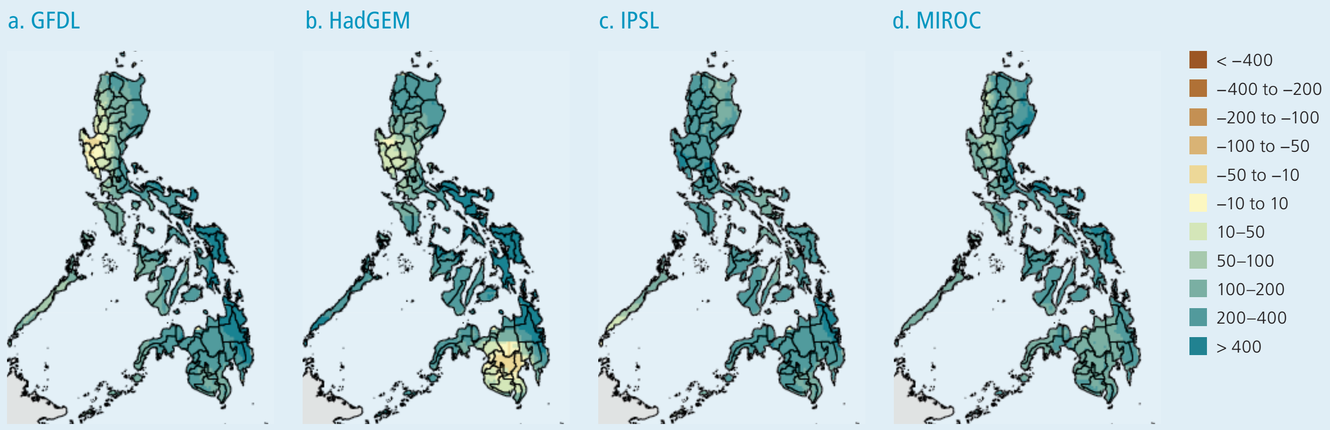
**Source:** Calculated by authors from WorldClim version 1.4 (Hijmans et al. 2005).

## PROJECTED FUTURE REGIONAL DIFFERENCES IN CLIMATE

The climate projections underlying the analyses presented in this policy note are for the period 2000–2050 and are the average results of four general circulation models (GCMs) from the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (for more information, see Policy Note 1 of this series):

1. GFDL-ESM2M, which was developed by the National Oceanographic and Atmosphere Administration General Fluid Dynamics Laboratory (Dunne et al. 2012, 2013);
2. HadGEM2-ES, developed by the Met Office Hadley Centre (Collins et al. 2011; Martin et al. 2011);
3. IPSL-CM5A-LR, generated by Institut Pierre-Simon Laplace (Dufresne et al. 2013); and

**FIGURE 6** Projected changes in mean yearly precipitation (mm) from four GCMs, 2000–2050



**Source:** Constructed by authors from data used in Müller and Robertson (2014).

**Notes:** GFDL = General Fluid Dynamics Laboratory; HadGEM = Hadley Centre Global Environmental Model; IPSL = Institut Pierre-Simon Laplace; MIROC = Model for Interdisciplinary Research on Climate. All are from the CMIP project for the Agricultural Model Intercomparison Project (AgMIP), and are for Representative Concentration Pathway (RCP) 8.5.

4. MIROC-ESM-CHEM, 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).

All four of the models indicate that the Philippines will generally receive more rainfall in 2050, ranging between 235 and 298 millimeters, depending on the climate model (Figure 6; Table 5). While the averages from the climate models do not differ much for the Philippines as a whole, there are significant regional differences. The most obvious differences across the maps are the significantly drier portion of CAR and western Luzon in the GFDL climate model; and the significantly drier portion of Mindanao (most of central and southern) and ARMM in the HadGEM climate model (which also has a modestly drier portion in western Luzon). These drier areas are likely to lead to the crop models projecting yield losses there, at least for some crops.

The HadGEM climate model predicts the greatest temperature changes of the four models, and is reasonably consistent across the country, although northern Luzon has noticeably higher temperature changes than elsewhere (Figure 7; Table 6). An error of a relatively low temperature increase in Central Luzon in the MIROC climate model was also noted. Overall, the temperature increases in the MIROC and GFDL climate models are modest.

All four GCMs project rainfall increases in both the wet and dry seasons (Table 7). Overall, the HadGEM model suggests the highest increase in wet season rainfall and the lowest increase in dry season rainfall.

**TABLE 5** Change in annual rainfall based on four GCMs, 2000–2050

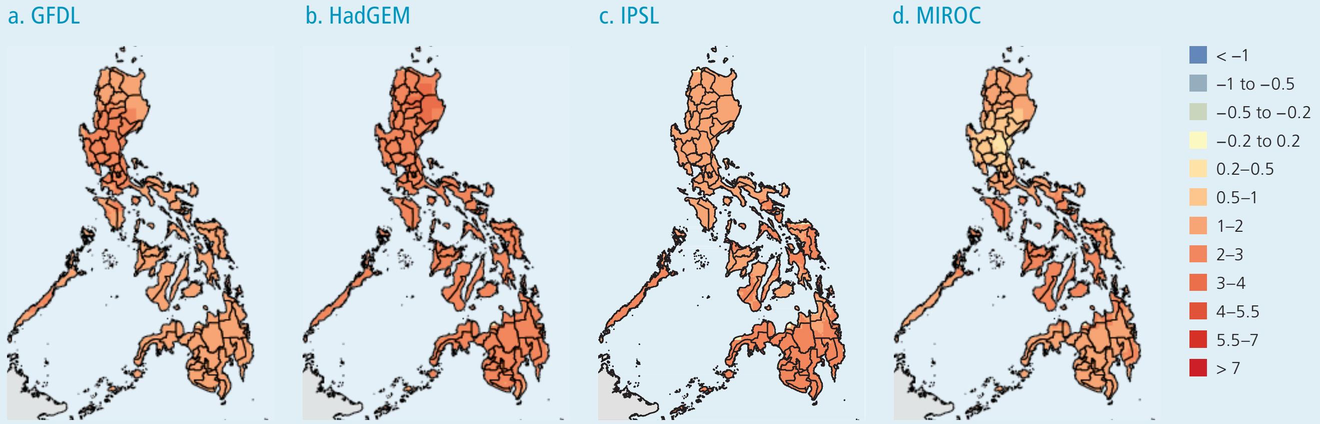
| | GFDL | HadGEM | IPSL | MIROC |
|---|---|---|---|---|
| Region | *Millimeters (mm)* | | | |
| 1. Luzon | 167 | 252 | 235 | 250 |
| 1.1 Luzon | 172 | 253 | 240 | 245 |
| 1.2 CAR | 133 | 248 | 204 | 280 |
| 2. Visayas | 309 | 531 | 297 | 261 |
| 3. Mindanao | 329 | 240 | 200 | 290 |
| 3.1 Mindanao |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

**Source:** Calculated by authors from 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.

The top five Philippine crops by harvested area are rice, coconuts, maize, vegetables, and bananas. With the exception of maize, harvested area increased during 2001–2012 for all of these crops, and the area expanded more rapidly for bananas than for rice and coconuts. While maize area did not expand during that period, its productivity did, with yields growing by more than 50 percent. The increase in banana productivity was even higher, at around 60 percent. Rice productivity rose at over 20 percent, whereas coconut productivity increased more modestly, at around 9 percent.

**FIGURE 7** Projected changes in mean daily maximum temperature (°C) in the warmest month from four GCMs, 2000–2050



**Source:** Constructed by authors from data used in Müller and Robertson (2014).

**Notes:** GFDL = General Fluid Dynamics Laboratory; HadGEM = Hadley Centre Global Environmental Model; IPSL = Institut Pierre-Simon Laplace; MIROC = Model for Interdisciplinary Research on Climate. All are from CMIP project for AgMIP project, and are for RCP 8.5.

**TABLE 6** Change in mean daily maximum temperature in the warmest month based on four GCMs, 2000–2050

| | GFDL | HadGEM | IPSL | MIROC |
|---|---|---|---|---|
| Region | *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:** Calculated by authors from 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.

**TABLE 7** Comparison of changes in rainfall during the dry and wet seasons based on four GCMs, 2000–2050

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

**Source:** Calculated by authors from data in Müller and Robertson (2014).

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

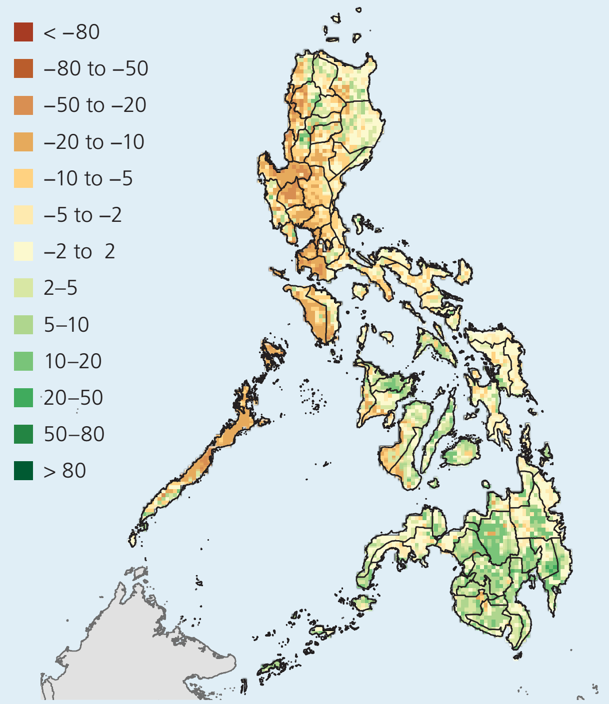
## THE DIRECT IMPACT OF CLIMATE CHANGE ON AGRICULTURE

The Decision Support System for Agrotechnology Transfer (DSSAT) software is a suite of crop models that simulate crop growth in daily time increments (Jones et al. 2003). Climate models were used together with the DSSAT crop models to determine the impact of climate change on yields. DSSAT was used to predict yields at high resolution (at every five arc-minute grid cell, representing approximately 9 or 10 kilometers), and then the results were averaged across subregions using cropping area as a weight (Figure 8).

Results indicate that the direct impact on rainfed rice in Luzon is highly negative in many locations, with a decrease in production exceeding 20 percent in some places. Whereas yield changes in the Cagayan Valley are minimal and mostly positive, Central Luzon and Mindoro, Marinduque, Romblon, and Palawan (MIMAROPA) Region are projected to suffer large negative impacts. In contrast, yields are projected to increase in Mindanao under climate change, with some areas experiencing productivity increases of up to 20 percent. The impacts on rainfed rice in Visayas are projected to be mostly neutral overall, with areas of increase offset by areas of decrease.

At the national level, climate change will have a modestly negative effect on rice, sugarcane, and bananas and a slightly positive effect on coconuts. However, it will have a large and negative effect on maize (Table 8). Results also indicate geographic differences that cannot be consistently characterized across crops. However, for rainfed rice, rainfed sugarcane, and bananas, our modeling projects that Luzon will experience the largest negative impact; Visayas will experience less adverse effects; and Mindanao even less.

**FIGURE 8** Median projected changes (%) in rainfed rice yields with low fertilizer use, 2000–2050



**Source:** Authors.

## THE TOTAL IMPACT OF CLIMATE CHANGE ON AGRICULTURE

The direct impact of climate change on productivity is only one part of the overall climate impact. Climate change has global impacts that will trigger worldwide changes in agricultural productivity. Reduced productivity and production will have a significant impact on the accessibility of agricultural commodities, and if climate change reduces supply, commodity prices will rise.

Modeling results indicate that the prices of agricultural food commodities will be considerably higher in 2030 and 2050 relative to what they would have been without climate change and that these price increases will disproportionately affect poor people. World prices of most food commodities are projected to rise, which will have flow-on effects for Philippine food prices.

Based on analyses from the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT), projections indicate substantial increases in consumer (retail) prices by 2050 for cereals (38 percent), roots and tubers (34 percent), and fruits and vegetables (27 percent) compared with baseline values (that is, without climate change). Similarly, meat prices are projected to rise by 4 percent, even though production declines only by 0.7 percent. Among cereals, rice prices are projected to rise by 26 percent, maize prices by 45 percent, and wheat prices by 15 percent.

Results from the four climate models used for the analyses project that the adverse impact of climate change on Philippine rice productivity will be in the range of −0.9 to −2.2 percent in 2030, and −2.2 to −4.3 percent in 2050. For maize, the projected impact ranges from −0.1 to 12.6 percent in 2030, and from −3.2 to 23.8 percent in 2050.

## THE IMPACT OF ADAPTATION STRATEGIES

Rosegrant et al. (2014) analyzed the potential benefits of developing various agricultural technologies for the purpose of adapting to the adverse impacts of climate change. Their

**TABLE 8** Summary of projected change in major crop yields under climate change, 2000–2050

| | Rice | | | | Maize | | Sugarcane | | Bananas | Coconuts |
|---|---|---|---|---|---|---|---|---|---|---|
| | Rainfed | | Irrigated | | Rainfed | | Rainfed | Irrigated | Rainfed | Rainfed |
| | Low | High | Low | High | Low | High | – | – | – | – |
| Region | *Percent change from baseline levels (%)* | | | | | | | | | |
| 1. Luzon | −7.1 | −7.4 | −0.2 | −0.1 | −18.8 | −20.6 | −8.6 | −3.6 | −12.7 | −0.5 |
| 1.1 Luzon | −7.2 | −7.5 | −0.2 | −0.2 | −18.9 | −20.7 | −8.7 | −3.6 | −12.6 | −0.5 |
| 1.2 CAR | −6.0 | −6.7 | 0.2 | 2.0 | −17.1 | −18.6 | −6.6 | −2.2 | −14.5 | −0.7 |
| 2. Visayas | 0.1 | −4.1 | −1.1 | −0.6 | −22.4 | −25.0 | −5.8 | −5.6 | −9.3 | −1.7 |
| 3. Mindanao | 5.0 | −0.5 | −0.8 | 0.7 | −19.1 | −21.2 | −0.5 | −1.2 | −1.1 | 2.7 |
| 3.1 Mindanao | 4.8 | −0.4 | −0.8 | 1.0 | −18.7 | −20.6 | −0.4 | −1.2 | −1.6 | 2.4 |
| 3.2 ARMM | 5.9 | −0.8 | −0.9 | −1.5 | −21.4 | −24.1 | −3.9 | −0.4 | 1.9 | 4.0 |
| Total | −1.2 | −4.5 | −0.4 | 0.0 | −19.5 | −21.6 | −4.7 | −4.3 | −5.6 | 1.0 |

**Source:** Calculated by authors from model simulation results.

**Notes:** Grid-cell values were calculated using weights from MapSPAM (You et al. 2014). "Low" and "High" refer to fertilizer levels, representing 30 and 90 kilograms of nitrogen per hectare, respectively. The sugarcane model did not respond to changing nitrogen levels, so this variable was excluded from the simulations.

analysis was done globally using a similar methodology to that used in this study, but using different climate models and climate change scenarios. The results are nevertheless useful in indicating the magnitude of the potential benefits of technology interventions, as well as providing information on regional differences. One drawback of the study is that it did not include calculations of the costs of each technology, making it more difficult to determine whether any particular technology is more economically beneficial.

In assessing the impact of various technologies on rainfed maize productivity, Rosegrant et al. (2014) projected the highest productivity increases stemming from integrated soil fertility management (ISFM)—more than a 30 percent increase nationally—followed by no-till agriculture, with an increase of more than 24 percent (Table 9). ISFM includes the use of both organic inputs and synthetic fertilizers to maximize soil fertility characteristics that benefit crop productivity. Both technologies increase soil organic matter, which is linked to enhancement of other soil fertility indicators, such as nutrient and water retention.

For irrigated rice, nitrogen-efficient varieties were projected to offer large benefits (more than 51 percent nationally), with ARMM benefiting the most, at around 57 percent (Table 10). Note, however, that this simulation assumes development of a crop technology not currently in existence for rice, so investment decisions should not be based on this projection alone. Nonetheless, it is encouraging to think that ongoing work in plant breeding could produce important yield breakthroughs.

The potential for improving rainfed rice with the technologies analyzed is far more limited than for irrigated rice or rainfed maize (Table 11). Nitrogen-efficient varieties of rainfed rice are projected to have the most potential across the country, but the gain is limited to 12 percent, much less than the 53 percent indicated for irrigated varieties.

**TABLE 9** Rainfed maize yields: Projected improvements from various technologies, MIROC, 2050

| Region | Drought-tolerant varieties | Heat-tolerant varieties | Nitrogen-efficient varieties | No-till agriculture | Crop-disease protection | Pest protection | Weed protection | Integrated soil fertility management | Water harvesting |
|---|---|---|---|---|---|---|---|---|---|
| | *Percent change from baseline levels (%)* | | | | | | | | |
| 1. Luzon | 6.0 | 17.8 | 11.1 | 26.8 | 11.2 | 16.2 | 12.5 | 31.5 | 0.6 |
| 1.1 Luzon | 7.4 | 21.8 | 9.8 | 28.1 | 11.2 | 16.5 | 12.9 | 28.9 | 0.7 |
| 1.2 CAR | 2.3 | 4.3 | 15.5 | 22.2 | 11.2 | 15.0 | 11.5 | 40.4 | 0.1 |
| 2. Visayas | 4.5 | 17.3 | 12.0 | 23.3 | 10.0 | 13.0 | 11.2 | 30.3 | 0.1 |
| 3. Mindanao | 2.6 | 11.1 | 13.3 | 23.2 | 12.0 | 16.9 | 14.5 | 30.7 | 0.9 |
| 3.1 Mindanao | 2.7 | 11.2 | 13.3 | 24.0 | 11.8 | 16.8 | 14.2 | 30.3 | 1.0 |
| 3.2 ARMM | 2.1 | 10.4 | 13.5 | 19.3 | 13.1 | 17.2 | 16.6 | 32.7 | 0.4 |
| **Total** | **3.4** | **13.3** | **12.8** | **24.0** | **11.7** | **16.5** | **13.9** | **30.8** | **0.8** |

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

**TABLE 10** Irrigated rice yields: Projected improvements from various technologies, MIROC, 2050

| Region | Heat-tolerant varieties | Nitrogen-efficient varieties | Precision agriculture | Crop-disease protection | Pest protection | Weed protection | Integrated soil fertility management |
|---|---|---|---|---|---|---|---|
| | *Percent change from baseline levels (%)* | | | | | | |
| 1. Luzon | 1.9 | 50.3 | 20.9 | 10.2 | 8.2 | 5.4 | 23.6 |
| 1.1 Luzon | 2.2 | 50.4 | 20.7 | 10.2 | 8.4 | 5.4 | 22.5 |
| 1.2 CAR | 0.0 | 49.5 | 23.2 | 10.5 | 7.2 | 5.1 | 32.5 |
| 2. Visayas | 0.3 | 45.2 | 28.7 | 8.4 | 11.0 | 7.6 | 30.1 |
| 3. Mindanao | 1.8 | 54.8 | 29.2 | 11.8 | 10.1 | 8.0 | 30.5 |
| 3.1 Mindanao | 2.1 | 54.5 | 28.7 | 11.8 | 10.0 | 7.9 | 29.8 |
| 3.2 ARMM | 0.1 | 57.1 | 33.2 | 12.0 | 10.7 | 8.7 | 35.6 |
| **Total** | **1.9** | **51.3** | **23.4** | **10.6** | **8.8** | **6.1** | **25.7** |

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

**TABLE 11** Rainfed rice yields: Projected improvements from various technologies, MIROC, 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 change from baseline levels (%)* | | | | | | | |
| 1. Luzon | 2.0 | 2.8 | 10.8 | 3.7 | 9.5 | 8.3 | 5.7 | 7.7 |
| 1.1 Luzon | 2.2 | 3.0 | 10.6 | 3.9 | 9.7 | 8.4 | 5.8 | 7.8 |
| 1.2 CAR | 1.4 | 2.2 | 11.9 | 3.1 | 8.9 | 7.8 | 5.4 | 7.5 |
| 2. Visayas | 0.7 | 0.0 | 13.0 | 1.4 | 9.5 | 9.8 | 6.3 | 7.0 |
| 3. Mindanao | 1.4 | 0.0 | 11.4 | 0.7 | 11.7 | 10.3 | 8.0 | 4.5 |
| 3.1 Mindanao | 1.6 | 0.0 | 11.2 | 0.8 | 11.4 | 10.1 | 7.6 | 4.0 |
| 3.2 ARMM | 0.6 | 0.0 | 12.2 | 0.0 | 12.8 | 11.2 | 9.7 | 6.9 |
| Total | 1.4 | 1.0 | 11.7 | 2.0 | 10.3 | 9.5 | 6.7 | 6.4 |

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

## THE TOTAL IMPACT OF CLIMATE CHANGE ON ECONOMIC GROWTH AND INCOME DISTRIBUTION

The dynamic computable general equilibrium model of the Philippines (Phil-DCGE model) was developed for this study to assess the economywide impacts of climate change on the agricultural sector and the economy and to explore policy options to offset these effects. The share of agricultural labor is projected to decline from 33.6 to 23.5 percent from 2011 to 2050, reflecting the projected declining importance of the agricultural sector to the Philippine economy. Nonetheless, 23.5 percent is still a significant share of the population. Despite the structural transformation of the economy, the agricultural sector remains important in terms of employment and food security for a highly vulnerable segment of Philippine society.

Analyses of the three economic sectors studied (agriculture, industry, and services) project that climate change will have the largest quantitative impact on agriculture, but 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. This occurs because higher global prices for agricultural commodities induce Philippine farmers to produce more, especially in the area of export crops (discussed further below).

**TABLE 12** Impact of climate change on sectoral GDP, 2050

| Sector | Impact on productivity | Impact on global trade | Total impact |
|---|---|---|---|
| | *Percentage change from baseline levels (%)* | | |
| Agriculture | −2.07 | 6.92 | 3.14 |
| Industry | −0.29 | −2.59 | −2.41 |
| Services | −0.19 | −0.65 | −0.79 |
| GDP | −0.37 | −0.55 | −0.90 |

**Source:** Calculated by authors based on Phil-DCGE model simulation results.
**Note:** GDP = gross domestic product.

The direct effect of climate change (the productivity shock) is negative in all three regional groupings but is least negative in Luzon (Table 13). In addition, when shifts in global prices due to climate change are also taken into account, the regional disparity in the impact on the agricultural sector is significant. Mindanao gains the most, Visayas experiences a small gain, and in Luzon, losses are relatively small.

The production of staple crops, dominated by rice, is projected to decline by 1.9 percent due to direct (productivity) impacts and by 1.8 percent due to indirect (global) impacts in 2050, causing a total reduction of 2.9 percent. The projected difference in productivity losses for staple crops is minimal across regions, but because Luzon produces more than half of the country's rice, even a small percentage change in production in that region has a significant impact on national production.

While productivity losses for export crops are even greater than the losses for staple crops, the impact of global trade is both positive and very large. As a result, the overall impact of climate change on Philippine export crop production is positive and significant. Mindanao is the largest producer of export crops among the three regions and stands to gain the most from increased global commodity prices. The total effect at the national level, therefore, is largely driven by the total effect in Mindanao, which is projected as an increase of around 36 percent in the production of export crops.

In order to understand the impact of climate change on income distribution, the analysis considered all sectors of the economy. The effect on income distribution can be captured by looking at the changes in the returns to input factors (that is, labor, land, livestock, and capital). As seen in Table 14, climate change is projected to have positive impacts on the wages of unskilled labor (those with primary-level or no education). This positive trend mainly stems from global climate

**TABLE 13** Climate impact on agricultural production by region, 2011–2050

| Commodity/ regional grouping | Impact on productivity | Impact on global trade | Total impact |
|---|---|---|---|
| | *Percentage yearly change from baseline levels (%)* | | |
| Agricultural total | –1.98 | 6.70 | 3.03 |
| Luzon | –1.84 | 1.19 | –0.96 |
| Visayas | –2.04 | 3.74 | 0.76 |
| Mindanao | –2.87 | 21.48 | 13.10 |
| Staple crops | –1.90 | –1.75 | –2.88 |
| Luzon | –1.90 | –0.69 | –2.10 |
| Visayas | –2.32 | –1.93 | –3.53 |
| Mindanao | –1.62 | –3.90 | –4.15 |
| Export crops | –5.19 | 55.54 | 35.60 |
| Luzon | –5.06 | 34.13 | 19.24 |
| Visayas | –3.54 | 24.75 | 14.85 |
| Mindanao | –5.72 | 70.32 | 46.07 |
| Other crops | –3.13 | –1.70 | –3.68 |
| Luzon | –7.14 | 3.23 | –4.14 |
| Visayas | –3.49 | 1.46 | –1.67 |
| Mindanao | –2.03 | –3.37 | –3.78 |
| Livestock | –0.79 | –2.45 | –2.85 |
| Luzon | –0.80 | –2.43 | –2.84 |
| Visayas | –0.78 | –2.49 | –2.87 |
| Mindanao | –0.78 | –2.49 | –2.87 |

**Source:** Calculated by authors from Phil-DCGE simulation results.

**Note:** Staple crops include rice and corn; export crops include bananas, coconuts, coffee, sugar, and other fruits.

impacts: higher international agricultural prices stimulate agricultural production, which increases the demand for all agricultural inputs including both labor and land. On the other hand, wage rates for more highly skilled labor (those with secondary or tertiary education) decline slightly in response to climate change. This is mainly driven by lower production in both industry and services in response to shifts in the labor market: increased demand for agricultural labor can be seen as a force that impedes the structural transformation process and, thus, long-term economic growth (for more details, see Policy Note 1 in this series).

**TABLE 14** Impact of climate change on factor returns, 2050

| Input factor/regional grouping/sector | | Impact on productivity | Impact on global trade | Total impact |
|---|---|---|---|---|
| | | *Percentage change from baseline levels (%)* | | |
| Labor (by education level) | No education | 0.18 | 4.84 | 3.96 |
| | Primary education | –0.30 | 3.34 | 2.23 |
| | Secondary education | –0.74 | –2.08 | –2.59 |
| | Tertiary education | –0.73 | –2.48 | –2.90 |
| Land | Luzon | 1.49 | 13.23 | 12.55 |
| | Visayas | 1.25 | 14.31 | 13.01 |
| | Mindanao | 2.40 | 21.31 | 19.64 |
| Livestock | Luzon | –0.39 | 1.76 | 1.29 |
| | Visayas | –0.37 | 1.74 | 1.30 |
| | Mindanao | –0.37 | 1.74 | 1.30 |
| Capital | Agriculture | 0.29 | 0.06 | 1.09 |
| | Nonagriculture | –0.56 | –2.61 | –2.69 |

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

## POLICY IMPLICATIONS

### Impact of Adaptation Technologies

The direct impact of climate change on irrigated crops is less than the impact on rainfed crops, at least for the two irrigated crops (rice and sugarcane) examined in this study. Among rainfed crops, losses for maize from direct climate impacts are projected to be much larger than for other crops. Losses for rainfed maize are fairly similar across the country, with the exception of Visayas, where the impact is slightly more negative than elsewhere. These results are supported by a careful analysis of projected monthly rainfall and temperature patterns with and without climate change, as well as documentation of the negative impact of higher temperatures on maize yields.

Because maize is an important crop for farmers in the Philippines, these results indicate that particular consideration should be given to adaptation strategies for maize. Furthermore, because yield losses are fairly high for both rainfed rice and rainfed sugarcane in Luzon, special attention to adaptation strategies in that region is in order. Moreover, the potential strategies for maize adaptation in Luzon are limited because the option of shifting cultivation to alternative crops, such as rice or sugarcane (viable in other parts of the country), would be ineffective there.

Potential adaptation strategies include investment in agricultural research to develop heat-tolerant varieties of maize, rice, and sugarcane. Rosegrant et al. (2014) suggest that heat-tolerant varieties would only be of modest help. Note, however, that the analysis in that study was based on older climate models, so results are not directly comparable. One possible alternative to heat-tolerant varieties would be the development of short-duration varieties (discussed in the next paragraph). Rosegrant et al. (2014) also suggest that no-till maize cultivation could potentially increase yields, as could improved pest protection and, most promising, ISFM. The study also noted the large potential of precision agriculture for improving the productivity of irrigated rice.

In irrigated areas, a possible adaptation strategy may be to shift the growing season slightly for rainfed crops to avoid the hottest months, using supplemental irrigation when necessary. This would require careful consideration as to the impact on both crops, and may require using shorter-duration varieties—that is, varieties requiring a shorter growing season—to ensure that neither crop is grown in the hottest part of the year. Areas with the potential to develop irrigation may benefit from this investment if it allows farmers to avoid planting in the hottest—but wettest—months.

Although some Philippine farmers use sufficient fertilizer, many do not, in which case additional application is potentially an effective means of adapting to climate change. Since food prices may rise faster than fertilizer prices, this may be an appropriate strategy. Alternatives to inorganic fertilizers include better use of manure and use of nitrogen-fixing plants as cover crops, either intercropped or in rotation.

## Impact of Investment Strategies

The study examined the impact of three investment strategies intended to mitigate the adverse effects of climate change: (1) investing in agricultural research to increase rice productivity, (2) expanding irrigated area by 90 percent over 14 years based on the National Irrigation Administration's master plan, and (3) reducing trade barriers for agriculture and food commodities to minimize domestic commodity price increases under climate change.

Similar trends result for the three investment options. However, the government's rice subsidy policy, administered by the National Food Authority (NFA), appears to have the unintended consequence of diverting production from higher value-added to lower value-added crops (Table 15), which affects the results. Staple crop production is higher under all three investment strategies when the NFA rice subsidy is in place, but the growth of export crops is slowed because labor and other inputs are diverted into rice production. In contrast, when the NFA rice subsidy is eliminated, higher-value export crop production is greater because the artificial incentive for farmers to focus on rice production is removed.

Table 16 shows the impact of climate change and the three possible adaptation policies on income distribution, taking into consideration location (rural or urban) and income level. The direct impact of climate change is an increase in income for rural households and a decrease for urban households. Most of the gain for rural households goes to upper-income households, though lower-income households also gain. Among urban households, upper-income households lose considerable welfare, while the lower-income households gain slightly. Investment in increased rice productivity is slightly better for rural lower-income households, while investment in expanded irrigation is more beneficial for rural upper-income households.

The benefits of the NFA subsidy for lower-income households are also presented in Table 14. The NFA subsidy has a negative effect on the overall economy. Gains in total household welfare are lower from all adaptation strategies with the NFA policy in place than without the NFA policy. Policy makers often ignore this consequence of the self-sufficiency policy, because of the perception that it helps poor farmers. For example, under a policy of increasing rice productivity, the NFA subsidy improves the welfare of rural lower-income

**TABLE 15** Impact of climate change and policy adaptation policies on sectoral GDP, 2050

| | With National Food Authority subsidy | | | | Without National Food Authority subsidy | | |
|---|---|---|---|---|---|---|---|
| Sector/ commodity grouping | Impact of climate change | Increasing rice productivity | Expanding irrigation infrastructure | Reducing agricultural tariffs | Increasing rice productivity | Expanding irrigation infrastructure | Reducing agricultural tariffs |
| | *Percent change from baseline levels (%)* | | | | | | |
| Agriculture | 3.14 | 5.57 | 5.32 | 3.44 | 5.19 | 5.09 | 3.18 |
| Staple crops | −2.88 | 1.07 | −1.25 | −3.10 | −2.59 | −4.71 | −7.59 |
| Export crops | 35.60 | 41.36 | 43.65 | 38.26 | 44.68 | 47.44 | 43.56 |
| Other crops | −3.68 | −2.92 | −1.52 | −4.96 | −2.40 | −0.96 | −4.28 |
| Livestock | −2.85 | −2.20 | −2.32 | −2.88 | −1.79 | −1.89 | −2.38 |
| Industry | −2.41 | −2.09 | −2.26 | −2.36 | −1.97 | −2.12 | −2.22 |
| Services | −0.79 | −0.67 | −0.66 | −0.83 | −0.22 | −0.20 | −0.37 |
| GDP | −0.90 | −0.54 | −0.60 | −0.89 | −0.25 | −0.28 | −0.57 |

**Source:** Calculated by authors from DCGE model simulation results.
**Note:** GDP = gross domestic product.

**TABLE 16** Net welfare impact of climate change and possible adaptation policies across households, 2011–2050

| Household/ income grouping | With National Food Authority subsidy | | | | Without National Food Authority subsidy | | |
|---|---|---|---|---|---|---|---|
| | Impact of climate change | Increasing rice productivity | Expanding irrigation infrastructure | Reducing agricultural tariffs | Increasing rice productivity | Expanding irrigation infrastructure | Reducing agricultural tariffs |
| | *Average yearly value (billion Php)* | | | | | | |
| Household welfare | –119.9 | –74.1 | –85.8 | –118.0 | –54.7 | –63.3 | –87.7 |
| Rural | 94.7 | 99.0 | 101.0 | 92.6 | 94.2 | 96.3 | 88.1 |
| Lower income | 8.4 | 11.5 | 11.0 | 8.2 | 8.5 | 8.2 | 5.8 |
| Upper income | 86.3 | 87.5 | 90.0 | 84.4 | 85.7 | 88.2 | 82.2 |
| Urban | –214.6 | –173.1 | –186.7 | –210.6 | –148.9 | –159.6 | –175.7 |
| Lower income | 4.8 | 6.9 | 6.6 | 4.8 | 5.6 | 5.4 | 4.0 |
| Upper income | –219.4 | –180.0 | –193.3 | –215.4 | –154.5 | –165.0 | –179.8 |

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

households by Php 3.0 billion per year (Php 11.5 billion – Php 8.5 billion) and urban lower-income households by Php 1.3 billion per year (Php 6.9 billion – Php 5.6 billion). The subsidy also generates gains for rural upper-income households of Php 1.8 billion per year. On the other hand, much lower welfare for the urban upper-income households was observed (Php –25.5 billion per year). Overall, the net effect at the national level is a loss of Php 19.4 billion per year (Php –74.1 billion + Php 54.7 billion) when the NFA subsidy is part of the adaptation policy.

Clearly, removing the NFA subsidy could increase total household welfare considerably under all three adaptation policies. However, removing the subsidy could also potentially reduce the welfare of vulnerable lower-income households. A possible alternative policy to reduce the vulnerability of the poor in the changing climate would be to replace the population-wide rice subsidy with a policy targeted to lower-income households, such as a cash transfer or other welfare program designed to help the poor cope with economic and climate shocks in both the short and long run.

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