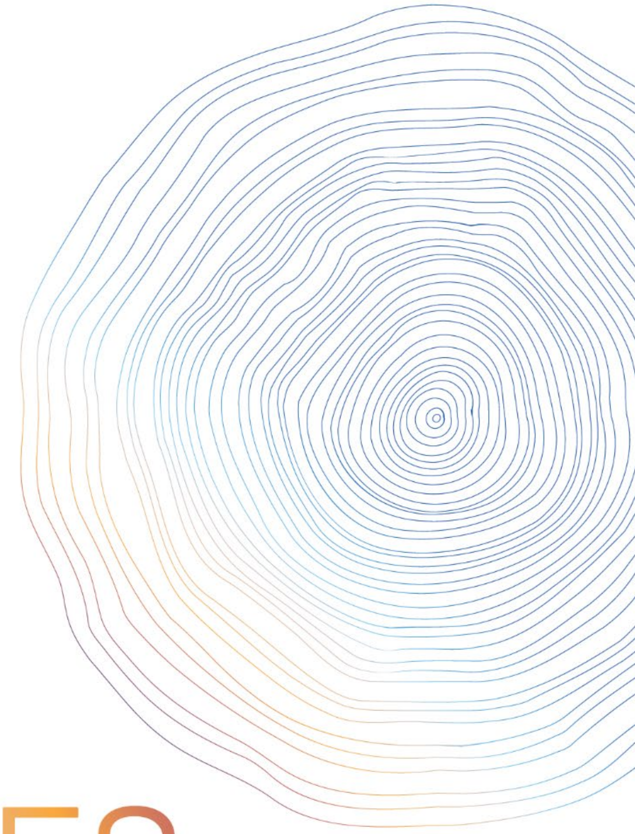
Background Paper PH-3

Agriculture



PHILIPPINES

COUNTRY CLIMATE AND DEVELOPMENT REPORT

Philippines CCDR Background Papers

PH-1	Climate Change Institutional Analysis
PH-2	Water
PH-3	Agriculture
PH-4	Philippine Energy Transition: Towards a Secure, Affordable and Clean Energy Future
PH-5	Transport
PH-6	Macroeconomic Modelling in the Philippines CCDR
PH-7	Climate Change and Environmental Risks in the Financial and Private Sector and Opportunities for Green Finance
PH-8	The Distributional Impacts of Climate Change Damage, Adaptation and Mitigation Policies in the Philippines
PH-9	Strengthening Adaptive Social Protection for Climate Change and Disasters
PH-10	Social Impacts of Climate Change in High-Risk Areas of the Philippines
PH-11	Disaster Risk Management in the Philippines

© 2023 The World Bank Group
1818 H Street NW, Washington, DC 20433
Telephone: 202-473-1000; Internet: www.worldbank.org

This work is a product of the staff of The World Bank Group with external contributions. “The World Bank Group” refers to the legally separate organizations of the International Bank for Reconstruction and Development (IBRD), the International Development Association (IDA), the International Finance Corporation (IFC), and the Multilateral Investment Guarantee Agency (MIGA).

The World Bank Group does not guarantee the accuracy, reliability or completeness of the content included in this work, or the conclusions or judgments described herein, and accepts no responsibility or liability for any omissions or errors (including, without limitation, typographical errors and technical errors) in the content whatsoever or for reliance thereon. The boundaries, colors, denominations, and other information shown on any map in this work do not imply any judgment on the part of the World Bank Group concerning the legal status of any territory or the endorsement or acceptance of such boundaries. The findings, interpretations, and conclusions expressed in this volume do not necessarily reflect the views of the organizations of the World Bank Group, their respective Boards of Executive Directors, and the governments they represent.

The contents of this work are intended for general informational purposes only and are not intended to constitute legal, securities, or investment advice, an opinion regarding the appropriateness of any investment, or a solicitation of any type. Some of the organizations of the World Bank Group or their affiliates may have an investment in, provide other advice or services to, or otherwise have a financial interest in, certain of the companies and parties named herein.

Nothing herein shall constitute or be construed or considered to be a limitation upon or waiver of the privileges and immunities of any of the organizations of The World Bank Group, all of which are specifically reserved.

Rights and Permissions

The material in this work is subject to copyright. Because The World Bank Group encourages dissemination of its knowledge, this work may be reproduced, in whole or in part, for noncommercial purposes as long as full attribution to this work is given and all further permissions that may be required for such use (as noted herein) are acquired. The World Bank Group does not warrant that the content contained in this work will not infringe on the rights of third parties, and accepts no responsibility or liability in this regard. All queries on rights and licenses should be addressed to World Bank Publications, The World Bank Group, 1818 H Street NW, Washington, DC 20433, USA; e-mail: pubrights@worldbank.org.

Table of contents

Acknowledgments

This background paper for the Philippines CCDR was produced by a team from the World Bank Group led by Anuja Kar and Eli Weiss and comprising Roehl Briones (Modelling Lead), Jim Hancock (Food and Agriculture Organization of the United Nations), Katarzyna Pankowska (Food and Agriculture Organization of the United Nations), Nicolo Massa Bernucci (Food and Agriculture Organization of the United Nations), John Nash, Maria Theresa Quinones, Paula Beatrice Macandog, and Rowell Conese Dikitanan. Additional inputs were received from Nkulumo Zinyengere, Ditte Fallsen, and Ma Fiorella Delos Reyes Fabella. Katrina Brandon and Megan Mayzelle edited the paper, and Mildren Penales provided administrative and logistical support. The report has hugely benefited from the guidance of Stefano P. Pagiola, Dina Umali-Deininger, Madhu Raghunath, Achim Fock, and Ndiame Diop, who oversaw the work.

The team thanks the Department of Agriculture for excellent collaboration, including the organization of the mission and meetings and the responsive provision of information and other inputs requested. Special thanks go to the Office of Policy and Planning and the Office of Regional Field Operations. Finally, the team extends its appreciation to all the focal points and staff of the various agencies contributing to this work and all other actors from the public and private sectors and academia for their constructive engagement, participation in numerous meetings and phone calls, and written and oral input into this report.

Acronyms and abbreviations

AMPLE-CGE	Agricultural Market Model for Policy Evaluation–Computable General Equilibrium
AWD	Alternate wetting and drying
BFAR	Bureau of Fisheries and Aquatic Resources
CIAT	International Center for Tropical Agriculture
CRA	Climate-resilient agriculture
CSA	Climate-smart agriculture
CSL	Climate-smart livestock
DA	Department of Agriculture
FAO	Food and Agriculture Organization of the United Nations
GHG	Greenhouse gas
GVA	Gross value added
IPCC	Intergovernmental Panel on Climate Change
Mfg	Manufacturing
MIA	National Irrigation Administration
PHP	Philippine peso
PRDP	Philippine Rural Development Project
PSA	Philippine Statistics Authority
R&D	Research and development
SRI	System of rice intensification
SRP	Sustainable Rice Platform
RCEF	Rice Competitiveness Enhancement Fund
WFP	World Food Programme

Executive Summary

Climate change poses major risks to the Philippines' agriculture sector achieving sustainable growth and higher productivity. Agriculture is significantly affected by climate shocks that damage crops, livestock, and rural infrastructure, e.g., irrigation canals, post-harvest facilities, and rural roads, and disrupt the logistics of agriculture products and supplies. Increasing temperatures affect crop and livestock yields, foster greater pest incidence, and reduce labor productivity. These impacts contribute to food deficits, increased food insecurity, and considerable social and economic disruptions.

Evidence suggests climate change will cause yields and suitable growing areas of many crops to decline. In 2030, the biggest decline in yield and production is expected for maize, followed by sugarcane, then rice; in 2050, maize will be most affected, followed by bananas and rice. The yields of irrigated sugarcane are projected to decline because it is grown in areas where water is already scarce, and changes in precipitation due to climate change are expected to exacerbate this problem. The largest decline in per-capita consumption relative to the baseline is projected for food corn, followed by rice, sugar, and fruits and vegetables. Reduced agricultural production will lead to higher prices, causing significant hardship. Large price increases are foreseen across the board, with the biggest jumps affecting corn, rice, and fruits and vegetables.

Transitioning to climate-smart agriculture (CSA) will require adherence to multi-dimensional policy reform. At the farmer level, Farmers, fisherfolk, and other value chain participants can change their behaviors and technologies to make the agri-food system more climate-smart but require incentives and the capacity to do so. These changes can help producers adapt to a changing climate by strengthening the resilience of production and livelihoods to long-term rainfall and temperature trends and to short-term weather shocks, which may become more frequent and more severe with global warming. Additionally, these adjustments can mitigate greenhouse gas (GHG) emissions from production activities. Some behavioral and technological modifications will improve adaptation, some will enhance mitigation, and some will do both. Some support both adaptation and mitigation objectives while simultaneously bringing immediate increases in productivity and profitability for producers regardless of the effects of climate change—the “triple win.” Reforming agricultural support policies can encourage the adoption of diversified production systems, which tend to be more resilient to climate shocks.

Repurposing public spending towards subsidizing the adoption of CSA production technologies is critical. It will help farmers adapt to climate change, which benefits the farmers who make the investments. Many instruments are being used worldwide that provide direct payments to farmers aimed at making agriculture more climate-smart. One general approach is “payments for environmental services,” in which producers are paid directly either by the government or private parties for better management to enhance the benefits of natural resources or avoid some environmental damage. An alternative used in some countries, including the United States, the European Union, Vietnam, and China, supplies direct support payments to farmers contingent upon their actions to preserve the environment in some measurable way. Such conditional climate-smart payments can make agricultural support or subsidy reform programs more politically palatable since they allow farmers to maintain their incomes while incentivizing them to use more climate-smart practices. Research by the FAO in Africa has also shown the potential of social protection and food aid to increase the adoption of CSA by small-scale farmers.

Improving the enabling environment for the private sector can drive faster adoption of CSA. The commercial private sector (such as input vendors and firms working in agricultural value chains) could play an important role in driving CSA adoption but currently has limited incentives to do so. A key first step is identifying government policies and regulations that undercut private-sector incentives for necessary changes, and then working to lower or eliminate barriers that impede the private sector from taking climate-smart action. In some cases, removing obstacles may be insufficient, and providing direct financial incentives may be appropriate and necessary.

Key messages

- There are substantial opportunities for win-win actions that increase resilience and reduce emissions.
- Many climate actions require policy reforms rather than significant investments.

Main policy recommendations

Action	*Urgency*	*Pathway*		*Dev impact*	*Lead agency*
		A	*M*		
Accelerate adoption of improved practices such as AWD	High	+	++	++	DA
Improve resilience in agriculture through diversification	Med	+		+	DA
Extend irrigation in rainfed areas	Med	+		+	DA
Develop Fishery Management Plans that incorporate adaptive management based on on-going data of changes in migration patterns, stocking rates, etc.	High	+		++	DA/BFAR

Notes: A: Adaptation pathway; M: Mitigation pathway
+, ++ indicate the expected magnitude of benefits in terms of increased resilience, reduced emissions, and overall development impact.
Lead Agencies: BFAR: Bureau of Fisheries and Aquatic Resources; DA: Department of Agriculture

1 Introduction

As the Philippine economy reached a lower-middle-income status, the agricultural sector's share in the economy declined as expected, reaching 10 percent of the gross domestic product. However, agriculture remains critical to food security, employment, and poverty reduction in the Philippines. The sector employs around 24.4 percent of the economically active population (World Bank, 2022; FAO, 2022). The poverty incidence among farmers and fisherfolk is nearly three times higher than among urban households (World Bank, 2020). Agriculture's share of the gross domestic product is expected to continue to decline while other economic sectors expand as part of a structural transformation. Yet agricultural sector growth in the past decade has been unusually weak (World Bank, 2020). A combination of factors, including the prevalence of small-scale and fragmented farms, a lack of infrastructure, and policy and institutional barriers, has left the sector underdeveloped and unable to meet the food requirements of the growing population (Dikitanan and others, 2017). Low rice productivity and a failure to diversify into high-value-added products are key issues in the suboptimal sectoral growth (World Bank, 2020).

Agriculture has not performed as well in the Philippines compared to other countries in the region in terms of overall sectoral growth and per-capita production of different product categories. Agricultural total factor productivity has increased by 32 percent in the Philippines over the past quarter-century, much lower than Indonesia at 50 percent, Thailand at 67 percent, Vietnam at 73 percent, and China at 130 percent. Worryingly, the agricultural total factor productivity growth rate in the Philippines has been steadily declining since 1970. This trajectory is not sustainable for a country with ample but not unlimited natural resources and a rapidly aging cadre of farmers. Notably, the growing domestic and regional demand for animal products and other high-value foods has generally not been met by the requisite supply response in the Philippines, even with some outlier success stories.

Despite high levels of rice production—the country's staple crop—the Philippines is one of the world's biggest rice importers. Sixty-three percent of the rice production area is irrigated, with the remainder rainfed (NIA, 2022; PSA, 2021). Rice yields have grown steadily, reaching 4.1 tons per hectare on average in 2020 (FAO, 2022). The mean rice yield gap—the difference between the mean and potential farm yield—is still large, especially in Central Luzon, where it is estimated at 3.8 and 4.8 tons per hectare in the wet and dry seasons, respectively (Silva and others, 2016). The amount of rice produced relative to domestic consumption remains insufficient to feed the Philippine population of around 110 million, and imports fill this gap. In 2020, the country was the world's second-largest rice importer (FAO, 2022).

Climate-related risks threaten the agriculture sector. Due to its geographic position and archipelagic formation, the country ranks fourth most affected by extreme weather events from 2000 to 2019 (Eckstein and others, 2021). The agricultural sector bears a large share of the damage from climate-related hazards. The Philippine Statistics Authority (PSA) estimates the damage from natural extreme events and disasters from 2010 to 2019 at around USD9 billion. Agricultural damage accounted for 63 percent of this value. Of these extreme events and disasters, the vast majority, 120, were meteorological disasters, with 16 geophysical disasters, like volcanic activities and earthquakes, and two meteorological incidents. Agricultural damage mainly occurs from meteorological disasters like typhoons 81 percent of the time, followed by climatological disasters like droughts and the El Niño in 18 percent of cases (PSA, 2020). Overall, climate hazards like typhoons, floods, and droughts negatively affect the production of staple crops, livestock, and fisheries.

Climate change is projected to negatively impact agriculture, disproportionately impacting the most vulnerable people. Puhlin and Tapia (2016) estimate that agricultural productivity in the Philippines will decline by 9 to 21 percent by 2050 due to climate change, largely driven by extreme events like typhoons, floods, and drought. Sea-based hazards like sea-level rise, storm surges, and saltwater intrusion will also have major impacts on coastal and freshwater fisheries, particularly in the marginalized coastal communities of Visayas and Mindanao (CIAT and WFP, 2021). Most agricultural areas across the country are rain-fed, making them very vulnerable to climate change

(CIAT and WFP, 2021).[1] Given the agricultural sector's acute exposure, rural communities are especially at risk of negative consequences.

Climate variability and hazards are projected to have the greatest consequences for on-farm production, with substantial impacts on the agriculture, livestock, and fisheries supply chains. Smallholder producers, who practice mono-cropping or backyard farming and have limited resources, are among the most vulnerable and are likely to be significantly affected. Smallholder farmers risk facing severe consequences if a disaster occurs in the Philippines. They must contend with challenges and constraints such as poor performance of their irrigation system and a lack of access to improved CSA technologies, especially those related to drought- or flood-resistant crop varieties, improved fertilizer management, or extension services. Similarly, a lack of access to finance to make investments, storage facilities to reduce postharvest losses, and agricultural insurance also impact smallholder farmers. World Bank field research was conducted in four municipalities of Guiuan and Salcedo in Samar and General Luna (Siargao Island) and San Francisco (mainland) in Caraga province, all located in highly vulnerable coastal areas. Smallholder farmers in Salcedo and Guiuan reported that climate change is already negatively impacting their lives and livelihoods. The respondents reported a reduction in the productivity of their farms in the past few years due to increased climate variability, including prolonged dry spells and frequent and more intense precipitation. Extended periods of high temperatures have threatened rice and food production[2] and reduced water accessibility and affordability (CTI Engineering International and others, 2008). The intrusion of saltwater into the groundwater sources has affected the water supply for agricultural production, and farmers reported an increased incidence of plant infestation during dry spells. Farmers explain how it takes a long time to restore parched soil after a drought and how re-fertilization costs have increased the burden on farmers (World Bank, 2022).

Communities highly dependent on fishing for their livelihoods have also observed that the previously rich fishing grounds of the Pacific Ocean are less reliable as repeated typhoons batter the coral reefs, and weather and seasons become less predictable. Small-scale fishers in Samar and Caraga reported that they have to venture further into the sea to catch fish but still report a harvest reduced by up to 80 percent. They also experience shorter fishing seasons due to increasingly unpredictable weather patterns, such as heavy rainfall during the summer months of March to April and stronger typhoons between November and January. Livelihoods are challenged, and households are left with limited resources to rely on during repeated disaster events. Only a few households have identified other sources of income as options in these areas remain extremely limited.

The poor lack the assets and knowledge required to change their livelihood or enhance the climate resilience of farming and fishing. Instead, poor households adopt several negative coping behaviors to survive. Testimonies of succumbing to a 'debt trap' are common as climate change has triggered a reliance on micro-credit organizations for access to uncollateralized loans. The amount households can borrow is normally insufficient for their requirements, or households struggle to make the debt payments forcing them to take loans from other sources, including loan sharks that levy high monthly interest rates. To augment the family's income, many children drop out of school to work on the piers as *kargadors* (porters) carrying Styrofoam boxes of iced fish for traders. Women migrate for work, straining family structures and disrupting the traditional source of emotional support (World Bank, 2022).

The agriculture sector has not seen sustained growth and productivity due in part to a focus on rice self-sufficiency[3] and legacy agricultural policies with limited focus on climate resilience.

---

[1] CIAT and WFP (2021) indicate that rainfed, often sloping, agricultural zones will be most affected by climate impacts, and that rainfed farmers, who also tend to be relatively poor, will comprise the majority of people impacted. Hence adaptation will be important for complex, sloping land farming areas, where farmers are less organized and accessible.

[2] Studies by the International Rice Research Institute (IRRI) show that rice yield decreased by at least 10 percent for each 1°C increase in growing-season minimum temperature in the dry season (IRRI).

[3] New agricultural policies and reforms, particularly the Rice Liberalization Act, signal a positive development, and the Rice Competitiveness Enhancement Fund (RCEF) supports affected rice farmers. Recently implemented policies have

The goal of rice self-sufficiency has meant that significant government resources and policies are aimed at increasing rice production, crowding out support for more nutritious foods and high-value commodities. Before the rice sector liberalization in 2019, producers were protected and had few incentives to change their practices and lower production costs. This resulted in sub-optimal productivity and competitiveness, with yields far below the average for Southeast Asian comparator countries despite substantial government support. This situation had spillover effects: firstly, limiting diversification into high-value-added products for local consumption and export, and secondly, constraining the integration of farmers into value chains, thereby undermining the rice sector's poverty reduction agenda. Public expenditure misalignment and agricultural support measures encourage high resource use intensity, e.g., water, land, and inputs, and unsustainable practices by farmers. Institutional capacity challenges hamper more effective delivery of key agricultural services. Furthermore, low rice profit margins compared to other commodities, coupled with the limited opportunities for price premiums for sustainably produced rice in the Philippines, especially at the local level, further discourage farmer adoption of low carbon technologies.

While agriculture contributes to food security and livelihoods, it can also exacerbate environmental degradation, including deforestation and biodiversity loss, water pollution, and the depletion of aquifers. Cultivating fragile and marginal upland areas can lead to deforestation, accelerated soil erosion, the sedimentation of rivers, and other cascading impacts. Overuse of inorganic fertilizers in rice and other cropping systems releases nutrients into water bodies through runoff and leaching, contaminating domestic water sources. Furthermore, pollution due to animal waste from the livestock sector can negatively affect water bodies and quality, even making the water unfit for irrigation (World Bank, 2016).

---

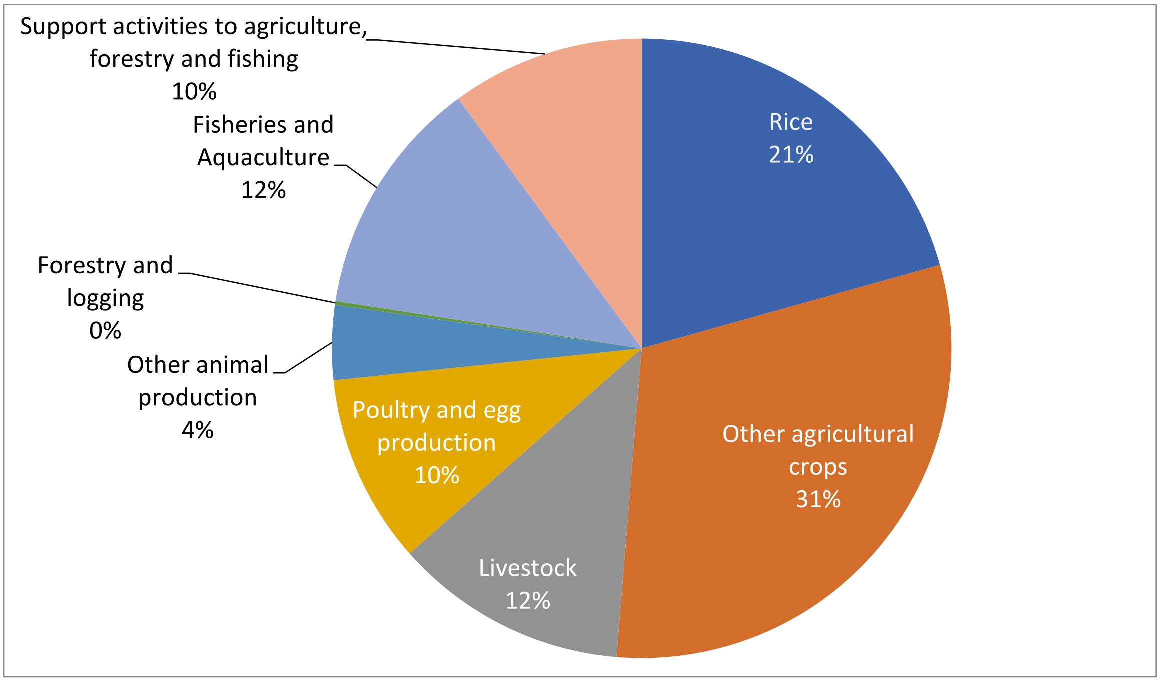
appropriately focused on modernizing, industrializing, consolidating, and professionalizing the agricultural sector. The Rice Liberalization Act (RA 11203), which in early 2019 abolished the quota system—a long-standing instrument to protect rice production—is indicative of this strategic shift. This policy was a fundamental reform and is the most important building block for achieving agricultural transformation in the Philippines toward a more competitive, diversified sector, where farmers can realize higher incomes. The RCEF has so far only sought to improve the productivity of rice farmers. Less competitive rice farmers—particularly in rainfed production systems—may instead need support to diversify into other, more profitable farm and non-farm activities. Other DA programs also overemphasize food staples, particularly rice.

2 The impacts of the Philippine agri-food system on climate change

Rice and livestock, particularly hogs, are the main economic contributors to agriculture and total agricultural GHG emissions in the Philippines. Among subsectors, crops comprised about half the gross value added (GVA) in the agriculture, forestry, and fisheries sectors (Figure 1). Rice was responsible for the biggest share among all crops, followed by banana, corn, and coconut. Rice is also the country's main staple and a primary source of livelihood in agricultural communities. Livestock accounted for around 12 percent; hogs make up most of the livestock production at 82 percent.

Around one-fourth of the GHG emissions in the Philippines, totaling 258 $MtCO_2e$, come from the agricultural sector. At 64 percent and 23 percent, respectively, rice and livestock contributed the most to total agricultural GHG emissions in 2019 (FAO, 2022) (Figure 2). The two main sources of GHG emissions from rice cultivation are firstly methane (Figure 3), which is 25 times more potent than carbon dioxide in trapping atmospheric heat, from the decomposition of organic amendments used for fertilization, and secondly methane emissions from the anaerobic decomposition of rice straw and husks (Arnaoudov and others, 2015). The Philippines has high GHG emissions intensity in rice production in Asia (Figure 3). Other sources are (i) CO_2 from burning of rice residues such as rice straw/husks after harvest, and (ii) post-harvest losses due to value chain inefficiencies, such as lower milling efficiency, i.e., the ratio of rice output to paddy input, being only 63 percent[4] (Figure 4). Modern mills can reach 70 percent. Livestock sources of methane are enteric fermentation and poor manure management. The cattle and carabao—Philippine water buffalo—industry is responsible for the highest emissions from enteric fermentation. Hogs are the largest source of manure-related emissions. The backyard and small commercial farms usually generate more untreated and ill-disposed waste due to farrow-to-wean operations. (World Bank, 2016).

Figure 1: Distribution of gross value added in agriculture, forestry, and fisheries by subsector in 2020

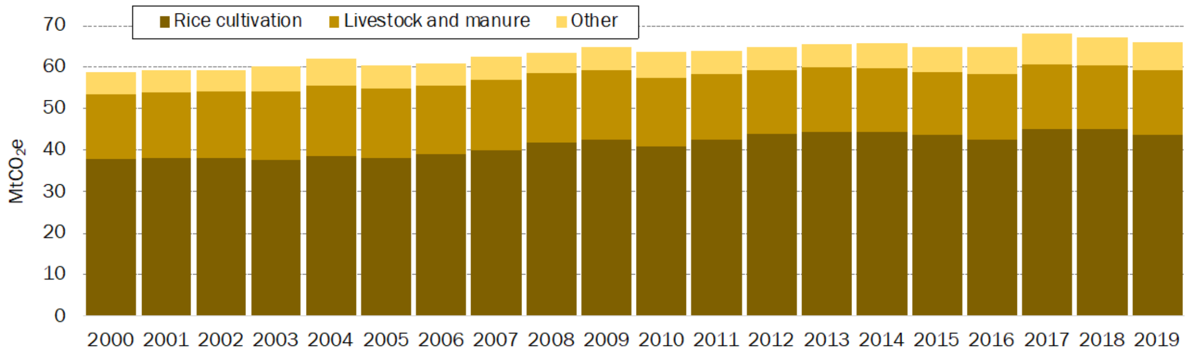


Source: CCDR Agriculture Team calculations based on PSA data.

---

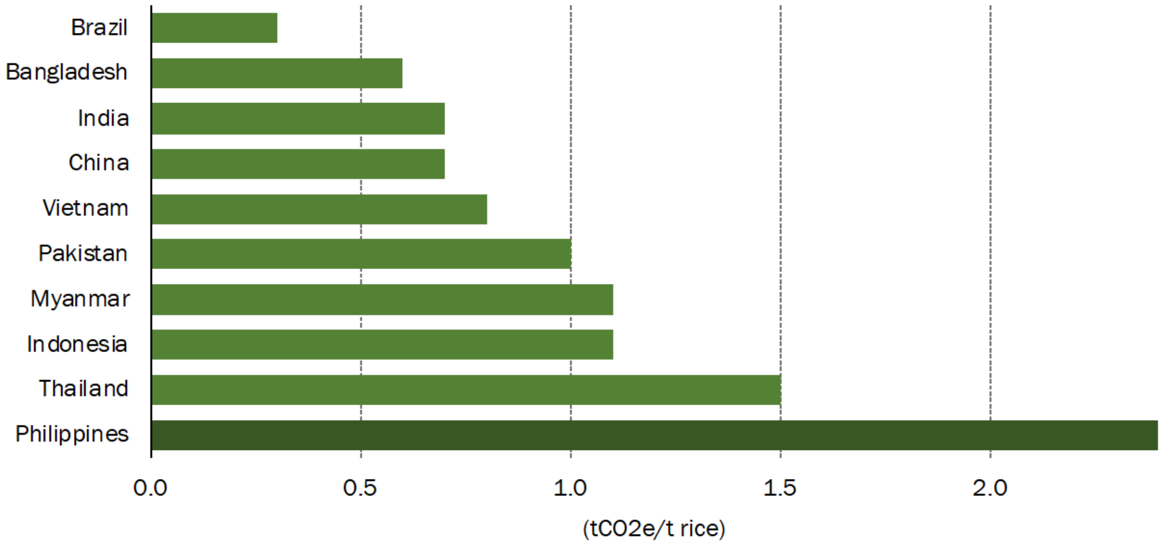
[4] Official estimates remains at 65.4 percent

Figure 2: Agricultural GHG emissions in the Philippines



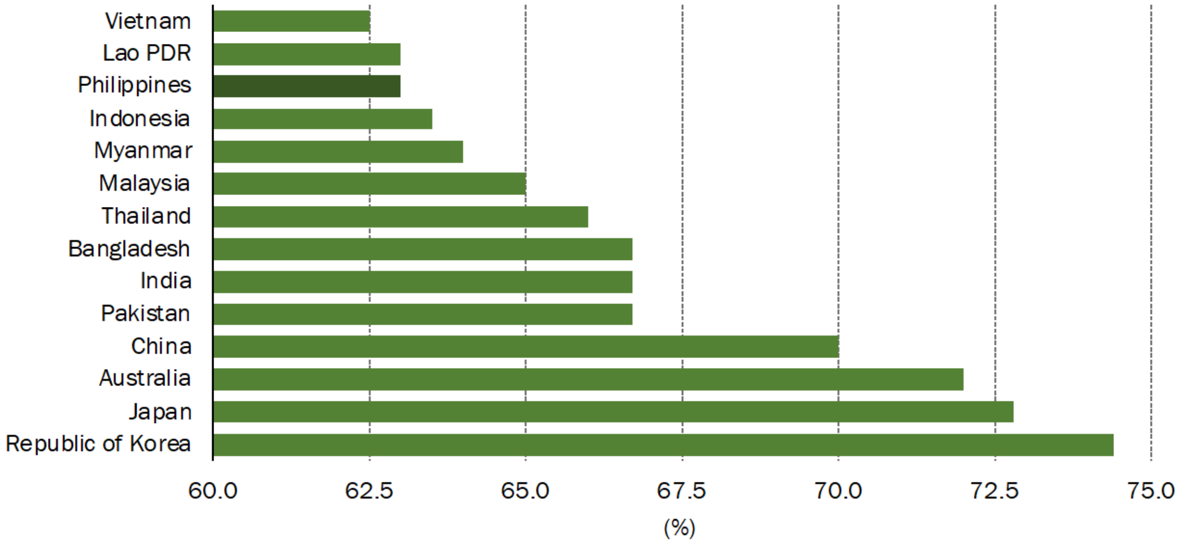
Note: This does not include emissions from forest loss.
Source: FAO data.

Figure 3: Intensity of methane emissions from rice farming



Source: World Bank staff calculation from FAOSTAT and CIAT climate data explorer (2018)

Figure 4: Rice milling efficiency in Asia



Source: United States Department of Agriculture data for 2021 from https://www.indexmundi.com

Intensive cultivation has caused land degradation affecting agricultural productivity and ecosystem services and contributing to GHG emissions. Agricultural land expansion, especially into forest areas, has contributed to significant GHG emissions and biodiversity loss. Widespread logging and the expansion of agriculture into upland areas have caused significant deforestation, with forest land decreasing from 7.8 million hectares in 1990 to 6.8 million hectares in 2010. Reforestation began in 2011 with a National Greening Program, but despite these efforts, the Philippines lost 0.7 million hectares of tree coverfrom 2011 to 2020, equivalent to 448 $MtCO_2e$ (GFW, 2022). Unsustainable farming, especially in upland areas, has resulted in soil degradation by reducing the productive potential of soils and accelerating erosion.

3 Projected impacts of climate change on the Philippine agri-food system

The Philippines is projected to experience diverse impacts from climate change, including rising temperatures, rising sea levels, saltwater intrusion, and increasing variability in annual rainfall. These will impact crop farming, negatively affecting food security and nutrition. Large declines in yield and production are expected for corn and other crops. Typhoons, climate shocks, and disasters also pose localized risks that can diminish crop production.

3.1 Climate projections for the Philippines

It is projected that average temperatures and sea levels will climb dramatically in the Philippines within the century, even under a moderate emission scenario; the effects of climatic extremes are less certain. The latest estimates from the Philippine Atmospheric, Geophysical and Astronomical Services Administration, the country's meteorology bureau, find that the mean temperature increase for the country was 0.68 °C or 0.1 °C per decade over the period 1951–2015 (DOST, 2018). Projections for the rest of the century are relative to the mean temperatures from 1971 to 2000 (Table 1). Under a moderate emission scenario, the mean temperatures will be 1–2 °C higher by 2065 and up to 2.5 °C higher by 2099. Under a high emission scenario, an increase of 2 °C will occur much earlier, before 2065; the rise in temperatures by 2099 may exceed 4 °C. For sea levels, estimated increases in some parts of the country were double the global average over the period 1951–2015, reaching 5.7 to 7.0 mm per year; by 2100, they are projected to climb one-fifth of a meter regardless of the emission scenario.

Table 1: Projected change in mean temperature by period and scenario (°C)

	2036–65	*2070–99*
Moderate	0.9–1.9	1.3–2.5
High	1.2–2.3	2.5–4.1

Source: PAGASA

Annual rainfall is expected to increase overall, with a decrease in rainfall during the dry season. Annual rainfall from 2000 to 2050 is projected to decline in Northern Luzon and Central and Western Mindanao but grow in Central Luzon, Eastern Visayas, and Western Mindanao (Table 2). Mindanao remains the wettest island group; the Visayas is expected to overtake Luzon as the second wettest area. Two out of four models predict lower rainfall during the driest three months of the year (Thomas and others, 2019).

Table 2: Projected changes in average annual rainfall by island region

(percentage)

Island region	*Total rainfall 1950–2000 (median, in mm)*	*2000–2050*			
		Model 1	*Model 2*	*Model 3*	*Model 4*
Luzon	2,465	6.8	10.2	9.5	10.1
Visayas	2,431	12.7	21.8	12.2	10.7
Mindanao	2,585	12.7	9.3	7.7	11.2
Total	**2,491**	**9.9**	**12.0**	**9.4**	**10.6**
Driest quarter	256	-15.2	28.9	12.1	-30.1

Source: Thomas and others, 2019.

Tropical cyclones may become slightly less frequent, although very severe cyclones may see a minimal increase in frequency over the century. On a global scale, higher sea surface and subsurface temperatures fuel typhoons and remove cold-water upwelling, which limits typhoon formation. In the Philippines, stronger typhoons place the population at greater risk, especially in coastal zones experiencing land degradation, such as places with depleted mangrove cover (Holden and Marshall, 2018).

3.2 The impacts of climate change on agriculture

Higher temperatures will negatively affect crop farming by increasing plant stress, reducing the suitable growing area for crops, and lowering overall yields. Local-level studies suggest a range of adverse impacts on cereal growth. In Isabela Province, a major corn-growing region in the northern Philippines, the area highly suitable for corn will shrink by about 5 percent by 2050 (Salvacion and Martin, 2016). Upland rice farming in the northern Philippines faces an added risk of water deficits during the dry season and flooding during the wet season (Soriano and Herath, 2019). This highlights the need for research and development (R&D) and dissemination of more heat-resistant crops, especially corn, and drought and flood-resistant rice varieties.

Thomas and others (2019) compiled national-level impact estimates for selected crops based on biophysical modeling (Table 3). The projected changes in yield are mostly negative, increasing to a 25 percent decline except for coconut. Yield declines are bigger for rainfed crops, given even greater water deficits during the dry season. These estimates are based on the assumption of static crop management practices. When the crop management shifts by simply changing the planting month, the negative growth impacts reverse, suggesting that the pathway of impact from climate change to crop yield is via changes in seasonal variation patterns. Hence, for instance, in irrigated areas, sugarcane crop yield switches from a -4.7 percent change (2000 – 2050) to a 0.7 percent change; for rice, the switch is from a -0.4 percent chance to a 1.2 percent change, under low fertilizer application. Meanwhile, for rainfed areas, the changes are much sharper: for sugarcane, the switch is from -4.7 percent to 1.6 percent; for maize, from -19.5 percent to 4.9 percent; and for rice, from -19.5 percent to 4.9 percent (both under lower fertilizer application).

Table 3: Projected yield changes due to climate change by island group and crop, from 2000 to 2050

(percentage)

Island group	*Rainfed rice*	*Irrigated rice*	*Rainfed maize*	*Rainfed sugarcane*	*Irrigated sugarcane*	*Coconut*	*Banana*
Luzon	-7.4	-0.1	-20.6	-8.6	-3.5	1.4	-11.2
Visayas	-4.1	-0.6	-25.0	-5.8	-5.5	0.9	-4.8
Mindanao	-0.5	0.7	-21.2	-0.5	-1.2	2.5	-1.4
Total	-4.5	0.0	-21.6	-4.7	-4.3	1.7	-3.7

Source: Thomas and others, 2019.

Adverse impacts on agriculture could worsen food insecurity because of climate change. Perez and Rosegrant (2019) incorporate the aforementioned biophysical projections into a partial equilibrium model for the Philippines in conjunction with the global International Model for Policy Analysis of Agricultural Commodities and Trade projections. Higher food prices worldwide and diminished crop yields lead to lower per-capita consumption compared to a baseline scenario without climate change. Model results are based on the average across four circulation models (Thomas and others, 2019) (Table 4).

In 2030, the biggest decline in yield and production is expected for corn, followed by sugarcane, then rice. By 2050, corn followed by rice will experience the largest yield decrease. Some other crops, however, are likely to experience improvements in yield, though production will only be higher under climate change for fruits and vegetables. Substantial price increases are foreseen across the board, with the biggest jumps impacting corn, rice, and fruits and vegetables. The greatest decline in per-capita consumption relative to the baseline is projected for food corn, followed by rice, sugar, and fruits and vegetables.

Table 4: Projected impact of climate change relative to 2030 and 2050 baselines, by crop

(percentage change relative to baseline)

	Yield		*Crop production*		*Prices*		*Consumption*	
	2030	**2050**	**2030**	**2050**	**2030**	**2050**	**2030**	**2050**
Corn	-7.6	-15.7	-5.6	-13.0	22.7	44.4	-3.2	-5.6
Rice	-1.7	-4.1	-0.6	-3.2	12.0	17.2	-2.2	-2.9
Fruits and vegetables	1.4	1.9	2.0	3.9	6.1	11.1	-1.2	-2.3
Pulses	0.3	0.7	-0.3	0.5	2.3	12.7	-0.2	-0.4
Roots and tubers	0.0	0.2	-0.5	-0.5	6.1	11.6	-0.5	-0.9
Sugarcane	-4.1	-8.3	-1.8	-3.0	3.9	5.8	-1.3	-2.4

Source: Perez and Rosegrant, 2019.

These production and market trends are likely to translate into a greater number of malnourished children and a larger population at risk of hunger. By 2030, without climate change, it is estimated that there would be 16.11 million persons at risk of hunger, similar to the base figure of 16.09 million in 2010; by 2050, this number will decline marginally to 15.16 million (Table 5). With climate change, however, the number of at-risk persons will be 8 percent higher in 2030 at 17.4 million, rising 12.8 percent higher by 2050. Similarly, without climate change, malnourished children will number 2.7 million in 2030, much lower than the base figure of 3.1 million in 2010. The number will fall to 2.2 million by 2050. With climate change, however, the number of malnourished children will be 1.5 percent higher in 2030, rising by 2.7 percent in 2050.

Table 5: Projected impacts of climate change on food security from 2010 to 2050 in millions

Scenario	*Malnourished children (million)*			*The population at risk of hunger (million)*		
Year	**2010**	**2030**	**2050**	**2010**	**2030**	**2050**
Without climate change	3.07	2.70	2.15	16.09	16.11	15.16
With climate change	3.07	2.74	2.20	16.09	17.40	17.11
Percentage difference	0.00	1.50	2.70	0.00	8.00	12.80

Source: Perez and Rosegrant, 2019.

The top rice-producing provinces of Nueva Ecija, Isabela, Pangasinan, Iloilo, Cagayan Valley, and Camarines Sur are acutely exposed to typhoons. A southward shift in the typhoon belt has been observed, so more rice-producing provinces in the Visayas and even Mindanao will be vulnerable to typhoons in the future (CIAT and WFP, 2021). Furthermore, due to climate change, typhoons are projected to worsen in intensity (Webster and others, 2005). Provinces where the predominant livelihoods involve livestock, including Apayao, Abra, Kalinga, Mountain Province, Ifugao, Benguet, and Nueva Vizcaya, are also expected to be negatively affected by climate-related hazards and are at risk of heat stress (CIAT and WFP, 2021).

Climate shocks are a risk that can lead to rapid increases in the prices of basic goods, mainly due to supply chain disruptions. In 2020, the inflation rate rose to 3.3 percent in November from 2.5 percent in October due in part to tropical cyclones Rolly (Goni) and Ulysses (Vamco) (PSA, 2022). Low-income consumers are particularly at risk from elevated food prices since they spend more of their income on food. These tropical cyclones badly hit Luzon in early to mid-November 2020; they caused massive damage to agriculture and fisheries, destroying rice, corn, high-value crops, agricultural equipment, boats, fishing gear, and other livelihood assets and resources.

Some rice production areas are expected to be less suitable for production and to experience acuter exposure to climate-related hazards like droughts and typhoons. Changes in rainfall, both in the total rainfall and its timing, can affect production. Increased rainfall at the wrong time can damage plants and multiply diseases and pests, while longer droughts also pose problems. Typhoons can cause significant damage to rice production by subjecting it to strong winds and excessive rainfall. They can also damage irrigation systems and post-harvest facilities and reduce market accessibility. Unpredictable or heavy rains might diminish the quality of harvests for those who depend on sunlight for drying. Furthermore, a lack of local storage capacity contributes to post-harvest losses when the distribution is slow, or aggregation points are inaccessible post-disaster (WFP, 2018).

Climate change may not significantly harm rice production and productivity at the national level but could have substantial negative consequences locally. Furthermore, while national production may expand, serious regional shortfalls may impact food security, such as when severe natural disasters occur (Israel and Briones, 2012). The results of future crop suitability models, including the latest evidence from typhoon Odette for rice, show that all major areas will experience production suitability losses from heightened exposure to climate-related hazards, particularly extreme rainfall events and droughts. By 2050, rising temperatures are expected to be conducive to the spread of plant diseases. Consequently, this situation could result in pesticide overuse. Rice sheath blight, bacterial sheath blight, and rice blasts are the diseases projected to increase in frequency and inflict the most damage on the rice sector (CIAT and WFP, 2021).

Climate change is likely to worsen stressors for livestock raising, though quantitative impacts on livestock farming productivity are unavailable. The key domesticated terrestrial animals, i.e., goats, cattle, poultry, and swine, realize optimum growing conditions within a band of temperature and humidity found in a 'thermoneutral zone'. Animals outside this zone may experience depressed growth, lower meat quality, lower immune functions, and lower reproductive performance in both male and female breeders. Zones currently growing livestock vulnerable to changes that may bring them out of the thermoneutral zone by 2050 include municipalities in Apayao, Abra, Kalinga, Mountain Province, Ifugao, Benguet, and Nueva Vizcaya, all in Luzon (CIAT and WFP, 2021).

3.3 Modeling the impacts of climate change on agriculture

This study utilizes the Agricultural Market Model for Policy Evaluation–Computable General Equilibrium (AMPLE-CGE) to evaluate the impacts of climate change on agricultural production in the Philippines (Box 1). Results are presented in this section. Data for the model was drawn from various sources, and the model involves several scenarios.

3.3.1 Aggregate-level outcomes

Climate change is associated with slower growth of the agricultural GVA, government savings, and agricultural wages. The slower growth of the agricultural GVA implies a 2 percent lower output level in 2050 (Table 6). Similarly, agricultural wages will diminish in 2050 as weakening economic activity limits labor demand. Government savings will shrink by 13 percent due to smaller outputs and less tax collection.

Climate change adaptation reverses these trends to a large extent, even if adaptation measures are only incorporated for two crops, namely rice and corn. By 2050, with adaptation, the agricultural GVA will be 10 percent higher, while agricultural wages may decline by 4 percent. Government savings will also decline by 3 percent, despite larger outlays for government consumption and a shift into increased capital formation for irrigation development.

Table 6: Changes in aggregate-level outcomes from 2018 to 2050

(change relative to baseline)

Outcome	*Base-year value (PHP, billions)*	*Climate change (%)*		*Adaptation (%)*	
		Change in growth	*Difference by 2050*	*Change in growth*	*Difference by 2050*
Real agricultural GVA	1,875.57	-0.06	-1.95	0.31	10.16
Government savings	553.07	-0.47	-13.41	-0.14	-4.18
Agricultural wages	1.00	-0.09	-2.94	0.02	0.78

Note: The change in growth is expressed in terms of percentage points.
Source: CCDR Agriculture Team calculations.

Box 1: The Agricultural Market Model for Policy Evaluation – Computable General Equilibrium

The Agricultural Market Model for Policy Evaluation – Computable General Equilibrium (AMPLE-CGE) is a 38-sector computable general equilibrium model of the Philippines that emphasizes agro-industrial sectors. The model incorporates twenty agro-industrial sectors: palay, corn, coconut, sugarcane, banana, livestock, poultry, agricultural services such as forestry, capture fishery, aquaculture, meat and dairy, plant-based processing, rice and corn milling, sugar, animal feed, beverages, tobacco, other food manufacturing, other cereals, and other crops.

As with other computable general equilibrium models, the AMPLE-CGE generates projections for output, exports, imports, producer and consumer prices, and per-capita and total household consumption. For crops, the model can project yield and area harvested. Lastly, it also generates projections for factor markets, namely labor employment in agriculture and outside agriculture, as well as capital utilization, which is assumed to be perfectly mobile across sectors. It determines the wage rates of different labor types and the capital rental cost. The model solution uniquely indicates only relative prices; economic values are expressed with a fixed value of the Consumer Price Index. The adaptation scenario involves a reversal of negative productivity shocks due to climate change, attributed to rice and corn, based on Perez and Rosegrant (2019). Adaptation practices and technologies under this scenario adjust to the water stresses posited under the climate change scenario while addressing productivity deficits in cereal farming—particularly rice —such as low fertilization rates. Note that the estimate for rice adaptation shock has been reduced by one-half in the revised figures.

3.3.2 Output changes

Climate change leads to lower outputs from selected major agro-industries, although adaptation halts these losses. Key agro-industries such as palay, corn, livestock, poultry, fisheries, rice and corn milling, and other food manufacturing (mfg.) will all experience slower output growth than the baseline (Table 7). By 2050, the output will be as much as 14 percent lower for livestock and 12 percent lower for poultry. Output changes will be the smallest for cereals and cereal products, as these will be buoyed up by rising world prices and natural import substitution under climate change.

Table 7: Changes in agro-industrial sector output from 2018 to 2050

(percent points change relative to baseline)

Industry	*Base-year value (PHP, billions)*	*Climate change (%)*		*Adaptation (%)*	
		Change in growth	*Difference by 2050*	*Change in growth*	*Difference by 2050*
Palay	501.00	-0.09	-2.77	0.78	27.87
Corn	138.86	-0.03	-0.98	0.49	16.69
Coconut	93.42	0.21	6.69	0.37	12.41
Sugarcane	40.86	0.21	6.74	0.34	11.17
Banana	169.74	0.50	16.89	0.55	18.86
Other crops	231.66	0.44	14.93	0.57	19.65
Livestock	770.22	-0.50	-14.41	-0.08	-2.36
Poultry	630.33	-0.42	-12.25	-0.09	-2.71
Agricultural services	246.89	-0.11	-3.40	0.27	8.73
Capture fishery	337.87	-0.18	-5.61	0.00	-0.14
Aquaculture	253.71	-0.21	-6.46	-0.03	-0.91
Meat and dairy	524.62	0.05	1.49	0.23	7.36
Plant-based processing	903.91	0.27	8.84	0.46	15.43
Rice and corn milling	674.85	-0.12	-3.78	0.61	21.26
Other cereal mfg.	1,999.29	-0.22	-6.72	-0.05	-1.55
Sugar mfg.	166.71	0.23	7.37	0.35	11.77
Other food mfg.	253.10	-0.20	-6.21	-0.03	-0.96
Animal feed mfg.	303.22	-0.39	-11.59	-0.02	-0.59
Beverage and tobacco mfg.	368.87	0.70	24.30	0.77	27.20

Source: CCDR Agriculture Team calculations.

Table 8: Changes in crop yields from 2018 to 2050

(percent points change relative to baseline)

Industry	Climate change (%)		Adaptation (%)	
	Change in growth	Difference by 2050	Change in growth	Difference by 2050
Palay	0.06	1.90	0.87	31.43
Corn	-0.02	-0.76	0.53	18.03
Coconut	0.36	11.96	0.35	11.68
Sugarcane	0.29	9.58	0.18	5.77
Banana	0.45	15.23	0.40	13.52
Other crops	0.46	15.60	0.46	15.39

Source: CCDR Agriculture Team calculations.

Table 9: Changes in the area harvested from 2018 to 2050

(percent points change relative to baseline)

Industry	Base year value ('000 ha)	Climate change (%)		Adaptation (%)	
		Change in growth	Difference by 2050	Change in growth	Difference by 2050
Palay	4,725	-0.15	-4.58	-0.09	-2.73
Corn	2,590	-0.01	-0.26	-0.04	-1.13
Coconut	3,542	-0.15	-4.69	0.02	0.64
Sugarcane	434	-0.08	-2.64	0.16	5.09
Banana	448	0.04	1.44	0.14	4.71
Other crops	873	-0.02	-0.59	0.11	3.69

Source: CCDR Agriculture Team calculations.

Table 10: Changes in agro-industrial sector exports from 2018 to 2050

(percent points change relative to baseline)

Industry	Base-year value (PHP, billions)	Climate change (%)		Adaptation (%)	
		Change in growth	Difference by 2050	Change in growth	Difference by 2050
Palay	9.35	1.68	69.77	5.68	477.51
Corn	0.37	2.63	126.65	5.37	419.64
Coconut	0.73	0.73	26.57	0.69	24.67
Sugarcane	1.13	1.29	49.99	1.23	47.34
Banana	50.10	2.06	91.19	1.93	83.78
Other crops	18.97	2.29	103.83	2.31	105.12
Livestock	0.43	0.36	11.74	0.84	29.96
Poultry	0.27	0.55	18.73	0.91	32.56
Agricultural services	0.54	-0.03	-0.82	0.16	5.21
Capture fishery	3.95	-0.29	-8.70	-0.04	-1.33
Aquaculture	2.54	-0.32	-9.47	-0.06	-1.89
Meat and dairy	34.98	0.94	34.20	1.14	42.80
Plant-based processing	168.42	0.90	32.61	1.11	41.27
Rice and corn milling	2.67	1.91	81.88	4.76	334.13
Other cereal mfg.	45.91	-0.24	-7.28	-0.07	-2.27
Sugar mfg.	2.58	1.46	57.81	1.52	60.67
Other food mfg.	10.48	-0.26	-7.84	-0.06	-1.96
Animal feed mfg.	0.70	-0.76	-21.29	0.08	2.57
Beverage and tobacco mfg.	48.88	2.70	130.33	2.69	129.73

Source: CCDR Agriculture Team calculations.

For these agro-industries, climate change adaptation effectively reverses these trends, such that outputs are higher in 2050 compared to the baseline. The differences are largest for the crops in which climate change adaptation was undertaken, namely palay and corn; however, outputs are also elevated for poultry, livestock, and fisheries. Even under climate change, some major agro-industries will experience accelerated output growth due to trade, as explained below.

For crops, climate change will cause lower outputs rather than reduced yields due to less area harvested; adaptation will mostly accelerate growth in both yield and area harvested. The crops whose outputs will diminish are palay and corn; for both crops, the area harvested will suffer a relative contraction over the projection period (Table 9). In contrast, the palay yield will grow in relative terms, despite the negative productivity shock from climate change (Table 8). Hence, the projected output decline must be entirely due to the area harvested. The area harvested will also diminish for the other crops, except bananas. With adaptation, the area harvested will expand except for paddy rice, and yield growth will accelerate further, with yields as much as 83 percent higher for paddy. However, sugarcane will only realize a 6 percent increase.

3.3.3 Trade outcomes

Climate change will accelerate export growth for agro-industrial products, with an even more favorable export outcome under adaptation. According to the base-year values, the major export agro-industries with exports over PHP 5 billion are palay[5], bananas, other crops, meat and dairy, plant-based processing, other cereal mfg., other food mfg., and beverage and tobacco mfg. (Table 10). Exports in 13 these sectors will dramatically increase by 2050, except for other cereal and other food mfg., due to higher world prices resulting from climate change. Even minor exports such as corn, sugar, or sugarcane will show faster export growth. Meanwhile, the positive productivity shock due to climate change adaptation leads to an even greater expansion of exports at the baseline.

Table 11: Changes in agro-industrial sector imports from 2018 to 2050

(percent points change relative to baseline)

Industry	*Base-year value (PHP, billions)*	*Climate change (%)*		*Adaptation (%)*	
		Change in growth	*Difference by 2050*	*Change in growth*	*Difference by 2050*
Palay	5.79	-1.93	-45.40	-6.75	-88.65
Corn	14.04	-2.66	-57.01	-3.89	-71.10
Coconut	5.81	-0.35	-10.17	0.34	10.89
Sugarcane	0.98	-0.93	-25.28	-0.33	-9.91
Banana	0.63	-2.37	-52.59	-1.59	-39.22
Other crops	47.18	-1.80	-43.42	-1.34	-34.47
Livestock	1.23	-1.34	-34.47	-0.73	-20.44
Poultry	1.91	-1.37	-35.17	-0.85	-23.37
Agricultural services	0.45	-0.20	-5.93	0.90	32.31
Capture fishery	0.16	-0.08	-2.34	0.19	6.13
Aquaculture	0.17	-0.11	-3.30	0.17	5.35
Meat and dairy	138.53	-1.00	-27.15	-0.72	-20.27
Plant-based processing	160.89	-0.67	-19.12	-0.37	-11.09
Rice and corn milling	42.59	-2.15	-49.42	-4.64	-77.44
Other cereal mfg.	68.83	-0.20	-6.13	0.11	3.63
Sugar mfg.	24.00	-1.04	-28.02	-0.70	-19.74
Other food mfg.	79.61	-0.14	-4.41	0.10	3.30
Animal feed mfg.	83.19	-0.02	-0.63	0.06	1.76
Beverage and tobacco mfg.	36.48	-2.30	-51.97	-1.93	-45.86

Source: CCDR Agriculture Team calculations.

---

[5] The Philippines only exports some amount of paddy seed and heirloom rice as paddy rice.

Climate change is projected to decelerate growth for agro-industrial imports, with adaptation causing an even sharper slowdown. Climate change implies higher world prices; hence, imports woi;d decline (Table 11). For key industries, the drop in imports by 2050 will be enormous, involving decreases of 57 percent for corn, 52 percent for beverages and tobacco, 49 percent for rice and corn milling, and 43 percent for other crops. Climate change adaptation will deepen the reduction in imports; under these conditions, rice and corn milling will plunge 77 percent, corn will dip by 71 percent, and beverage and tobacco mfg. imports will slide 46 percent.

3.3.4 Consumption outcomes

Climate change causes higher consumer prices, which are only partly offset by adaptation measures. Worsening scarcity under climate change leads to heightened consumer and retail prices for most agro-industries except bananas, agricultural services, beverages, and tobacco (Table 12). By 2050 the largest price increases are expected for corn at 12 percent, rice and corn milling at 7 percent, and palay at 7 percent. Climate change adaptation reverses the trend for palay and corn, as well as for rice and corn milling; however, the rest of the agro-industries are expected to experience climbing consumer prices on the horizon.

Table 12: Changes in agro-industrial-sector consumer prices from 2018 to 2050

(percentage points change relative to baseline)

	Climate change (%)		*Adaptation (%)*	
Industry	*Change in growth*	*Difference by 2050*	*Change in growth*	*Difference by 2050*
Palay	0.22	7.16	-1.32	-34.65
Corn	0.36	12.10	-0.11	-3.44
Coconut	0.06	1.83	0.16	5.16
Sugarcane	0.05	1.69	0.14	4.70
Banana	-0.09	-2.73	0.04	1.44
Other crops	0.06	1.87	0.11	3.62
Livestock	0.02	0.78	0.02	0.57
Poultry	0.02	0.62	0.02	0.76
Agricultural services	-0.02	-0.65	0.06	2.01
Capture fishery	0.03	0.84	0.02	0.72
Aquaculture	0.03	0.83	0.02	0.73
Meat and dairy	0.04	1.40	0.04	1.45
Plant-based processing	0.02	0.55	0.03	0.81
Rice and corn milling	0.22	7.19	-0.66	-19.07
Other cereal mfg.	0.00	0.15	0.01	0.42
Sugar mfg.	0.05	1.53	0.08	2.51
Other food mfg.	0.01	0.34	0.00	0.13
Animal feed mfg.	0.07	2.31	-0.01	-0.43
Beverage and tobacco mfg.	-0.09	-2.71	-0.04	-1.28

Source: CCDR Agriculture Team calculations.

Climate change will diminish per-capita consumption, which will tend to be offset for key food products under adaptation. Lower outputs, fewer imports, and elevated consumer prices suggest less per-capita consumption for the agro-industrial sectors in the future (Table 13). The agro-industries with the largest expenditure shares will be poultry, fisheries, meat and dairy, plant-based processing, rice and corn milling, other cereal mfg., other food mfg., and beverages and tobacco. These are the same sectors with a negative trend for per-capita consumption relative to the baseline. Per-capita consumption by 2050 will be 12 percent lower for rice and corn milling, 4 percent lower for beverages and tobacco, and 6 to 7 percent lower for the other major expenditure items. Fortunately, climate change adaptation will be strong enough to overcome this trend for all major food items; by 2050, rice and corn milling will see 25 percent higher per-capita consumption than baseline levels.

Table 13: Changes in agro-industrial sector consumption per capita from 2018 to 2050

(percentage points change relative to baseline)

Industry	*Base-year expenditure share (%)*	*Climate change (%)*		*Adaptation (%)*	
		Change in growth	*Difference by 2050*	*Change in growth*	*Difference by 2050*
Palay	0.5	-0.41	-12.29	1.35	52.82
Corn	0.1	-0.54	-15.79	0.19	6.04
Coconut	0.3	-0.26	-8.02	-0.06	-1.95
Sugarcane	0.1	-0.27	-8.13	-0.06	-1.81
Banana	0.6	-0.13	-4.19	0.04	1.29
Other crops	2.3	-0.27	-8.21	-0.02	-0.69
Livestock	0.3	-0.24	-7.36	0.06	2.06
Poultry	3.2	-0.24	-7.18	0.06	1.92
Agricultural services	0.6	-0.20	-6.05	0.02	0.75
Capture fishery	4.2	-0.24	-7.37	0.06	1.96
Aquaculture	3.8	-0.24	-7.35	0.06	1.96
Meat and dairy	10.5	-0.26	-7.82	0.04	1.27
Plant-based processing	6.6	-0.23	-7.10	0.06	1.87
Rice and corn milling	14.3	-0.42	-12.37	0.71	25.01
Other cereal mfg.	39.9	-0.22	-6.69	0.07	2.22
Sugar mfg.	1.6	-0.26	-7.94	0.01	0.31
Other food mfg.	4.5	-0.23	-6.93	0.08	2.51
Animal feed mfg.	0.4	-0.28	-8.58	0.10	3.06
Beverage and tobacco mfg.	6.4	-0.14	-4.23	0.12	3.88

Source: CCDR Agriculture Team calculations.

4 Responding to climate change: Adaptation and mitigation

4.1 Policy and institutional levers for action

Within the international framework for effective action, the Philippines has made progress toward accomplishing national strategies to adapt to and mitigate the impacts of climate change. Some of the DA's programs and projects have leveraged science-based planning to align adaptation and mitigation strategies defined by the National Climate Change Action Plan on climate-smart industry and services, sustainable energy, and food security outcomes. The government's flagship Philippine Rural Development Project (PRDP) adopted a CSA approach as a pathway to transform and reorient the agri-food system to support development and ensure food security in a changing climate. It provides useful lessons and approaches that can be quickly scaled up in the whole country to make the agri-food system greener and more climate-resilient.

Climate change adaptation and mitigation are integrated into designing and constructing hard investments that strengthen resilience in the agri-food system. The PRDP addresses climate vulnerability in agriculture through various mutually reinforcing investments, especially in climate-resilient rural roads. This approach features a mainstreaming framework that provides climate-resilient technical planning parameters for rural infrastructure aligned with the 2015 Department of Public Works and Highways Design Guidelines, Criteria, and Standards. The design standards for roads and bridges require infrastructure to permit all-weather access, considering the potential impacts of increasingly extreme, frequent, and severe weather events. Since roads become inaccessible for extended periods due to flooding and landslides, the design of PRDP roads and bridges gives careful attention to slope protection, drainage and cross-drainage, flood levels, and forecasts. Better all-weather connectivity of PRDP roads and bridges facilitates adaptation to extreme weather events. The project also involves communal irrigation system investments that enable adaptation by addressing water scarcity and avoiding the risk of large-scale crop failure. PRDP investments in irrigation systems using ram pumps and solar-powered pumps reduce energy use as part of the project's mitigation measures. Warehouse facilities and solar dryers are adaptation measures that prevent post-harvest crop losses, including from floods induced by typhoons. Installing solar panels for renewable energy generation in post-harvest facilities also enhances mitigation. Finally, investments in greenhouses are expected to cut production losses and improve food quality through efficient use of water, pest and disease control, and protection from the elements, enabling both adaptation and mitigation.

Climate change adaptation and mitigation and environmental management strategies are also embedded in the enterprise development component of the PRDP. This component emphasizes integrating natural resource management and climate-smart practices into enterprise subprojects to ensure investment sustainability and build climate resiliency. The project offers complementary technical assistance to small-scale producer groups to strengthen their knowledge and operational skills. Through Climate Field Schools, producer groups are also provided with weather-related production information and introduced to climate-smart agricultural and fisheries practices and technologies such as crop diversification, integrated pest management, the construction of rain shelters, and drip irrigation.

4.2 Technology and innovation options

There is a need for technology and innovations to respond to climate change and generate positive net benefits for farmers, build their resilience to climate change, and provide other climate co-benefits, including GHG emission reductions. Experiences from several countries point to various CSA strategies that generate net benefits in virtually all circumstances. They are referred to as no-regret options and include, for example, methods for improving water use efficiency in rice production, such as the alternate wetting and drying irrigation system. Alternate wetting and drying (AWD) allow fields to drain periodically to enhance the aeration of the soil, inhibiting methane-producing bacteria and thereby shrinking methane emissions.

Adopting CSA practices such as AWD water management combined with good agriculture practices, such as Vietnam's 1M-5R (described below), has shown the potential to significantly cut methane and nitrous oxide emissions. These approaches include a package of improving irrigation water delivery, land leveling, and use of improved seeds (e.g., drought-, pest-, and flood-resistant high-yielding varieties), improved tillage practices, soil testing combined with improved fertilizer application, and farmer training, often facilitated by digital technology. The successful application of these practices has been demonstrated by the Vietnam Sustainable Transformation Project, which supported the adoption by over 240,000 rice farm households of the government's 1M-5R program in the Mekong Delta. 1M-5R refers to the one 'must' of using improved seeds and five 'reductions' in irrigation water, seeding rate, nitrogen fertilizer, pesticides, and post-harvest losses in drying and milling. The program increased farmer yields by 10–18 percent, increased farmer profits by about 28.6 percent, and reduced GHG emissions by 7.3 tons CO_2e/ha/yr, while lowering water use by 15–40 percent.

Similarly, the China Climate Smart Staple Crop Production Project (CSSCP) promoted farmer adoption of a CSA package for rice, consisting of improved seeds, water services, and good fertilizer, pesticide, tillage, and rice straw management practices. Farmers in Huaiyuan County, Anhui Province, where rice is a key crop, benefited from an increase in rice yields of 22 percent, reduced GHG emissions by about 2.9 t CO_2e/ha while cutting fertilizer and water use by 30 percent and 38 percent, respectively, thus increasing farmer incomes. Building on the lessons learned, the CSSCP developed technical guidelines to enable the scaling up of these CSA packages to other regions in China.

Nevertheless, considerable challenges remain in promoting the adoption of alternate wetting and drying and upscaling its use even after 20 years of experience in the Philippines (Enriquez and others, 2021). Internationally, alternate wetting and drying and the related system of rice intensification (SRI) show strong CSA properties and have, in some cases, been upscaled in Vietnam and India (Boxes 2 through 4). These practices can only be taken up with the right enabling conditions. Such factors often go beyond technical aspects and include coordinated water management, incentives for water efficiency, cooperation between farmers, and accessible local extension mechanisms—preferably farmer-to-farmer—to test innovative local and farm conditions and fine-tune techniques. In the Philippines, current policies providing free water to farmers or water charges not tied to volume use reduce incentives to adopt water efficiency measures, including alternate wetting and drying.

Overall, two important reasons for farmers not adopting alternate wetting and drying are:

- **Farmers don't see any profit increase, except possibly in farms requiring pump irrigation.** In gravity irrigation, farmers have been shielded from the true cost of water, previously by the water pricing scheme and more recently by the repeal of water pricing altogether. They need the package of AWD and reduced fertilizer use to reduce production costs and improved varieties to increase yields/output. The combination of reduced costs and increased yield enables increased profits, which gives farmers the incentive to adopt the package. Good agriculture extension is also necessary to demonstrate the value of adopting the package. The Sustainable Rice Platform also partners with private companies to pay a premium for low-carbon rice, which can be further explored in the Philippines.
- **Combining AWD and SRI with other rice-related technologies and practices calls for strategic approaches to rice systems, such as those promoted under the Sustainable Rice Landscape Initiative in key producer countries in the Association of Southeast Asian Nations.** Launched in 2018 during the Sixth Global Environment Facility Assembly meeting, the Sustainable Rice Landscape Initiative has created a unique consortium of public, private, and civil society partners. The initiative brings together technological, ecological, policy, and market-led approaches to address the challenges of rice sustainability. By implementing landscape-based rice initiatives, this consortium plans to deliver large GHG emission reductions at scale through nature-based solutions but also prioritizes the role of landscapes essential to ecosystems, biodiversity, and livelihoods.

Box 2: Asian experiences of alternate wetting and drying

Implementing alternate wetting and drying in several countries in Southeast Asia has had different results. In Bangladesh, the technology could not be upscaled because there were insufficient extension workers to transfer it to local farmers. The practice was adopted in paddy areas and associated with power pumps in the Philippines. In fields where gravity irrigation was in place, adoption was lower due to an irrigation service fee computed based on the area served rather than the quantity of water utilized.

In the Mekong Delta in Vietnam, specifically in An Giang Province, alternate wetting and drying and other good agriculture practices spread more extensively. Giang Province contributes 17 percent of the total rice production in Vietnam. Rice farming in the Mekong Delta occurs in relatively large fields and is primarily linked to exports. Paddy is cultivated all year round because the temperature rarely drops below 25 °C, and precipitation remains around 1,400 mm. Since 2005, alternate wetting and drying has featured regularly in agrarian practices in An Giang Province. Demonstrations on large-scale paddy fields showed increased productivity, resulting in higher rice yields during dry and rainy seasons. In addition, alternate wetting and drying brought beneficial water savings of up to 30 percent and reductions in fertilizer use and methane emissions, which decreased by up to 48 percent. Since 2011, Vietnam's Ministry of Agriculture and Rural Development has highlighted alternate wetting and drying as an efficient climate-resilient practice to upscale.

Sources: Nelson and others, 2021; Tivet and Boulakia, 2017.

Box 3: The Sustainable Rice Platform (SRP)

The Sustainable Rice Platform (SRP) Standard for Sustainable Rice Cultivation is the world's first voluntary sustainability standard for rice. SRP is a global multi-stakeholder alliance launched in 2011 and led by UN Environment, IRRI, and GIZ, comprising over 90 institutional stakeholders, including public and private sector stakeholders, research, financial institutions, and NGOs. SRP's goal is to minimize the environmental impacts of rice production and consumption while enhancing smallholder incomes and contributing to food security.

The SRP standard presents an opportunity for scaling up low-carbon rice production techniques. It provides a mechanism to improve the flow of finance to sustainable practices in the rice value chain based on public-private collaboration. The SRP provides a mechanism through which upfront investment can be made for companies, suppliers, and farmers to switch to climate-smart production methods. Through SRP, sustainable sourcing contracts for climate-smart rice are forged between the key players in the rice value chain. Better coordination is fostered between millers and processors who act as a key point of aggregation for farm produce and warehouse receipt operators who enable farmers to deliver their produce to a warehouse where they are presented with a receipt that can be used as collateral for obtaining credit from banks or micro-finance institutions. This, in turn, provides farmers with a viable form of collateral, mitigates the risks involved in lending to them, and allows them to access loans at lower interest rates. Through the SRP, contracting mechanisms enable the purchase of sustainable rice from farmer cooperatives to ensure quality and traceability. Similarly, developing brand value from sustainable rice linked to a lower environmental footprint and fairer trade to position sustainable rice in local, regional, and global markets is possible through appropriate offtake agreements. A series of contractual arrangements along the value chain can help lower risks and increase access to capital. For example, offtake agreements — by which a company promises to buy a certain volume of a crop at a fixed price at a certain date in the future — are a useful risk mitigation tool in smallholder farming. This can create three-way relationships between farmers, processors, and banks; banks provide credit to farmers, who sell their produce on a forward contract to processors, who then repay the loan to the banks.

Some large-scale rice supply chains, such as global agri-business Olam International—a Better Rice Initiative Asia member—are working with almost 3,000 farmers. By 2022, they intend to reach 10,000 smallholder rice farmers in Vietnam's Mekong Delta region, to increase production sustainably and secure long-term supply. Many other companies working in the rice value chain have expressed plans to transition towards low-carbon rice.

Source: Sustainable Rice Platform, 2019.

Box 4: Experience with the SRI in India and Nepal

SRI is a set of management practices, and its principles have spread to more than 50 countries in Asia, Africa, and Latin America (FAO, 2016; World Bank, 2010). These principles promise climate co-benefits and heightened production with reduced input and water use, leading to higher farm incomes. SRI presents a shift in focus toward agronomy practices and away from inputs. It is based on the principle of cultivating fewer, healthy, large, and deep root systems that can better resist droughts, waterlogging, and wind damage. The plants develop stronger stalks and more tillers, with higher yields and better flavor qualities. SRI management practices enhance tolerance to abiotic stresses such as droughts, heat waves, cold snaps, and winds, as well as biotic stresses like pests and diseases, while diminishing methane emissions. SRI also considerably increases the soil carbon biomass and microbiota. It involves wider spacing of plants, line transplanting, and mechanical weed management, integrating SRI principles into conventional rice production systems.

SRI trials in Nepal entailed 40–50 percent yield increases, 75 percent reductions in seed requirements, 50–75 percent decreases in water use, and less labor for transplanting and irrigation. The cost of weeding was 50–60 percent higher, however. By the end of 2016, SRI had been promoted in 35 districts through Nepal's Mega Rice Production Program. SRI is gaining popularity among paddy farmers in several states in India, namely Andhra Pradesh, Tamil Nadu, Karnataka, and West Bengal. In India, long-term results indicated the superior performance of SRI over normally transplanted, flooded rice in terms of grain yield and water productivity. The SRI method brought a 16–23 percent higher grain yield with mean water savings of 18–32 percent during the wet and dry seasons compared to transplanted flooded rice. Given 50 percent yield benefits, its adoption has spread rapidly among smallholders using family labor in India as farmers have shared their experiences, especially in areas with strong farmer field school systems and networks that facilitate peer-to-peer learning. Because of lessened flooding and reliance mostly on organic fertilization, methane emissions are greatly diminished, with 50 percent reductions in GHG emissions per kilogram of rice produced. Like alternate wetting and drying, SRI requires an ability to control the water supply.

SRI’s emphasis on agronomic practices is a key challenge because these practices are location-specific and knowledge- and management-intensive, making them more difficult to prescribe. SRI must be linked with strengthened advisory services and farmer training programs, supporting farmers’ innovation in adapting and adopting SRI, often on part of their land, as shown in Nepal.

Sources: SRI International, 2015; Uprety, 2016.

Box 5: How can climate-resilient agriculture (CRA) strategies leverage the risks of Filipino farmers?

Climate change and extreme weather events will impact the incomes of Filipino farmers. Climate change effects, especially the predicted inter-zonal and temporal variations in the volume and frequency of rainfall across the Philippine archipelago, will change farmers' income over time. The less predictable rains and consequential periods of longer-lasting droughts or more prevalent onsets of floods will influence agricultural yields of multiple commodities, hence farmers' incomes in all agro-ecological zones. Filipino agricultural production is mainly rain-dependent since the irrigation and drainage infrastructure remains absent or suboptimal. The traditional farming practices that concentrate on monocultural agricultural production are characteristic of small-scale Filipino farmers. These farmers are expected to be particularly affected by changing climate if they do not adopt CRA strategies. While the immediate effects of extreme weather events differ from the weather variations associated with the longer-run climate change, it is expected that the intensity of severe weather will increase in contango with the changing climate. Consequently, Filipino farmers will become more exposed and vulnerable to material and agricultural production damage caused by sudden and disastrous weather events.

CRA practices could help farmers in mitigating climatic and extreme weather risks. There exist multiple CRA strategies that Filipino farmers could adopt to reduce their vulnerability to climate change and extreme weather events. Increased use of more stress-tolerant rice and corn varieties, increased use of natural and commodity-suitable fertilizers in situ of chemical fertilizers, simultaneous planting of different commodities (intercropping), or annual crops rotation are critical for adapting to both flooding and drought (as well as salinity in some coastal areas). Practices such as alternate wetting and drying reduce water consumption, help adapt to reduced precipitation and contribute to reducing methane emissions. Integrated sloping land agriculture technology (SALT) is a critical practice for corn, coconut, and upland crops. Integrated SALT improves soil composition and stability by layering cropping systems to better harness water in drought conditions, reduce the impacts of heavy rainfalls, and provide increased shelter from strong wind. Vegetable shelters and small water harvesting systems (e.g., watershed management integrated with indigenous food production systems) might also be necessary for upland crops and farming systems.

Quantification of potential benefits of selected CRA strategies. The results below in Table A outline indicative financial and economic gains to farmers adopting four selected and modeled CRA strategies, respectively. The average indicative carbon emission savings per 1 ha of land cultivated under each of the four CRA strategies are also presented.

Sources: Alliance of Bioversity International and CIAT & World Food Programme, 2021; World Bank and Asian Development Bank, 2021; PSA, 2014.

5 Policy recommendations

Farmers, fisherfolk, and other value chain participants can change their behaviors and technologies to make the agri-food system more climate-smart but will need capacities and incentives to do so. These changes can help producers adapt to a changing climate by strengthening the resilience of production and livelihoods to long-term rainfall and temperature trends and to short-term weather shocks, which may become more frequent and more severe with global warming. Additionally, these adjustments can mitigate GHG emissions from production activities. Some behavioral and technological modifications will improve adaptation, some will enhance mitigation, and some will do both. Some support both adaptation and mitigation objectives while simultaneously bringing immediate increases in productivity and profitability for producers regardless of the effects of climate change—the "triple win."

The private sector will drive these climate-smart changes through its own decisions and investments, yet government policies will have to play a critical role in promoting and supporting them. A key first step is ensuring that existing government policies, regulations, and investments do not undercut private-sector incentives for necessary changes. The second step involves lowering or eliminating barriers that impede the private sector from taking climate-smart action. Potential barriers include inadequate information about climate change impacts and solutions, poorly functioning mechanisms to disseminate information to producers, weak implementation capacity at all levels, inadequate coordination when collective action by producers is required, and imperfect access to the right financial instruments. A third potential governmental action entails providing direct financial incentives when appropriate and necessary. In general, the benefits from investments in adapting to adverse climate change impacts accrue primarily to the private parties undertaking adaptation, so they are strongly incentivized to act if they are well informed. Yet the advantages of reducing GHG emissions are global, making the incentives for private investment much weaker. Therefore, direct subsidies are usually more appropriate for actions aimed primarily at mitigation than those targeting adaptation. The discussion of specific recommendations below—while not exhaustive—is organized around this three-part taxonomy of policies.

Reform current policies that discourage climate-smart action

Reforming agricultural support policies can encourage the adoption of diversified production systems, which tend to be more resilient to climate shocks. In contrast, policies that include heavy incentives to cultivate specific crops discourage diversification and the resilience it brings. Support for rice encourages the production of one of the biggest GHG emitters. Agricultural policies require reform as a major step in an agenda to promote CSA. World Bank (2021) furnishes a comprehensive plan to implement such a reform program, focused on replacing some current support mechanisms with more efficient, climate-friendly alternatives (Section 6.3).

Improving water management and pricing policies can increase incentives for efficient use. For example, policies that undercut the adoption of climate-smart production technologies include providing free irrigation water or relying on non-volumetric water charges based not on the quantity used but on the area of land irrigated. Such policies do not entail any direct cost reduction from using less water—for example, from water-efficient technologies such as alternate wetting and drying in rice production—and consequently offer no incentive to adopt them.

Phasing out fertilizer subsidies can reduce the overuse of nitrogen fertilizers, leading to higher GHG emissions and degrading soil and water quality. Nitrogen fertilizers produce nitrous oxide, an often overlooked but highly potent GHG with 265 times more global warming potential by volume than carbon dioxide. Although politically popular, fertilizer subsidies are a poor use of public funds, as shown by a large body of research spanning many years and countries. Other more efficient and climate-friendly mechanisms exist to support farmers (World Bank, 2021). Unfortunately, the current political climate demands even greater subsidies owing to the recent fertilizer price surge. Instead, high imported fertilizer prices should be an opportunity to advocate for developing indigenous alternatives, such as locally-produced organic fertilizers.

Legal and regulatory reform can provide greater tenure security to farmers to encourage investments. Often smallholders and upland communities recognize the resilience of more integrated and diversified agriculture systems yet are reluctant to invest in them. This situation stems partly from the weakness of policy and implementation approaches for tenure systems, especially for marginal and upland farmers. To support policy reform, it is important to better track CSA: from budget tagging and allocations to monitoring the adoption of locally appropriate CSA practices and technologies, to setting up a monitoring, reporting, and verification system in the DA to track better GHG emissions in agriculture and enable to access climate finance.

Reduce or eliminate barriers to information generation and dissemination to promote CSA technology adoption

Increased public investment can be directed toward generating information about climate change impacts and appropriate responses. Much climate change research on agriculture in the Philippines exists, but it often focuses on rice. This research must expand into other important topics such as integrated, upland, and rain-fed systems, combining mitigation and adaptation and reducing poverty and food insecurity. Such research can be linked with comprehensive and strategic support frameworks, for example, by creating CSA investment plans (CSAIPs), including the CSAIPs completed with World Bank support in Nepal, Bangladesh, and African countries. On a more localized level in the Philippines, the DA has started rolling out climate risk and vulnerability assessments to better analyze and target CSA options by LGUs and local stakeholders. These will need further refinement and regular updating, and scientific guidance on implementing the CRVA recommendations.

Enhanced systems can disseminate relevant information to farmers. Information should be accessible, understandable, and actionable for ordinary people and communities and must reach a much wider range of vulnerable farmers through the strengthening and diversification of extension systems. Therefore, policies and support for research and extension must have better local relevance. Linkages between extension and the needs of farmers and the private sector can be improved, including through products such as information services from the Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA), the national weather agency. Such products would include downscaled early warning and forecasting systems for agriculture and fisheries, long-term climate change trends and advisory, and localized advisories on CSA technologies and practices. Recent investment preparation work has been undertaken by the DA Adaptation and Mitigation Initiative in Agriculture (AMIA) for potential funding from the Green Climate Fund, the Food and Agriculture Organization of the United Nations, and other partners. These efforts have analyzed climate trends, likely impacts, and relevant responses for different regions and farming systems. This process identified entry points to build resilience and the means of capacity development toward mainstreaming and scaling up CSA, including through AMIA villages. It has also helped determine localized opportunities and planning, resource, and risk mitigation needs that will attract the private sector to further invest in CSA.

The Mandanas process can build local capacity to mainstream CSA into policies and planning. Much attention is currently being focused on devolving responsibility from the central government to local government units for various programs and functions because of the Mandanas ruling of the Supreme Court. This process must ensure that local government units have the incentives, information base, and capacity to mainstream CSA into their strategies and planning. Methods to do so while building implementation capacity are being developed and tested through the PRDP, and lessons learned can be incorporated into the devolution process. Even with additional resources coming from the Mandanas, mainstreaming CSA might remain a problem for poor municipalities with low capacity; these might benefit from additional support to ensure they have the technical capacity to inform development plans and investments to reach the poorest, most vulnerable communities.

Barriers to community participation can be lowered by ensuring inclusion in CSA planning. One clear lesson from promoting CSA approaches, especially those based on integrated land management, is that these solutions can only be sustained if there is strong community ownership

(World Bank and BioCarbon Fund, 2021). Farming communities are unlikely to embrace climate-smart practices unless they have participated in a socially inclusive process of developing and implementing plans and policies that affect them. Practices and participatory approaches building on traditional kinships and enhancing community social cohesion are important entry points. Engaging women, the youth, indigenous peoples, and other marginalized sectors in CSA programming can make such strategies more gender-sensitive and socially inclusive. The Philippines' successful models could be leveraged, including the Kalahi-CIDSS National Community Driven Development Project (KC-NCDDP).

Farmers' institutional strength and networks are critical to their links to local and national institutions and knowledge. Hence it is fundamental to strengthen farmer groups, for them to experiment and learn from others, engage with value chains and financial institutions, participate and have a voice in local planning decisions, gain various economies of scale, and make choices in adopting CSA. There is an extensive user experience to build on in the Philippines, from the DA, the Department of Agrarian Reform, by building on the experiences of the PRDP, many highly motivated and capable farmer federations, and NGOs. More marginal and vulnerable farmers must receive extra support to develop skills and organizational capacities to reduce their risks and overcome start-up hurdles.

Government policy instruments can strengthen coordination mechanisms. Some CSA investment options, such as solar-powered pumps, biodigesters, and small-farm reservoirs, come with high investment costs. Cooperation among small-scale farmers when investing in such solutions can enable economies of scale. This reality can inform the DA's push for initiatives such as agro-ecological zones and province-led agriculture and fisheries extension systems, which will support the formation of farmer clusters and groups at the local level to promote CSA.

For livestock farmers to adopt GHG mitigation measures, and range of tools and incentives will be needed. Several technologies for GHG mitigation were identified in the process of preparing this report (see Appendix 1): reducing enteric fermentation through changed feeds, more localized feed sources, better manure management, biogas production, better animal health and feed systems, to create healthier and more efficient stock, thus reducing GHG emissions per unit protein. Developing profitable biogas production for sale and strengthening farmer capacity to increase efficiency has obvious private payoffs. However, for more environmentally oriented aspects, strong regulatory systems for livestock systems are important and have strong co-benefits, for example, reducing pollution. Further, as GHG emission reduction activities also produce global public goods, the general principle is that these technologies should be subsidized with public funding, preferably from global resources. Of course, this needs to be done intelligently, selecting low net-cost technologies per ton of GHG reduction and considering other benefits. Systematic studies to estimate these costs for each technology would be important.

Widening the availability of finance products can support CSA. Government policies related to financial markets can enable the development of instruments such as crop insurance that help farmers mitigate risks from weather shocks and appropriate lending instruments to finance climate-smart investments. The improved databases and information systems mentioned above, particularly about weather risks, are key to developing and refining finance products, including credit and insurance and their delivery mechanisms. An overall approach supporting institutionalized, localized, coordinated CSA can identify production and enterprise finance needs, arrive at a realistic risk assessment, and pinpoint bottlenecks hindering product uptake. For example, while several index-based insurance products have been developed and piloted, they must match the delivery requirements of many farmers. Insurance schemes are available under the Philippine Crop Insurance Corporation. However, the instruments require refinements in combination with localized risk assessments, and the range of engaged private-sector actors must be broadened. A comprehensive review of how financial system regulations and related programs could better advance CSA would be useful but is beyond the purview of this report.

Establishing a robust monitoring reporting and verification system for GHG emissions and climate co-benefits that ensures accountability, transparency, and good governance will help build the confidence of international and private sector climate finance providers. It would also generate data and foster information-sharing with the private sector, NGOs, the public sector, and international actors.

Subsidize the adoption of CSA production technologies where appropriate, and utilize social safety nets

Programs involving direct payments to farmers are generally more appropriate to subsidize their investments in reducing emissions, which is a global public good, than programs to help farmers adapt to climate change, which benefits the farmers who make the investments. Of course, exceptions to this principle may be needed to meet equity objectives, for example, in the case of poor, resource-constrained farmers who would not be able to finance investments for adaptation purposes without government assistance. In these cases, even beyond humanitarian considerations, it may be more cost-effective to finance ex-ante preventative actions than ex-post disaster relief. A comprehensive CSA strategy will entail measures to ensure that farmers are included in disaster relief programs, with payments delivered in a timely way to assist recovery and replanting in the earliest possible season.

Many instruments are being used worldwide that provide direct payments to farmers aimed at making agriculture more climate-smart. One general approach is ‘payments for environmental services’, in which producers are paid directly either by the government or private parties for better management to enhance the benefits of natural resources or for avoiding some type of environmental damage. An alternative used in some countries, including the United States, the European Union, Vietnam, and China, provides direct support payments to farmers contingent upon their actions to preserve the environment in some measurable way. Such conditional climate-smart payments can make agricultural support or subsidy reform programs more politically palatable since they allow farmers to maintain their incomes while incentivizing them to use more climate-smart practices. Research by the FAO in Africa has also shown the potential of social protection and food aid to increase the adoption of CSA by small-scale farmers. Payment schemes may be a workaround to politically unpalatable reforms such as the repeal of free irrigation. Maintenance subsidies may be conditional on adopting water-saving practices such as AWD (Briones and others, 2020).

There are many excellent resources to understand the suite of actions that support CSA (World Bank, 2020; Cassou, 2018). A good resource to explore how CSA approaches can be implemented through integrated land use programs can be found at www.biocarbonfund-isfl.org/knowledge-center. This website also includes resources to explore various international programs that help finance climate-smart payments in individual countries.

Appendix 1. Examples of selected climate-resilient practices

Climate-smart livestock systems

Major pathways acknowledged by the FAO and Asia Pacific regional countries reduce emissions from livestock production and increase resilience to climate change. These recognize that a combination of existing climate-smart livestock (CSL) options will be required. These incorporate technologies such as those recommended by the DA and internationally (see below). These emphasize the core win-win of increasing efficiency, and thus emissions per unit protein, that help mitigation, productivity, and resilience through producing healthier and hardier animals. The overall production and mitigation benefits from a combination of approaches and technologies can be identified more systematically using the FAO Global Livestock Environmental Assessment Model (GLEAMi6) tool.[7]

Livestock productivity

Improving productivity per animal or animal group will lead to improved food security and reduced GHG emissions in livestock production systems. Production efficiency will lead to fewer emissions per unit of livestock product and can be achieved, for example, through better animal husbandry and livestock support services.

Natural resource use efficiency

Improving natural resource use efficiency will lead to improved food security and reduced GHG emissions. The efficient use of natural resources like land, water, energy, and other inputs will reduce waste along the value chains and reduce GHG emissions.

Carbon sequestration

The potential for carbon sequestration in livestock production systems mainly focuses on grasslands, legumes, and fodder trees. Sequestration can be achieved through agroforestry systems, particularly in upland areas, and efficient use of crop residues, having important mitigation outcomes.

Integration in the circular bioeconomy

A circular bioeconomy minimizes the leaks of energy and materials from the system by recirculating them as much as possible within production systems. CSL solutions related to better livestock integration include the use of local manure and animal traction for increasing crop productivity, as well as the share of the local crop and livestock by-products in livestock feed, nutrient recycling, or energy generation, such as the use of manure in biogas to use as fuel in households or other local economic activities.

Specific adaptation options

Some specific CSL adaptation solutions are not directly related to any other CSL options, for example (livestock) insurance, early warning systems, disease surveillance, and climate control in animal housing systems. The DA has communicated to the Climate Change Commission the following CSA solutions with a mitigation potential as its contribution to the Philippine Nationally Determined Contributions (NDC). The following interventions and other emerging practices and

---

[6] The Global Livestock Environmental Assessment Model is a GIS framework that simulates the bio-physical processes and activities along livestock supply chains under a life cycle assessment approach. https://www.fao.org/gleam/en/

[7] https://www.fao.org/gleam/en/

international experiences are particularly important for reducing emissions from livestock. However, they must be implemented in the right combinations for local and farmer contexts.

Use of biodigesters for livestock

Biogas is produced by the fermentation of organic materials, e.g., animal waste, in an airtight or anaerobic condition. Biogas mainly contains methane, a GHG that could be used as an energy source. Further, the slurry from the digester is rich in ammonium and other nutrients that can be used as an organic fertilizer (Rajendran and others, 2012). Biogas as an alternative energy source is sustainable, affordable, and has no negative effect on people's health or the environment if handled properly (Green and Sibisi, 2002). Proper biogas storage is necessary since leakage increases methane and carbon dioxide emissions and may cause fire explosions (Khoiyangbam, 2011).

Some medium to large commercial hog farms have biogas systems. The potential emission reduction from carbon emission reduction and fuel oil displacement resulting from a biogas system in hog farming is 1.79 $MtCO_2e$/yr (IIEC and others, 2009). Environmental benefits of using biogas digester include reduction in deforestation, soil erosion, and reduced loss of cultivable land (Gautam and others, 2009). Further, the use of biodigesters resulted in reduced wastewater and air pollution as well as job creation (Tanigawa, 2017). The profitability of the biogas systems and, thus, its sustainability may require selling the fertilizer slurry at sufficient volumes and combining technologies in a strategic approach, as shown by the Thailand case (Box A.1).

Box A.1: Balanced feed rations for dairy systems in India, also applicable to beef cattle

In India, a program by the National Dairy Development Board (NDDB) has developed user-friendly computer software for advising milk producers to balance dairy feed rations with available feed resources, implementable at a large scale. With the help of trained "Nutrition Masters," knowledgeable about feed ingredients across various agro-climatic regions, farmers were trained to prepare balanced rations. The activities included the development of software on hand-held devices that enabled the 'Nutrition Masters' to collect data and formulate appropriate feed rations for smallholders using local feed resources.

Surveys indicate that feeding a balanced ration can increase smallholder farmers' net daily income by 10–15 percent. Both milk production increased, and the cost of feeding decreased. Milk production efficiency (milk yield/dry matter intake) for cows before and after ration balancing were 0.58 and 0.78 kg, respectively, and for buffaloes, the corresponding values were 0.53 and 0.66 kg, respectively. Feeding a balanced ration to dairy animals for sixty days also significantly reduced fecal egg counts of internal parasites. Furthermore, feeding balanced rations was estimated to reduce enteric methane emissions by 15– 20 percent per kg of milk produced. Furthermore, the rations positively affected the nitrogen utilization in the feed, as less nitrogen was secreted. Similar approaches can also be adapted for growing beef animals, considering local feeding and management conditions.

Source: FAO 2021

Use of lactobacillus as a feed supplement for livestock

A range of feed additives and alternatives is being assessed for whether they can reduce methane emissions from livestock (Boxes 5 and 6). Probiotics are feed additives used to restore the gut microbial population while recuperating the host immune system (Liao and Nyachoti, 2017). It was observed that hogs fed with probiotics, lactobacillus being the most common, gained weight faster and consequently led to savings in the cost of feeds. Probiotics help the hogs digest the feed efficiently and prevent the proliferation of harmful organisms, which could minimize antibiotic use (Sarian, 2017). Further, manure from pigs fed with the supplemented diets emitted lower amounts of environmentally harmful gases such as methane and ammonia (Prenafeta-Boldu and others, 2016).

Use of alternative feeds for livestock

Grain demand continues to increase, exacerbating food and feed production competition. However, there are alternative resources that can be used for feed production. Among them, forage, cassava residue, algae residue, moringa, and even insects are protein sources (Labios and others, 2019).

Box A.2. Pig production in Thailand

The total GHG emissions from livestock production are estimated at 11.43 Mt CO2eq. Regarding pig production, manure management is the largest emission source, with a value of 1.552 MtCO2eq per year in 2017, corresponding to 70 percent of all emissions from pig production.

The Department of Livestock Development launched the Green City Project in 2015, which subsidizes the construction cost of biogas digesters and the promotion of wastewater treatment systems. The main goal was to reduce GHG emissions and air and water pollution in the pig production system. Pig farmers reduced their energy costs by an average of 64 percent after installing a biogas system. Anaerobic digesters, e.g., biogas systems, can increase farm profits by 10 to 20 percent and help reduce the environmental impact of livestock production. They are recommended as a mitigation strategy for CH4 to generate renewable energy, but their effect on N2O emissions is unclear. Payback time was estimated at six years. Based on the results, the suggested CSL options for pig production are as follows:

- Encourage mixed farming systems for smallholders to utilize natural resources effectively.
- Improve animal health services to cope with changing disease agents.
- Design buildings to use natural ventilation, increase insulation, and use creep boxes for piglets.
- Select crop varieties that can cope with changes in the climate.
- Invest in water storage facilities.
- Use less intensive rearing techniques, e.g., outdoor production systems.

More R&D about GHGs is required, however.

Appendix 2. Financial and economic returns of selected CSA practices

Table A2.1: Financial and economic returns and GHG co-benefits of selected CSA practices

Indicative Annual Financial Net Inflows Due to CRA Intervention Adoption (per 1 ha of cultivated land)	Incremental Financial Internal Rate of Return (FIRR) and FNPV Analysis over 20 years @10% discount rate[a] Without subsidy, with a specific loan assumed	Incremental Economic Internal Rate of Return (EIRR) and Economic Net Present Value (ENPV)[b] Analysis over 20 years @10% discount rate Without subsidy, with a specific loan assumed and lower bound carbon valuation	Incremental Economic Internal Rate of Return (EIRR) and Economic Net Present Value (ENPV) Analysis over 20 years @10% discount rate Without subsidy, with a specific loan assumed and upper bound carbon valuation	Estimated GHG Emissions (Carbon Savings) Observed After CRA Intervention (per 1 ha of cultivated land per year and over 20 years of analysis)
Intervention 1: Introduction of blight-resistant white potatoes-green cabbage crops rotation and construction of rainwater harvesting tank for irrigation purposes in Cordillera Autonomous Region (CAR) and Luzon				
PHP 98,900 (average net gain (real values) per year when compared to the "without project scenario" (WOP) scenario)	Incremental FIRR = 33% MIRR = 17% FNPV = PHP 541,024	Incremental EIRR = 24% EMIRR = 15% ENPV = PHP 345,451	Incremental EIRR = 24% EMIRR = 15% ENPV = PHP 345,699	0.01 ton of carbon savings/year/ha or 0.2 ton of carbon savings/20 yrs/ha
Loan details:[c] Loan with the following terms was assumed in cash flows: (i) Total required funding before down payment: PHP 266,375. Note: The total estimated loan funding is equal to the total estimated average cost of the necessary inputs, including labor costs for the initial planting season. (ii). Assumed down payment covered by the farmer (20 percent of the total necessary amount as per (i)): **PHP 53,275.** Note: It is assumed that the farmer can provide this down payment. If the farmer cannot provide this down payment from their own resources, the down payment would be the potential amount necessary for grant provision. (iii) Total necessary loan funding after down payment: PHP 213,100. (iv) Assumed interest rate: 15%. (v) Loan term: 48 months. (vi) Grace repayment period: 1 year. (vii) Monthly repayment: PHP 5,930.70 (viil) Total annual repayment: PHP 71,168.79.				

Indicative Annual Financial Net Inflows Due to CRA Intervention Adoption (per 1 ha of cultivated land)	Incremental Financial Internal Rate of Return (FIRR) and FNPV Analysis over 20 years @10% discount rate[a] Without subsidy, with a specific loan assumed	Incremental Economic Internal Rate of Return (EIRR) and Economic Net Present Value (ENPV)[b] Analysis over 20 years @10% discount rate Without subsidy, with a specific loan assumed and lower bound carbon valuation	Incremental Economic Internal Rate of Return (EIRR) and Economic Net Present Value (ENPV) Analysis over 20 years @10% discount rate Without subsidy, with a specific loan assumed and upper bound carbon valuation	Estimated GHG Emissions (Carbon Savings) Observed After CRA Intervention (per 1 ha of cultivated land per year and over 20 years of analysis)
Intervention 2: Introduction of rice-onion crops rotation with early maturing rice cultivars in Cordillera Autonomous Region (CAR) and Visayas				
PHP 59,900 (average net gain (real values) per year when compared to the “without project scenario” (WOP) scenario))	Incremental FIRR = 38% MIRR = 18% FNPV = PHP 382,862	Incremental EIRR = 15% EMIRR = 12% ENPV = PHP 61,558	Incremental EIRR = 16% EMIRR = 13% ENPV = PHP 77,385	0.64 ton of carbon savings/year/ha or 12.8 tons of carbon savings/20 years/ha
Loan details: Loan with the following terms was assumed in cash flows: (i) Total required funding before down payment: PHP 121,600. Note: The total estimated loan funding is equal to the total estimated average cost of the necessary inputs, including labor costs for the initial planting season. (ii) Assumed down payment covered by the farmer (20% of the total necessary amount as per (i)): **PHP 24,320.** Note: It is assumed that the farmer can provide this down payment. If the farmer cannot provide this down payment from their own resources, the down payment would be the potential amount necessary for grant provision. (iii) Total necessary loan funding after down payment: PHP 97,280. (iv). Assumed interest rate: 15%. (v) Loan term: 48 months. (vi) Grace repayment period assumed: 1 year. (vii). Monthly repayment: PHP 2,707.38. (viii) Total annual repayment: PHP 32,488.50				

Indicative Annual Financial Net Inflows Due to CRA Intervention Adoption (per 1 ha of cultivated land)	Incremental Financial Internal Rate of Return (FIRR) and FNPV Analysis over 20 years @10% discount rate[a] Without subsidy, with a specific loan assumed	Incremental Economic Internal Rate of Return (EIRR) and Economic Net Present Value (ENPV)[b] Analysis over 20 years @10% discount rate Without subsidy, with a specific loan assumed and lower bound carbon valuation	Incremental Economic Internal Rate of Return (EIRR) and Economic Net Present Value (ENPV) Analysis over 20 years @10% discount rate Without subsidy, with a specific loan assumed and upper bound carbon valuation	Estimated GHG Emissions (Carbon Savings) Observed After CRA Intervention (per 1 ha of cultivated land per year and over 20 years of analysis)
Intervention 3: Introduction of yellow corn-peanuts (groundnuts) rotation with drought-resistant yellow corn cultivars. Additional introduction of Sloping Agricultural Land Technology (SALT) in North-East Luzon (Cagayan Valley) and Visayas				
PHP 12,800 (average net gain (real values) per year when compared to the "without project scenario" (WOP) scenario))	Incremental FIRR = 44% MIRR = 19% FNPV = PHP 84,696	Incremental EIRR = 64% EMIRR = 22% ENPV = PHP 122,702	Incremental EIRR = 77% EMIRR = 23% ENPV = PHP 140,755	0.73 ton of carbon savings/year/ha or 14.6 tons of carbon savings /20 years/ha
Loan details: Loan with the following terms was assumed in cash flows: (i) Total required funding before down payment: PHP 30,650. Note: The total estimated loan funding is equal to the total estimated average cost of the necessary inputs, including labor costs for the initial planting season. (ii) Assumed down payment covered by the farmer (20% of the total necessary amount as per (i)): **PHP 6,130**. Note: It is assumed that the farmer can provide this down payment. If the farmer cannot provide this down payment from their own resources, the down payment would be the potential amount necessary for grant provision. (iii) Total necessary loan funding after down payment: PHP 24,520. (iv). Assumed interest rate: 15%. (v) Loan term: 48 months. (vi) Grace repayment period assumed: 1 year. (vii). Monthly repayment: PHP 682.41. (viii) Total annual repayment: PHP 8,188.92.				

Indicative Annual Financial Net Inflows Due to CRA Intervention Adoption (per 1 ha of cultivated land)	Incremental Financial Internal Rate of Return (FIRR) and FNPV Analysis over 20 years @10% discount rate[a] Without subsidy, with a specific loan assumed	Incremental Economic Internal Rate of Return (EIRR) and Economic Net Present Value (ENPV)[b] Analysis over 20 years @10% discount rate Without subsidy, with a specific loan assumed and lower bound carbon valuation	Incremental Economic Internal Rate of Return (EIRR) and Economic Net Present Value (ENPV) Analysis over 20 years @10% discount rate Without subsidy, with a specific loan assumed and upper bound carbon valuation	Estimated GHG Emissions (Carbon Savings) Observed After CRA Intervention (per 1 ha of cultivated land per year and over 20 years of analysis)
Intervention 4: Introduction of organic rice cultivation (2 rotations per year) with alternate wetting and drying irrigation-SRI in North-East Luzon (Cagayan Valley) and Visayas				
PHP 14,400 (average net gain (real values) per year when compared to the "without project scenario" (WOP) scenario))	Incremental FIRR = 25% MIRR: 16% FNPV = PHP 72,993	Incremental EIRR and EMIRR are below the chosen discount rate of 10%, suggesting a lack of viability if farmers need to take and repay a commercial loan Negative ENPV = -PHP 48,167	Incremental EIRR and EMIRR are below the chosen discount rate of 10%, suggesting a lack of viability if farmers need to take and repay a commercial loan Negative ENPV = -PHP 37,039	0.45 ton of carbon savings/year/ha or 9 tons of carbon savings/20 years/per ha
Loan details: Loan with the following terms was assumed in cash flows: (i) Total required funding before down payment: PHP 60,970. Note: The total estimated loan funding is equal to the total estimated average cost of the necessary inputs, including labor costs for the initial planting season. (ii) Assumed down payment covered by the farmer (20% of the total necessary amount as per (i)): **PHP 12,194**. Note: It is assumed that the farmer can provide this down payment. If the farmer cannot provide this down payment from their own resources, the down payment would be the potential amount necessary for grant provision. (iii) Total necessary loan funding after down payment: PHP 48,776. (iv) Assumed interest rate: 15%. (v) Loan term: 48 months. (vi) Grace repayment period assumed: 1 year. (vii). Monthly repayment: PHP 1,357.4. (viii). Total annual repayment: PHP 16,289.67.				

Notes: *a. The same discount rate was used in the financial and economic part of the analysis. The 10 percent discount rate is suggested by the National Economic Development Authority (NEDA) as the Economic Opportunity Cost of Capital (EOCK). While the financial discount rate can be lower than 10 (the latest estimates for the Philippines based on the Weighted Average Cost of Capital (WACC) were suggesting est. 7.5 percent), a higher discount rate was used to remain conservative. Currently, the world and the Philippines are in a volatile macroeconomic setup, hence the conservative approach. If the financial results* *calculated using a higher discount rate—in this case, 10 percent—are positive and suggest that the scenario would be financially profitable, using a lower discount rate, in this case, est. 7.5 percent, would produce even more positive, financially encouraging results.*

b. For carbon valuation in the economic analysis, the prices used were taken from the November 2017 World Bank's Guidance Note on Carbon Pricing. Lower and upper carbon pricing was used, respectively. Also, the economic prices (shadow prices) and, consequently, the economic results presented in Table A were estimated by adjusting financial prices through calculated Conversion factors (CFs). The CFs taken under consideration all applicable taxes specific to analyzed commodities. The terms of trade (e.g., import (CIF) basis or export (FOB) basis were also considered in estimating CFs. The selection of proper trade basis for each commodity depends on the trade volumes of these commodities observed in the Philippines. The UN Comtrade database was used to establish trade conditions for outputs associated with each of the presented interventions (either CIF or FOB trade basis).

c. In this analysis, a Land Bank type of loan for crop production was used with an interest rate of 15 percent per annum. The maximum loan under this program is PHP 300,000 for term loans, with 20 percent of the down payment (up to 80 percent of the project's funding). This is a loan crafted for agri-enterprises and livelihood projects. Source: https://www.landbank.com/loans/loans-to-farmers-fishers/for-farmers/agricultural-and-fishers-financing-program

Source: CCDR Agriculture Team calculations.

Discussion of results

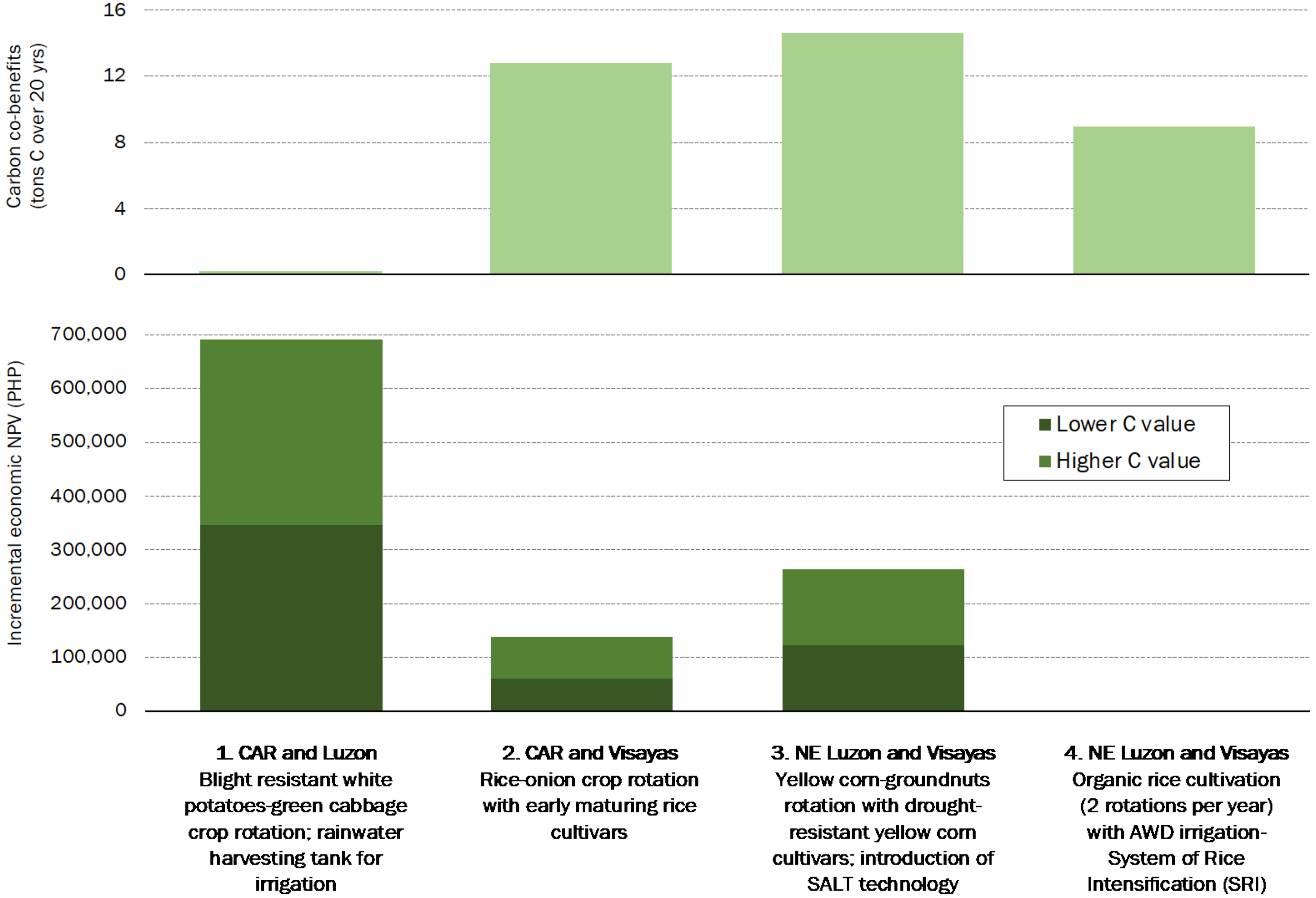
In the case of presented interventions 1, 2, and 3, farmers will be profitable financially even without any subsidy, assuming that they can secure Land Bank loans as described in Table A above. However, according to the Land Bank loan conditions, farmers would also need to be able to put down payments for such loans. If said farmers do not possess the resources or abilities to cover the down payment, they would need to receive support for that purpose. The levels of potential grant support for each intervention, respectively, are stated in Table A2.1. The economic results also show that under the assumptions used in the case of interventions 1, 2, and 3, it is likely that the entire Philippine economy will also benefit as the ENPVs are positive and EIRRs are higher than 10 percent.

In the case of Intervention 4, farmers should also be financially profitable when taking and repaying the proposed loan, assuming that they possess the resources to provide a down payment. If they do not have resources for that down payment, a provision of a grant to cover the down payment could be considered. The negative ENPVs and lower than 10 percent EIRRs in the case of Intervention 4 are associated with import basis terms of trade in rice. In the analysis, rice was treated on Cost Insurance and Freight (CIF) basis due to higher rice imports than exports. This affected CFs and economic results. However, in reality, one needs to consider that farmers observe financial, not economic, prices. Therefore, what matters for farmers in their daily operations are financial, not economic results. The economic results are essential from the perspective of the entire Philippine economy and the well-being of the whole nation. And in the case of Intervention 4, if farmers are obliged to take and repay the outlined loan, the economic results will be negative. The economic results would be positive if farmers received a grant instead of a loan.

Potential expenditures associated with the training of farmers are not included in the results. In the case of all presented possible interventions, farmers need to be trained on the proper agricultural practices and informed on potential gains associated with adjusting their current farming management to activities described in proposed interventions 1-4. The potential expenditures related to these activities were not included in the estimates provided in the Table above.

GHG emissions and carbon co-benefits. The potential economic benefits from GHG emissions mitigation, i.e., carbon co-benefits, were estimated using Ex-Act software, assuming seven years of the implementation phase and 13 years of capitalization per IPCC guidance (a total of 20 years, as prescribed). The estimated volume of carbon co-benefits per 1 ha of cultivated land ranges from 0.2 tons to 14.6tCO2e/ha/20 years. The ENPVs and volume of carbon co-benefits over 20 years are presented in Figure A2.1 below.

Figure A2.1: Financial and economic returns and GHG co-benefits of selected CSA practices



Source: CCDR Agriculture Team calculations.

References

Alliance of Bioversity International and CIAT and World Food Programme (CIAT and WFP). 2021. *Philippine Climate Change and Food Security Analysis*. Manila, Philippines.

Arnaoudov, V., E. Sibayan, and R. Caguioa. 2015. *Adaptation and Mitigation Initiatives in Philippine Rice Cultivation*. New York: United Nations Development Programme.

Calub, A., R. Saludes, and E. Tabing. 2016. An Overview of Agricultural Pollution in the Philippines: The Livestock Sector. Washington: World Bank.

Cheng, M., B. McCarl, and C. Fei. 2022. "Climate Change and Livestock Production: A Literature Review". *Atmosphere*. 13, 140. URL: https://doi.org/10.3390/atmos13010140

Climate Risk Country Profile: Philippines (2021): The World Bank Group and the Asian Development Bank. https://openknowledge.worldbank.org/handle/10986/36370 Washington: World Bank.

Cornell University College of Agriculture and Life Sciences: SRI International Network and Resources Center. 2015. *Country Profile: Nepal*. New York. URL: http://sri.ciifad.cornell.edu/countries/nepal/index.html

Dikitanan, R., G. Grosjean, A. Nowak, and J. Leyte. 2017. *Climate-Resilient Agriculture in the Philippines*. CSA Country Profiles for Asia Series. International Center for Tropical Agriculture (CIAT) and Department of Agriculture-Adaptation and Mitigation Initiative in Agriculture, Government of the Philippines. Manila, Philippines.

Eckstein, D., V. Künzel, and L. Schäfer. 2021. *Global Climate Risk Index 2021*. Germanwatch. Bonn, Germany.

Enriquez, Y., Yadav, S., Evangelista, G. K., Villanueva, D., Burac, M. A., and Pede, V. 2021. Disentangling Challenges to Scaling Alternate Wetting and Drying Technology for Rice Cultivation: Distilling Lessons From 20 Years of Experience in the Philippines. Front. Sustain. Food Syst., 21. https://www.frontiersin.org/articles/10.3389/fsufs.2021.675818/full

Escarcha, J. F. , Lassa, J. A. , Palacpac, E. P., Zandera, K. K. 2018. Understanding climate change impacts on water buffalo production through farmers' perceptions Climate Risk Management. Volume 20, 2018, Pages 50-63. https://doi.org/10.1016/j.crm.2018.03.003

Food and Agriculture Organization of the United Nations (FAO). 2017. *Food and Agriculture Data*. Rome, Italy. URL: https://www.fao.org/faostat/en/#home

Food and Agriculture Organisation of the United Nations (FAO). 2021. "Climate-smart livestock production- A practical guide for Asia and the Pacific region." Bangkok: FAO.

Giles, J., P.B. Macandog, A. Nowak, J. Pablo, B. Sebiano Jr, B., L.K. Palao, J.G. Balanza, J. Hildebrand, J., and G. Grosjean. 2019. "Climate-resilient agriculture in the Philippines: Climate Risk Profile, Luzon". International Center for Tropical Agriculture (CIAT); Department of Agriculture - Adaptation and Mitigation Initiative in Agriculture, Government of the Philippines; The Food and Agriculture Organization of the United Nations (FAO). Manila, Philippines. https://ciatph.github.io/#/crads/crp

Giles, J., Macandog, P.B., Sova, C., Seriño, M.N.V., Ruales, J.H., Enerlan, W.C., Palao, L.K., Balanza, J.G., Hildebrand, J., and Grosjean, G. (2019). Climate-Resilient Agriculture in The Philippines: Climate Risk Profile, Visayas. International Center for Tropical Agriculture (CIAT); Department of Agriculture - Adaptation and Mitigation Initiative in Agriculture, Government of the Philippines; The Food and Agriculture Organization of the United Nations (FAO). Manila, Philippines. https://ciatph.github.io/#/crads/crp

Giles, J., Macandog, P.B., Sova, C., Digal, L., Balgos, C., Loquias, M., Orbeta, M.L., Astronomo, I.J.T., Palao, L.K., Balanza, J.G., Hildebrand, J., and Grosjean, G. (2019). Climate-Resilient Agriculture in The Philippines: Climate Risk Profile, Mindanao. International Center for Tropical Agriculture (CIAT); Department of Agriculture - Adaptation and Mitigation Initiative in Agriculture, Government of the Philippines; The Food and Agriculture Organization of the United Nations (FAO). Manila, Philippines. https://ciatph.github.io/#/crads/crp

Global Forest Watch (GFW). 2022. *Country Profile: Philippines*. Washington: GFW.

Hallegatte, S., A.C. Vogt-Schilb, M. Bangalore, and J. Rozenberg. 2016. "Unbreakable: Building the resilience of the poor in the face of natural disasters." Washington: World Bank.

Intergovernmental Panel on Climate Change (IPCC). 2014. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Geneva: IPCC.

Israel, C., and R. Briones. 2012. "Impacts of natural disasters on agriculture, food security, and natural resources and environment in the Philippines." Discussion Paper No.2013-15. Jakarta: Economic Research Institute for ASEAN and East Asia.

Nelson, K., T. Bui, and B. Sander. 2021. Guide to Supporting Agricultural NDC Implementation: GHG Mitigation in Rice Production in Vietnam. Los Baños: International Rice Research Institute.

Perez, N., and M. Rosegrant. 2019. "A partial equilibrium approach to modelling alternative agricultural futures under climate change." In: M. Rosegrant and M. Sombilla (eds), *The Future of Philippine Agriculture under a Changing Climate: Policies, Investments and Scenarios*. Singapore: ISEAS-Yusof Ishak Institute.

Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA). 2018. *Observed and Projected Climate Change in the Philippines*. Quezon City: PAGASA.

Philippine Statistics Authority (PSA). 2021a. *Agricultural Indicators System (Economic Growth: Agriculture)*. Quezon City: PSA.

Philippine Statistics Authority (PSA). 2021b. *Swine Situation Report: January – December 2020*. Quezon City: PSA.

Philippine Statistics Authority (PSA). 2021c. Summary Inflation Report Consumer Price Index (2012 = 100): December 2020. Quezon City: PSA.

Philippine Statistics Authority (PSA). 2021d. *2016-2020 Crops Statistics of the Philippines*. Quezon City: PSA.

Philippine Statistics Authority (PSA). 2020. "Damages due to natural events and disasters amounted to PhP 463 Billion." Press release. Quezon City: PSA.

Pulhin, J. and Tapia, M. 2016. "Vulnerability and Sustainable Development: Issues and Challenges from the Philippines' Agricultural and Water Sectors". In: J. Uitto and R. Shaw (eds), *Sustainable Development and Disaster Risk Reduction*. Tokyo: Springer.

Reyes, C. 2021. "Eradicating poverty in the Philippines by 2030: An elusive goal?" Discussion Paper No.2021-42. Quezon City: Philippine Institute for Development Studies.

Reyes, C., A. Tabuga, R. Asis, and M. Datu. 2012. "Poverty and agriculture in the Philippines: Trends in income poverty and distribution." Discussion Paper No.2012-09. Quezon City: Philippine Institute for Development Studies.

Salvacion, A., and A. Martin. 2016. "Climate change impact on corn suitability in Isabela province, Philippines." *Journal of Crop Science and Biotechnology*. 19:223-229

Samoy-Pascual, K., Yadav, S., Evangelista, G. K., Burac, M. A., Rafael, M., Cabangon, R., Tokida, T., Mizoguchi, M., and Regalado, M. J. 2022. "Determinants in the adoption of alternate wetting and drying technique for rice production in a gravity surface irrigation system in the Philippines." *Water*, 14(1):5.

Scognamillo, A. and Sitko, N. 2021. "Leveraging social protection to advance climate-smart agriculture: An empirical analysis of the impacts of Malawi's Social Action Fund (MASAF) on farmers' adoption decisions and welfare outcomes." *World Development*, 146.

Silva, J., P. Reidsmaa, A. Laborte, and M. van Ittersuma. 2016. "Explaining rice yields and yield gaps in Central Luzon, Philippines: An application of stochastic frontier analysis and crop modelling." *European Journal of Agronomy*, 82:223–241.

Soriano, M., and S. Herath. "Climate change and traditional upland paddy farming: A Philippine case study." *Paddy Water Environment*, 18:317–330.

Sustainable Rice Platform. 2019. *Standard on Sustainable Rice Cultivation: Version 2, January 2019*. Bangkok, Thailand. URL: www.sustainablerice.org

The Compendium of Philippine Environment Statistics (2014 and 2016): https://psa.gov.ph/content/compendium-philippine-environment-statistics-0

Thomas, T., V. Nazareth, and R. Folledo Jr. 2019. "A Biophysical Approach to Modelling Alternative Agricultural Futures under Climate Change". In: Rosegrant, M. and M. Sombilla, (eds), *The Future* *of Philippine Agriculture under a Changing Climate: Policies, Investments and Scenarios*. ISEAS-Yusof Ishak Institute, Singapore.

Tivet, F. and S. Boulakia. 2017. Climate Smart Rice Cropping Systems in Vietnam. State of Knowledge and Prospects. Montpellier, France: CIRAD.

UNDP & DENR n.d. (2014?). Adaptation and mitigation initiatives in Philippine rice cultivation . United Nations Development Programme UNDP Philippines DENR. http://www.undp.org/content/dam/undp/library/Environment%20and%20Energy/MDG%20Carbon%20Facility/AMIA%20Philippines%20Final.pdf

Uprety, R. 2016. Agricultural Intensification in Nepal, with Particular Reference to Systems of Rice Intensification. PhD thesis. The Netherlands: Wageningen University.

World Bank (World Bank). 2022. *World Bank Open Data*. Washington: World Bank.

World Bank (World Bank). 2020. Transforming Philippine Agriculture : During COVID-19 and Beyond. Washington: World Bank.

World Food Programme (WFP). 2018. *Fill the Nutrition Gap Philippines, Summary Report*. World Food Programme, UNICEF, DOST-FNRI. Manila, Philippines