INSTITUTIONALIZATION OF CLIMATE RESILIENT AGRICULTURE

POLICY OPTIONS AND INVESTMENT ROADMAP FOR BUILDING LONG-TERM RESILIENCE IN AGRI-FOOD VALUE CHAINS IN THE PHILIPPINES

APRIL 2024

ASIAN DEVELOPMENT BANK

INSTITUTIONALIZATION OF CLIMATE RESILIENT AGRICULTURE

POLICY OPTIONS AND INVESTMENT ROADMAP FOR BUILDING LONG-TERM RESILIENCE IN AGRI-FOOD VALUE CHAINS IN THE PHILIPPINES

APRIL 2024

Prepared by TRTA Consultant under

TA-10009 PHI: Accelerating Climate Resilience in Agriculture, Natural Resources, and the Environment - 01 TA Consulting Firm (55268-002)

CONTENTS

LIST OF TABLES

List of Figures

EXECUTIVE SUMMARY

This report explores the intersection of agriculture and economic resilience in the Philippines, particularly under the pressures of climate change. It provides a comprehensive analysis of the current status of the agriculture sector, its economic implications, and the anticipated impacts of climate variability. The report concludes with strategic investment and policy recommendations aimed at enhancing long-term resilience and sustainability.

Agriculture is crucial for food security, income, and livelihoods in the Philippines, especially in the context of economic recovery post-pandemic. However, the sector faces significant threats from climate change. The introduction emphasizes the need for strategic policies and investments to enhance agricultural resilience and adaptability, ensuring it remains a catalyst for economic growth

Accounting for about 11% of GDP and 26% of employment, agriculture is a key economic pillar. Despite minimal decline during the pandemic, the sector's vulnerability to international market fluctuations and climate impacts underscores the need for sustainable practices and increased domestic production. Key facts include a reliance on imports for essential food commodities and the resilience shown during economic downturns, highlighting the sector's role in economic stability.

Projected climatic changes by 2050, including significant temperature increases and variability in rainfall, pose threats to agricultural productivity. Detailed biophysical and economic modeling predicts reductions in crop yields, with corn and sugar yields potentially decreasing by up to 23% and 11%, respectively. The chapter underscores the urgency of adopting adaptive strategies to mitigate these effects through technology improvements and agricultural practice enhancements.

The review of various investment and policy options to counteract the impacts of climate change, suggests technology, infrastructure, and market responses, such as the development of climate-resilient agricultural technologies. A comparative analysis of investment programs like AMIA Plus and AMIA Enterprise offers insights into potential benefits, emphasizing that strategic investments are crucial for maintaining agricultural productivity under changing climatic conditions.

The report concludes with key policy recommendations, advocating for a comprehensive policy framework and significant investments in resilient technologies and infrastructure. The necessity of developing detailed implementation roadmaps for these strategies is highlighted, along with their integration into national and local government planning to ensure the agricultural sector's long-term sustainability and resilience.

The report underscores the critical role of proactive measures and strategic planning in safeguarding the Philippine agriculture sector against the backdrop of global climate change. Through detailed analysis and targeted recommendations, it aims to guide policymakers in fostering an agricultural sector that is both resilient and capable of contributing to the nation's economic growth.

ACRONYMS

ADAPTs	Agricultural Development and Policy Transformation Strategies
AMIA	Adaptive Management of Information in Agriculture
AR5	Fifth Assessment Report
AR6	Sixth Assessment Report
CH4	Methane
CMIP6	Coupled Model Intercomparison Project Phase 6
CO2	Carbon Dioxide
CRA	Climate-Resilient Agriculture
CS	Climate-Smart Agriculture
DSSAT	Decision Support System for Agrotechnology Transfer
FAOSTAT	Food and Agriculture Organization Corporate Statistical Database
GCM	Global Climate Model
GDP	Gross Domestic Product
GHG	Greenhouse Gas
IPCC	Intergovernmental Panel on Climate Change
N2O	Nitrous Oxide
Phil-DCGE	Philippines Dynamic Computable General Equilibrium
R&D	Research and Development
RCP 8.5	Representative Concentration Pathway 8.5
SPAM	Spatial Production Allocation Model
SSP2	Shared Socioeconomic Pathway 2
WDI	World Development Indicators

1 INTRODUCTION

The recent health pandemic and regional conflicts highlighted the importance of a resilient agriculture in providing food security, livelihoods and household income and in cushioning the adverse impacts of subsequent years of economic slowdown. Similarly, in the context of post-pandemic economic recovery, the country can continue to rely on the agriculture sector to be the catalyst in spurring economic growth. However, agriculture itself is under threat – of changing climate that poses an even more significant and longer-lasting danger to the future of the food systems and food security.

The resilience, competitiveness, and sustainability of Philippine agriculture depend on the strategic decisions of the government, agricultural producers, and consumers to adapt to and mitigate climate impacts. This report models the productivity and economic effects of climate change on Philippine agriculture, highlighting adaptation and mitigation potentials. It emphasizes the importance of formulating proactive government policies and investment strategies that support the country's nutrition and food security goals. These strategies must be institutionalized at national and local levels and integrated into development planning. Investments in agriculture are crucial for long-term resilience in the agri-food system through the development of technologies, infrastructure building, and community mobilization for climate adaptation.

Climate change is a growing and lasting threat exacerbated by land and water scarcity. Temperatures are projected to continue increasing, accompanied with wider annual and seasonal variability in rainfall can drastically reduce farm yields and production. Climate change, along with water and land scarcity, need to be addressed and mainstreamed in government policies and strategic investments on adaptation and mitigation.

The impacts of climate change on the agricultural sector are often subtle as temperature and precipitation regimes are changing gradually. These gradual changes are interspersed with extreme events, such as droughts and flooding that are increasing in frequency and in intensity with climate change. Higher temperatures and low precipitation in this already arid country can result in adverse impacts for the country's agriculture and food systems.

Land and water scarcity will further exacerbate the production impact of climate change to Philippines's agricultural future. The limited fertile lands suited for agriculture is in decline due to high rate of urbanization in the last 20 years. Water is also in limited supply, relying mostly on small river basins and groundwater resources. Agriculture as the dominant user of freshwater consumes the equivalent to 82% of total supply. With increasing population, growing investment in industry, and the increasing loss to evaporation – reduced water availability will be a growing threat to the country's agricultural economy.

Agriculture also contributes 10% of the country's GHG emissions, next to energy (72%) and industry (14%) sectors. GHG emissions from agriculture are mostly in the form of methane (CH_4) and nitrous oxides (N_2O), and in terms of CO_2 equivalent the major contributors are enteric fermentation from livestock (35%), synthetic fertilizers (21%), animal manure (17%), rice cultivation (13%) and on-farm energy use (11%) (FAOSTAT). Additionally, unaccounted food losses and GHG emissions permeate the food supply chain – due to poor harvesting and post-harvesting practices, inadequate storage, transport and handling facilities, and inefficiencies in the market system.

2 AGRICULTURE AND THE PHILIPPINE ECONOMY

Agriculture is a key sector in the Philippine economy, representing around 11% of annual GDP and 26% of employment, while the industrial sector accounts for 30% of GDP and a fifth of employment. The service sector accounts for the largest share of GDP and employment (Table 1). The agriculture sector was the most resilient during the pandemic year of 2020 – declining only by 0.2%, compared to service sector's 9% decline and industry's -13% (WDI), although the industry and service sectors were growing of agriculture during the last three decades and during the last ten years.

The Philippines remains highly vulnerable to international market developments because it relies on imports for key food commodities, including wheat and rice. All wheat and around 22% of recent rice demand are imported. Food imports are twice the value of food exports and constitutes 11% of the country's merchandise import receipts – and growing at annual rate of 8% from 1990 to 2020.

The number of undernourished population and malnourished children have been declining respectively by 5.5% and 0.2% during the last two decades, and even more so in the last ten years.

Table 1: Agriculture and the Philippine Economy, 1990, 2000, 2010 and 2020

Indicators	Units	Decades				Annual Growth Rates by period (%)			
		1990	2000	2010	2020	1990-2000	2000-2010	2010-2020	1990-2020
Gross domestic product (GDP)									
Gross domestic product (GDP)	constant 2015 US$ billion	107.1	142.8	228.6	358.5	3.3	5.0	5.7	4.7
GDP growth	annual rate (%)	3.1	4.4	7.3	-9.5				
Agriculture, forestry, and fishery	constant 2015 US$ billion	17.6	21.2	29.9	35.5	1.7	3.8	1.7	2.8
Agriculture, forestry, and fishery	% of GDP	19.2	13.9	13.7	10.2				
Agriculture, forestry, and fishery	annual rate (%)	0.2	3.4	1.3	-0.2				
Industrial sector	constant 2015 US$ billion	36.2	46.4	69.8	106.3	4.3	3.1	4.2	5.8
Industrial sector	% of GDP	38.2	35.0	32.3	28.4				
Services sector	constant 2015 US$ billion	53.3	75.1	128.8	216.7	5.4	3.9	5.7	6.4
Services sector	% of GDP	42.7	51.1	53.9	61.4				

Indicators	Units	Decades				Annual Growth Rates by period (%)			
		1990	2000	2010	2020	1990-2000	2000-2010	2010-2020	1990-2020
Food Production and Trade									
Food production	index: 2014–2016 = 1.00	58.0	70.0	91.5	100.7	1.9	3.0	0.8	2.2
Food imports	current US$ billion	1.3	2.6	6.4	12.5	10.6	10.2	8.8	8.1
Food exports	current US$ billion	1.7	1.8	3.8	6.0	1.3	8.0	3.6	5.2
Labor and Employment									
Total labor force	million	23.9	29.8	38.1	42.4	2.6	2.5	1.4	2.4
Employment rate	% of labor force	96.1	96.2	96.4	97.5				
Employment in agriculture	% of total employment	45.5	37.1	33.0	24.8				
Employment in industry	% of total employment	16.0	16.2	15.5	18.3				
Employment in services	% of total employment	38.5	46.7	51.5	56.9				
Population									
Total population	million	61.6	78.0	94.6	112.2	2.4	2.0	1.7	2.0
Population growth	annual rate (%)	2.4	2.2	1.8	1.6				
Rural population	million	32.6	42.0	51.7	59.0	2.6	2.1	1.3	2.0
Rural population	% of population	53.0	53.9	54.7	52.6				
Health and Nutrition									
Life expectancy	years	65.9	69.4	70.8	72.1	0.5	0.2	0.2	0.2
Rate of undernourishment	% of population	--	18.6	12.3	8.1				
Undernourished population	million	--	14.5	11.6	9.1		-3.8	-8.7	-5.5
Children malnourishment	% of children < 5 years	--	34.8	32.6	29.7				
Malnourished children	million	--	3.7	3.8	3.5		0.3	-0.7	-0.2

(Note: "--" means no data; blank cells not estimated. **Source: Data from World Development Indicators)**

Agricultural and food productivity grew rapidly during the past 30 years, with rice production almost doubling from 1990 to 2020, and combined meat products almost tripled during the same period. However, in terms of annual growth, moderate growth were achieved by the poultry and dairy sectors at around 5% annual growth, with all food commodities gaining positive growth rates, albeit modest.

Table 2: Performance of the Philippine Agriculture Sector – Food Production Growth, 1990-2020.

Food Commodities	Production (*000 mt*)				Annual Growth Rates by period (%)				Change from 1990 to 2020
	1990	2000	2010	2020	1990-2000	2000-2010	2010-2020	1990-2020	
All meat products	1,151	2,140	2,991	3,234	6.1	3.5	1.1	3.6	181
Beef	246	517	592	345	8.4	1.5	-5.3	2.2	40
Mutton/Goat meat	47	59	96	55	2.8	6.5	-6.1	2.1	18
Pork	906	1,543	2,082	1,909	5.0	3.2	-0.5	2.7	111
Poultry meat	158	364	587	926	8.5	4.5	5.1	5.7	484
Dairy	285	404	578	894	3.5	3.8	4.4	3.6	214
Eggs	13	6	9	15	-7.7	4.2	4.9	2.2	14
All cereals	10,844	12,229	16,026	19,835	0.9	3.7	1.6	2.7	83
Corn	4,628	4,092	5,784	7,364	-1.4	5.4	1.8	2.5	59
Rice	6,389	8,008	10,194	12,471	2.0	3.0	1.5	2.8	95
Fruits	11,574	13,294	19,780	20,122	1.4	4.4	0.3	2.3	74
Vegetables	4,585	5,265	6,356	7,178	1.2	1.8	1.2	1.6	57
Oilseed crops	13,384	14,733	17,085	16,877	1.2	1.4	-0.4	1.0	26
Pulses	71	63	66	76	-0.7	0.8	0.8	0.5	7
Roots and tubers	2,413	2,257	2,611	3,043	-0.6	2.1	1.9	1.0	26
Sugar	3,135	2,611	2,206	3,002	-1.1	-0.2	0.3	0.4	-4

Source: Data from FAOSTAT online.

3 IMPACTS OF CLIMATE CHANGE TO AGRICULTURE AND THE ECONOMY

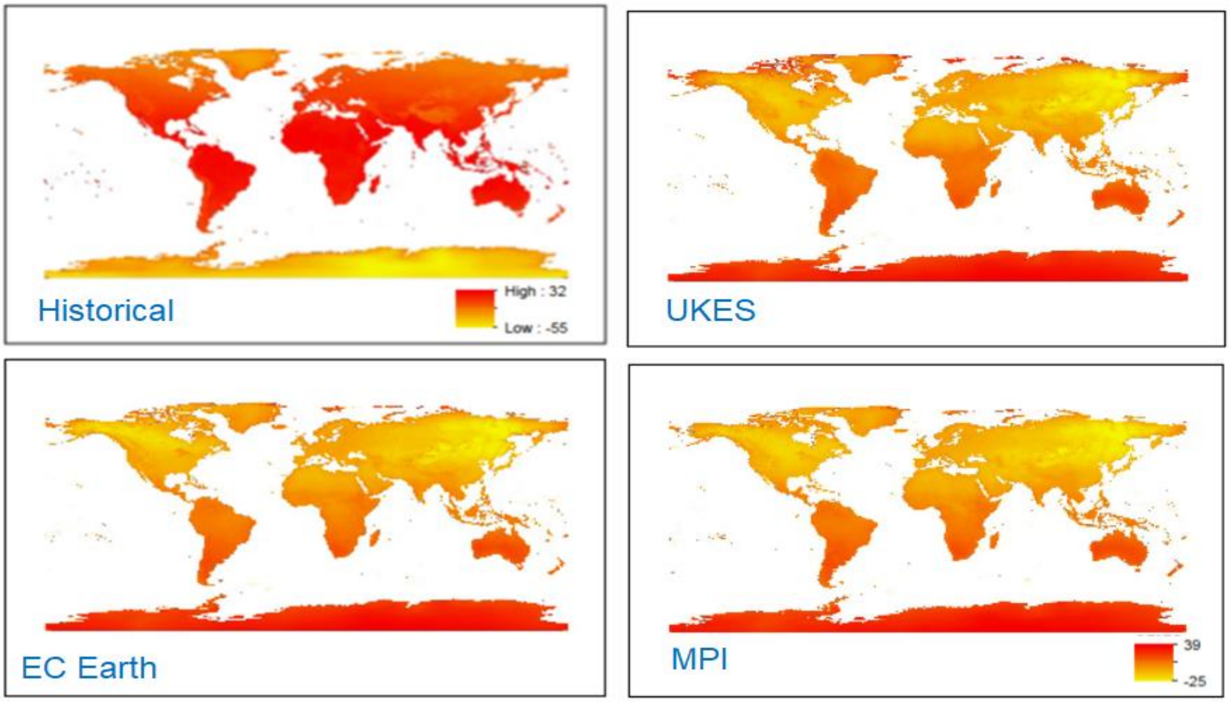
Projections of future climates for the Philippines and the entire world are implemented by comparing the average historical (*or* baseline) climate data for 1970-2000 with projections of future climate centered on 2050 (2040-2060) using downscaled datasets of three CMIP6 global climate models (GCMs) of UK-ESM, EC Earth and MPI-ESM under RCP 8.5 and SSP2. These selected GCMs project the highest, lowest and medium temperatures to represent an ensemble of at least 12 downscaled CMIP6 GCMs. Changes in rainfall (*or* precipitation) and temperature are examined to gain better understanding of the potential impact of climate change to Philippine agriculture.

3.1 Changing climate patterns

3.1.1 Changes in Temperature Patterns by 2050

Figures 1 and 2 present the temperature gradient-maps of the historical and projected changes in the mean daily temperature for the world and for the Philippines. The higher temperature changes are projected for the below the equator countries and regions of south America, southern Africa and Australia. Projected temperature changes range from maximum increase of 31.6 ^oC to minimum of -23.0 ^oC, and temperature mean of 4.4 ^oC, on average (Table 3)

Figure 1: Projections of Average Global Temperature, by 2050



Source: WorldClim 2.0 online

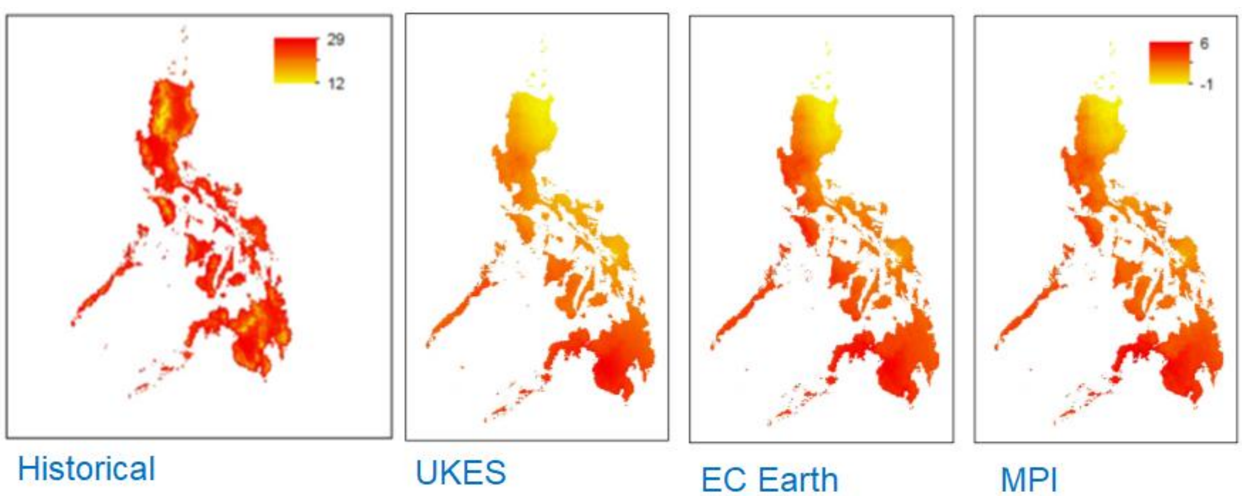
For the Philippines, the western and southern regions of the country are projected to be hottest by 2050, with maximum average temperature increase of 4.3 ºC, and minimum temperature decrease of 0.4 ºC – and mean average temperature of 2.3 ºC (Table 4)

Table 3: Historical and Projected Average Global Temperatures, By 2050

Temperature (ºC)	Historical (1970-2000)	Change from Historical (2040-2060)			
		UK-ESM (UK-ESMM1-0-LL)	EC Earth (EC-Earth3-Veg)	MPI-ESM (MPI-ESM-ESM1-2-H-R)	Average
Maximum (ºC)	31.4	38.9	28.1	27.7	31.6
Mean (ºC)	-4.4	6.7	4.0	2.5	4.4
Minimum (ºC)	-54.8	-20.8	-23.6	-24.6	-23.0

Note: The global climate models are adopted from UK Earth System Modeling (UK-ESM); European Community Earth System Model (EC Earth); and Max Planck Institute for Meteorology Earth System Model (MPI-ESM). Source of basic data: WorldClim 2.0 online

Figure 2: Projections of Average Philippines Temperature by 2050



Source: WorldClim 2.0 online

Table 4: Projections of Average Philippine Temperature by 2050

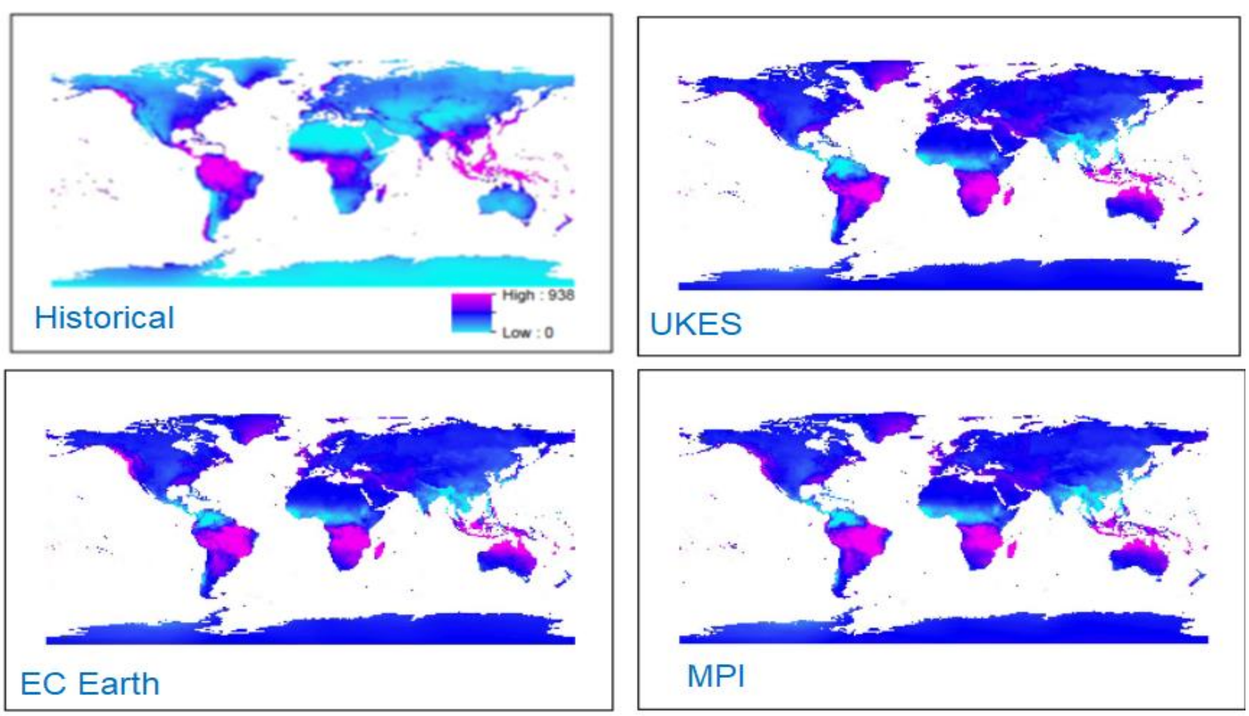
Temperature (ºC)	Historical (1970-2000)	Change from Historical (2040-2060)			
		UK-ESM (UK-ESMM1-0-LL)	EC Earth (EC-Earth3-Veg)	MPI-ESM (MPI-ESM-ESM1-2-H-R)	Average
Maximum (ºC)	28.9	5.9	4.3	2.8	4.3
Mean (ºC)	25.7	3.0	2.6	1.4	2.3
Minimum (ºC)	12.4	-0.1	-0.2	-0.9	-0.4

Note: The global climate models are adopted from UK Earth System Modeling (UK-ESM); European Community Earth System Model (EC Earth); and Max Planck Institute for Meteorology Earth System Model (MPI-ESM-ESM). Source of basic data: WorldClim 2.0 online

3.1.2 Changes in Rainfall Patterns by 2050

Corresponding changes in rainfall patterns are shown in Figure 3 and Table 5 for the world, and Figure 4 and Table 6 for the Philippines. Globally, the average mean monthly rainfall is projected to decline slightly by 0.4 mm, but with average maximum rainfall increase of 765 mm/month. Higher increases in rainfall are projected for the regions just below the equator – the countries of Brazil and Argentina, Central African countries and Southeast Asian countries and northern Australia. In the Philippines, average mean rainfall is to decline by 47.2 mm/month, with average maximum increase in rainfall of 529.7. The eastern corridor of Visayas and Mindanao can be the relatively wetter part of the country by 2050.

Figure 3: Projections of Average Global Rainfall, by 2050



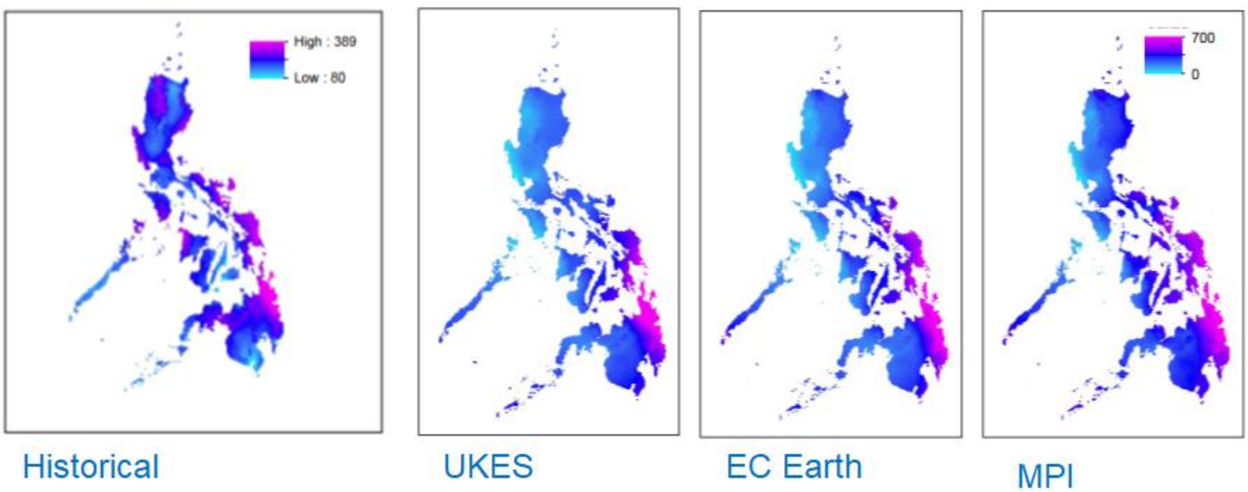
Source: ***WorldClim*** *2.0 online*

Table 5: Historical and Projected Average Global Rainfall, by 2050

Rainfall (mm/month)	Historical (1970-2000)	Change from Historical (2040-2060)			
		UK-ESM (UK-ESMM1-0-LL)	EC Earth (EC-Earth3-Veg)	MPI-ESM (MPI-ESM-ESM1-2-H-R)	Average
Maximum	938.0	715.0	816.0	764.0	765.0
Mean	43.9	-0.5	0.9	-1.7	-0.4
Minimum	0.0	0.0	0.0	0.0	0.0

Note: The global climate models are adopted from UK Earth System Modeling (UK-ESM); European Community Earth System Model (EC Earth); and Max Planck Institute for Meteorology Earth System Model (MPI-ESM-ESM). Source of basic data: WorldClim 2.0 online.

Figure 4: Projections of Average Rainfall, Philippines by 2050



Source: WorldClim 2.0 online

Table 6: Historical and Projected Average Rainfall, Philippines by 2050

Rainfall (mm/month)	Historical (1970-2000)	Change from Historical (2040-2060)			
		UK-ESM (UK-ESMM1-0-LL)	EC Earth (EC-Earth3-Veg)	MPI-ESM (MPI-ESM-ESM1-2-H-R)	Average
Maximum	389.0	701.0	589.0	299.0	529.7
Mean	209.8	-59.4	-26.3	-56.1	-47.2
Minimum	80.0	0.0	0.0	0.0	0.0

Note: The global climate models are adopted from UK Earth System Modeling (UK-ESM); European Community Earth System Model (EC Earth); and Max Planck Institute for Meteorology Earth System Model (MPI-ESM-ESM). Source: WorldClim 2.0 online

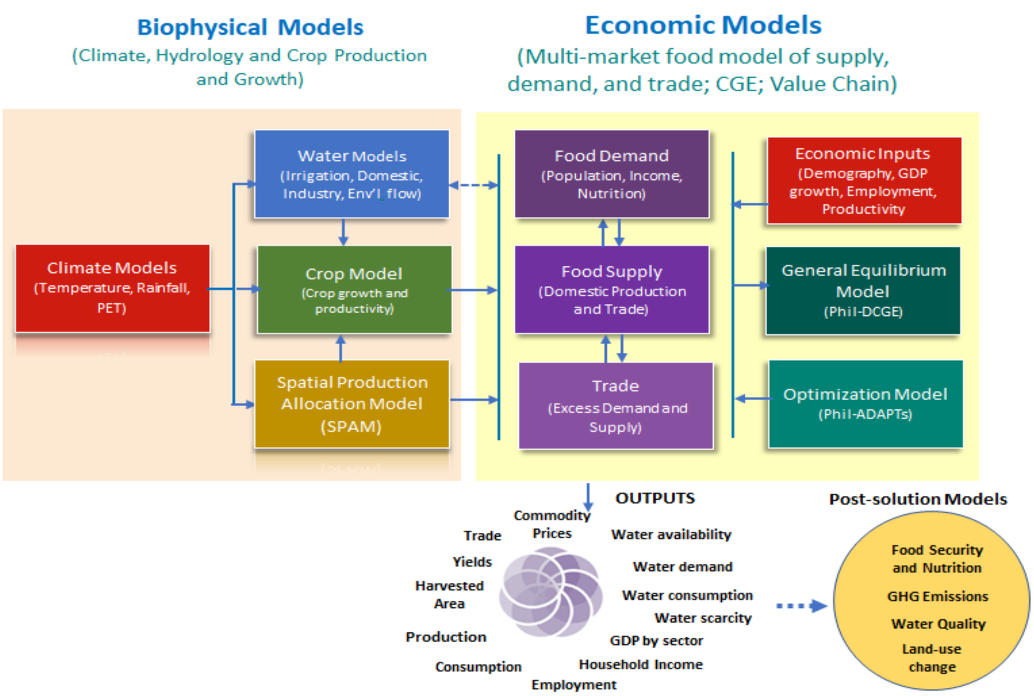
3.1.2.1 Impact of Climate Change to the Food System

Quantifying the impacts of climate change to the agriculture sector and to the entire economy can be a daunting task that needs to include the bio-physical effects on production and crop productivity; the economic effects on food prices, income and employment; producer and consumer responses to market signals; and the welfare-effects and food security implications.

3.1.3 Implementation of Biophysical-Economic Modeling

A suite of biophysical and economic models were calibrated for Philippines and implemented to estimate the impacts of climate change to the agriculture sector and to the entire economy in a more comprehensive manner (Figure 8). The biophysical models include; (a) three water modules (*i.e.,* global hydrology, water allocation, and water-stress model) that focus on water supply and demand and allocation to competing uses such as irrigation, domestic and industrial uses, and environmental flow; (b) a crop module (*i.e.,* DSSAT Model) that determines crop growth and productivity under different soil, water, and climate conditions; (c) a spatial production allocation model (SPAM) that maps the geographical distributions of foodcrops globally under different land- and water environment; (d) general circulation models (GCMs) of future climates to 2050. (See Appendix B on Methodology for details).

Figure 5: The Impact Modelling Framework



Note: The Phil-DCGE and Phil-ADAPs Optimization models are still to be calibrated and added to the Philippine version of IMPACT. Source: Authors' depiction.

The economic models include: (a) a core multi-market food model of supply, demand, and trade; (b) a computable general equilibrium model of Philippines (Phil-DCGE) to evaluate the economy-wide impacts of climate shocks; (c) an optimization module (ADAPTs) that focuses on production and value chains analyses; and (d) macro-economic module (demography, national income, employment and productivity) that serves as inputs and initial values for the model.

3.1.3.1 Productivity-effect, and Farmers Supply Response to Prices

The influence of climate change can be categorized into biophysical and economic effects. The biophysical effects are reflected in the changes of plant growth and productivity due to heat-stress from higher temperatures; water-stress due to projected decline in rainfall and increasing crop-water demand through increase in plant evapotranspiration. Table 7 shows that the cumulative effects of biophysical stressors can reduce yields by as much as 23% for corn and 11% for sugar crops. The least affected are rootcrops and other crops.

Table 7: Biophysical and Economic Effects of Climate Change on Crop Productivity in Philippines, by 2050

Food commodities	Climate Effects (Heat and Water Stress)	Climate and Economic/ Market Effects*
Yield Levels	----------------------------*% from NoCC*------------------------	
All foodcrops	-8.50	-3.93
All cereals	-11.04	-8.53
Corn	-22.86	-19.40
Rice	-4.64	-3.76
Other crops	-3.12	-4.21
Fruits	-5.01	-1.65
Vegetables	-5.01	5.81
Oilcrops	-5.02	-4.29
Pulses	-5.51	-4.80
Roots & tubers	-4.49	-0.25
Sugar crops	-11.25	-9.64

**** Market effects include positive response of producers to higher prices***

*Notes: Results are averages of 3 climate models UK-ESM, EC Earth and MPI-ESM under RCP 8.5 and SPP2; * NoCC means no climate change that serves as the counterfactual scenario. The direct effects of climate change on animal-sourced foods were not simulated. Instead, they reflect indirectly the effects of climate on feedstuffs like corn and oilseed crops. Source: Biophysical and Economic Modules in IMPACT.*

On the other hand, the economic effects of climate change are triggered by increasing market prices of food induced by global reduction in yields and production (Table 9 and Table 10 and Figure 7). They work through the economic concept of *producer supply response* that motivates farmers to take advantage of previous year's favorable prices in boosting their incomes in the current year – by producing more, either by expanding production area or by implementing available productivity- enhancing technologies on their farms. In the Philippine context, where farm areas are limiting, the logical supply response is through the adoption of better technologies, and in this case – climate change adaptation technologies, or climate-smart agriculture (CSA) technologies.

This shows that farmers, by their own initiative, are willing to adopt CSA technologies made available to them in order to take advantage of increasing prices of their produce.

Combined with the economic effects, *i.e.,* farmers' positive *supply-response* to increasing food prices, productivity losses due to climate change are dampened while productivity gains are further enhanced (Table 7 and Table 8) – especially for vegetables where increases in price are high enough to reverse the productivity effects of climate change. For all other foodcrops, farmers supply responses are to effectively reduce the yield-effects of climate change – notably for corn (from -23 % to -19%), rootcrops (-4.49% vs -0.25%) and fruits (-5.01% vs -1.65%). Overall, however, farmers supply response alone is not sufficient to fully counter the negative productivity-effects of climate change. Government interventions and investment policies are still needed to fully counter the effects of climate change and related economic and biophysical shocks.

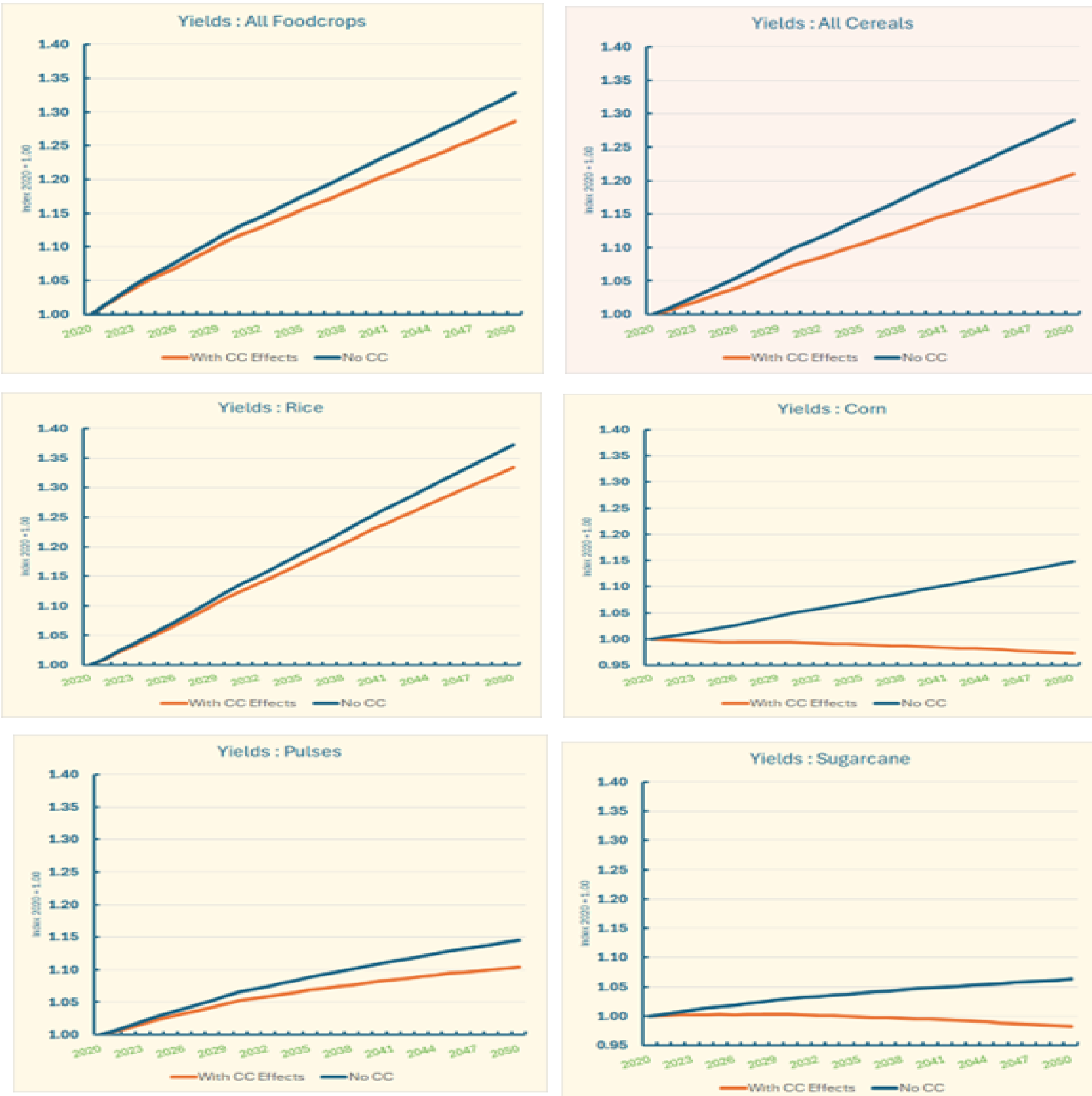
Table 8: Impact of Climate Change on Yields of Food Commodities in the Philippines by 2050

Food commodities	2020	2050 Projections		
		No Climate Change (NoCC)	With Climate Change	Change from No CC
Yields	-------------- *mt/ha*	------------------		%
All Foodcrops	7.71	10.25	9.84	-3.93
All cereals	2.81	3.63	3.32	-8.53
Corn	2.71	3.11	2.51	-19.40
Rice	2.88	3.95	3.80	-3.76
Other Crops	1.30	1.55	1.49	-4.21
Fruits	15.26	20.52	20.18	-1.65
Vegetables	10.70	13.78	14.58	5.81
Oilseed crops	4.59	5.27	5.04	-4.29
Pulses	0.92	1.06	1.00	-4.80
Roots and tubers	8.16	10.20	10.17	-0.25
Sugar	83.19	88.46	79.93	-9.64

*Note: Results are averages of 3 climate models UK-ESM, EC Earth and MPI-ESM under RCP 8.5 and SPP2; * NoCC means no climate change that serves as the counterfactual scenario. Productivity-effects of climate change were not simulated for animal-sourced foods. Source: IMPACT-Phil simulations.*

The negative yield effects of climate change, however, do not mean that yield levels are not to increase, *i.e.,* negative rate of growth. Yields are still to have positive growth but at lower rates. Figure 6 illustrates the divergence of yield pathways due to climate change. The gaps between the *NoCC* pathways and *CC- effects* are the *percentage differences* described by the negative values in Table 7 and Table 8 The wider the gaps the more severe the effects of climate on crop productivity.

Figure 6: Diverging Trajectories of Yields Under the Influence of Climate Change, 2020-2050



*Note: Results are averages of 3 climate models UK-ESM, EC Earth and MPI-ESM under RCP 8.5 and SPP2; * NoCC means no climate change that serves as the counterfactual scenario. Source: IMPACT-Phil simulations*

Subsequent effects of productivity losses are further reflected in the production of food commodities. Note that although direct productivity-effects of climate on animal-sourced foods are not estimated, their production is indirectly affected by the productivity losses of feedstuff (*i.e.,* coarse grains and cereals).

Production of most food commodities, including animal-sourced foods are projected to decline due to climate change – except for rootcrops, fruits and vegetables which are to get production boost from climate change. Highest production declines are projected for pulses (-9.55%) and cereals (-8.67%), especially for corn (-21.57%) and rice (-8.10%), while egg and mutton productions are to increase by 2.02% and 0.39% relative to the *no-climate-change* (*i.e.,* counterfactual) scenario (Table 9).

Table 9: Impact of Climate Change on Food Production in the Philippines by 2050

Food commodities		2050 Projections		
	2020	No Climate Change (NoCC)	With Climate Change	Change from No CC
Production	-------------- *000 mt* ---------------			%
All meat products	3,234	5,090	5,016	-1.45
Beef	345	635	627	-1.28
Mutton/Goat meat	55	95	95	0.39
Pork	1,909	2,714	2,710	-0.13
Poultry meat	926	1,646	1,583	-3.79
Dairy	15	20	20	-1.68
Eggs	894	1,738	1,773	2.02
All cereals	19,835	26,476	24,179	-8.67
Corn	7,364	8,668	6,798	-21.57
Rice	12,471	17,808	17,381	-2.40
Other crops	656	1,001	955	-4.61
Fruits	20,122	33,524	33,971	1.34
Vegetables	7,178	11,575	12,629	9.10
Oilseed crops	16,877	19,809	19,520	-1.46
Pulses	76	95	86	-9.55
Roots and tubers	3,043	3,922	3,939	0.44
Sugar	3,002	4,383	4,163	-5.02

*Note: Results are averages of 3 climate models UK-ESM, EC Earth and MPI-ESM under RCP 8.5 and SPP2; * NoCC means no climate change that serves as the counterfactual scenario. Source: IMPACT-Phil simulations.*

3.1.4 Effects on Access to, Availability and Consumption of Food

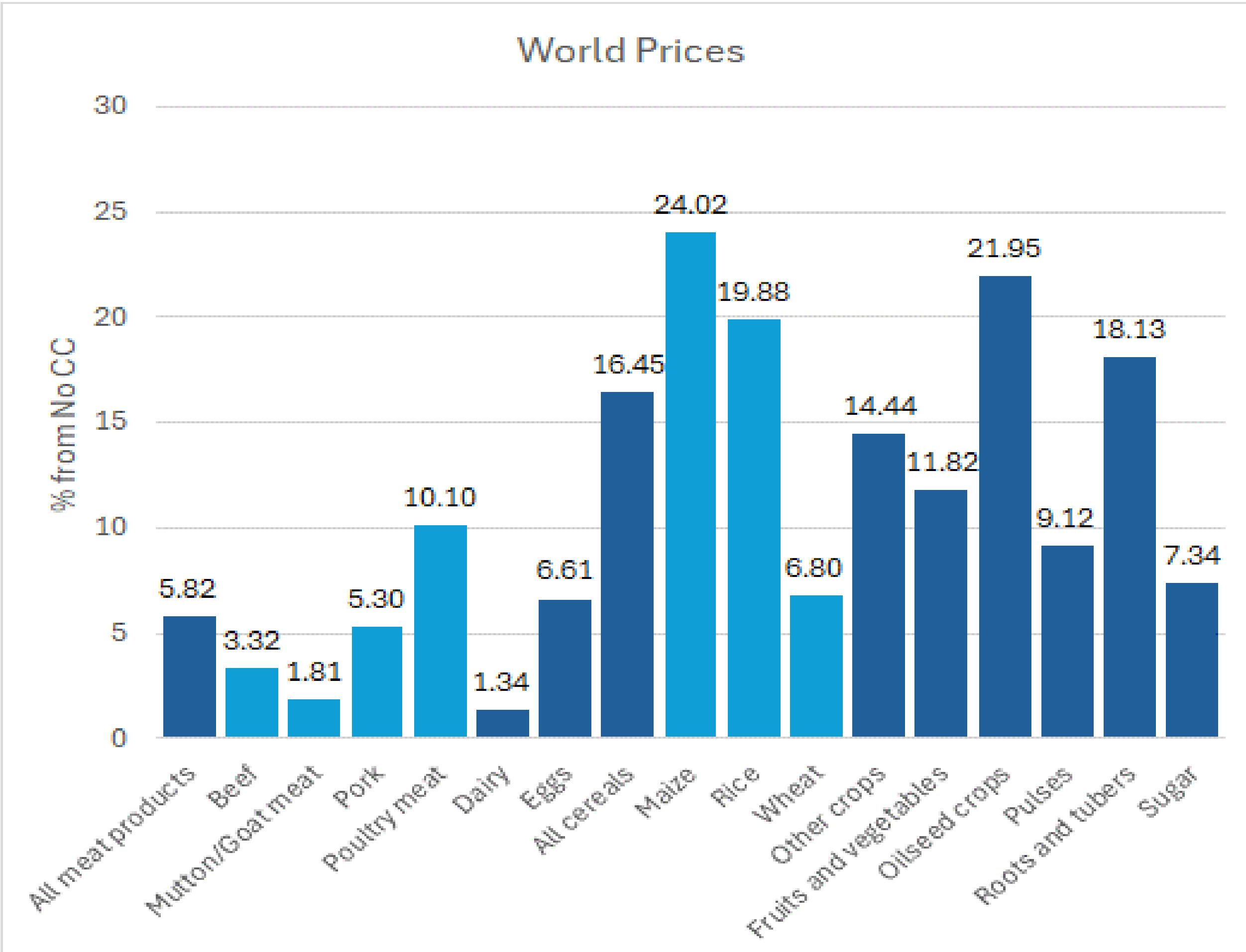
Similar trends of climate-induced productivity losses and production declines in Philippines are projected globally. Subsequently, prices of food commodities are also to increase by as much as 24% for corn, by 22% for oilseed crops, and by 18% for rootcrops (Table 10 and Figure 7) – making food less affordable and thus less accessible for the poor.

Table 10: Changes in the World Prices of Food Due to Climate Change, by 2050

Food commodities		2050 Projections		
	2020	No Climate Change (NoCC)	With Climate Change	Change from No CC
World Prices		------- *US$/mt* --------		%
All meat products	3,034	3,472	3,675	5.82
Beef	3,933	4,258	4,400	3.32
Mutton/Goat meat	4,985	4,578	4,661	1.81
Pork	2,708	3,214	3,384	5.30
Poultry meat	2,318	2,857	3,145	10.10
Dairy	555	591	599	1.34
Eggs	2,356	2,587	2,758	6.61
All cereals	248	285	332	16.45
Corn	179	220	273	24.02
Rice	413	487	584	19.88
Wheat	259	298	318	6.80
Other crops	1,368	1,541	1,763	14.44
Fruits and vegetables	1,007	1,246	1,394	11.82
Oilseed crops	528	570	695	21.95
Pulses	1,098	1,170	1,277	9.12
Roots and tubers	391	465	549	18.13
Sugar	403	473	508	7.34

*Note: Results are averages of 3 climate models UK-ESM, EC Earth and MPI-ESM under RCP 8.5 and SPP2; * NoCC means no climate change that serves as the counterfactual scenario. Source: IMPACT-Phil simulations.*

Figure 7: Projected Increases in World Prices of Food Due to Climate Change by 2050



*Note: Results are averages of 3 climate models UK-ESM, EC Earth and MPI-ESM under RCP 8.5 and SPP2; * NoCC means no climate change that serves as the counterfactual scenario. Source: IMPACT-Phil simulations.*

Domestic production and trade are determinants of available food for consumption in the country. Net food trade for Philippines is projected to decline – generally less imports for cereals (*i.e.,* corn and rice), and rootcrops; and for the Philippine case, more exports of fruits and vegetables and oilseed crops (Table 11). While imports of sugar, wheat, and meat products are to increase.

However, changes in trade position can be either due to changes in domestic production or due to higher world prices. For rootcrops, pulses, fruits and vegetables, and poultry, the changes in trade positions are due to changes in production, i.e., decline in imports of rootcrops and increase of exports of eggs and fruits and vegetables are due to increases in domestic production. While the import declines of rice, corn, dairy and pork are due to increases of prices in the world market.

Table 11: Impact of Climate Change on Trade of Food in the Philippine by 2050

Food commodities		2050 Projections		
	2020 Baseline	No Climate Change (No CC)	With Climate Change	Change from NoCC*
Net Trade	------------------ 000 mt ----------------			%
All meat products	-829	-2,380	-2,418	1.58
Beef	-391	-926	-931	0.50
Mutton/Goat meat	-6	-49	-49	0.13
Pork	-257	-1,004	-994	-0.98
Poultry meat	-174	-402	-444	10.62
Dairy	-1,936	-3,094	-3,086	-0.26
Eggs	317	643	692	7.59
All cereals	-7,320	-16,484	-16,149	-2.04
Corn	516	-4,737	-4,422	-6.66
Rice	-3,708	-3,476	-3,281	-5.61
Wheat	-3,792	-7,816	-7,983	2.14
Other foodcrops	-139	-150	-164	9.35
Fruits and vegetables	5,391	9,037	11,673	29.16
Oilseed crops	3,248	2,779	2,857	2.81
Pulses	-123	-240	-251	4.35
Roots and tubers	-841	-1,430	-1,280	-10.46
Sugar	-106	-561	-674	20.11

*Note: Results are averages of 3 climate models UK-ESM, EC Earth and MPI-ESM under RCP 8.5 and SPP2; * NoCC means no climate change that serves as the counterfactual scenario. *Negative values mean either decline in exports or increase in imports, positive values mean either increase in exports or decline in imports. Value less than -100 means a shift from net importer to net exporter (or from net exporter to net importer). Source: IMPACT-Phil simulations.*

Since domestic production of these imported commodities are projected to decline, the general declines in imports are attributable to higher food prices – as they become less affordable for consumers, and thus, to cause declines in consumption, threatens the food security and state of nutrition the country.

Declines in consumption, brought about by high world prices of food and declines in domestic food production are presented in Table 12. Consumption of all food commodities is projected to decline, except for pulses and mutton. Declines in consumption are to be highest for oilseeds (-4.37%), rice (-3.27%) and corn (-3.16%). In terms of calories intake, daily per capita consumption declines by 2.32% with climate change.

In addition, less access to food has nutritional and health repercussions, as it increases the risk of hunger or undernourishment to the population and contributes to children's malnutrition. Due to higher prices of food, the number of undernourished populations is to increase by 8% and malnourished children by 3%.

Table 12: Changes in Daily Calories Intake and Annual Food Consumption, Philippines, 2050

Food commodities		2050 Projected Consumption		
	2020 Baseline	No Climate Change (NoCC)	With Climate Change	Change from NoCC
Annual consumption	---------- *kg/capita/year* --------			*%*
All meat products	37.0	50.1	49.9	-0.49
Beef	6.7	10.5	10.5	-0.22
Mutton/Goat meat	0.6	1.0	1.0	0.31
Pork	19.7	24.9	24.9	-0.36
Poultry meat	10.0	13.7	13.6	-0.97
Dairy	17.0	20.0	19.9	-0.27
Eggs	4.8	6.7	6.6	-1.26
All cereals	170.6	180.2	174.9	-2.93
Corn	14.3	12.9	12.5	-3.16
Rice	127.8	122.4	118.4	-3.27
Wheat	27.9	44.4	43.5	-1.95
Other foodcrops	4.1	4.2	4.1	-3.60
Fruits and vegetables	177.0	212.2	206.0	-2.93
Oilseed crops	5.4	6.1	5.9	-4.37
Pulses	1.8	2.2	2.2	0.44
Roots and tubers	27.7	27.2	26.5	-2.40
Sugar	26.1	31.0	30.3	-2.26
Food Security/Nutrition				
Calorie Consumption (*Kcal/day*)	2,721	2,984	2,915	-2.32
Undernourished population (*million*)	9.1	8.2	8.8	8.01
Malnourished children (*million*)	3.5	2.4	2.5	3.14

*Note: Results are averages of 3 climate models UK-ESM, EC Earth and MPI-ESM under RCP 8.5 and SPP2; * NoCC means no climate change that serves as the counterfactual scenario. Source: Source: IMPACT-Phil simulations.*

3.1.5 Economic Costs of Climate Change to Agriculture

The economic surplus framework for cost-benefit analysis (CBA) was used to estimate the long-term economic impact of climate change on the welfare of food producers and consumers, and hence on society as a whole. It measures the costs and benefits that accrue to society from projected shifts in supply and demand over time due to climate change.

At the global level, the economic cost of climate change is calculated to be US$2.734 trillion for the 25-year period from 2025 to 2050 (Table 13) with consumers bearing the brunt of the costs by paying higher prices for food, incurring overall welfare losses of $4.89 trillion. Producers, on the other hand, are to register a net gain of $2.47 trillion overall, because of higher prices for their produce, which on average are projected to offset declines in production.

The economic costs to the Philippine population are estimated at $17.2 billion for the 2025–2050 period, or $690 million per year. Similarly, Philippine consumers are to bear most of the costs of climate change, amounting to $80.2 billion for the 25-year period or $3,207 million per year, while producers gain $62.9 billion overall, or $2,517 million per year, implying that shifts to higher prices, on average, can more than compensate for declines of productivity. However, most farmers — and especially smallholder farmers — are marginal producers and net buyers of food themselves, and thus are expected overall to suffer net economic losses from the combined producer and consumer effects of climate change.

Table 13: Changes in Society's Welfare due to Climate Change, World and the Philippines, 2025-2050

	Welfare Measure		
Country/Region	**Producer Surplus**	**Consumer Surplus**	**Total Economic Surplus**
	US$ billion		
World	**2,968**	**-5,703**	**-2,734**
Philippines	**62.9**	**-80.2**	**-17.2**
Annual value US$ million)	**2,517**	**-3,207**	**-690**

*Note: Results are averages of 3 climate models UK-ESM, EC Earth and MPI-ESM under RCP 8.5 and SPP2, in comparison with the no-climate-change, i.e., counterfactual scenario. *Application of real discount rate equal to 3% Source: IMPACT-Phil simulations.*

4 Investment and Policy Options for Building Long-Term Resilience

The impacts of climate change and water scarcity can be substantial, estimated for Philippines to be around US$690 million annually, thus the urgency to put in place the investment policies and adaptation options for long-term resilience and sustainability in the agri-food systems.

The recent IPCC AR6 Report, Climate Change 2022: Impacts, Adaptation and Vulnerability, not only assess the impacts of climate change, but also reviews vulnerabilities associated with representative key risks areas in the land and water ecosystems, that include water and food security. Feasible climate adaptation options to respond to water security risks comprise water-use efficiency and water resource management, while adaptation options to food security risks include improved cropland management and efficient livestock systems. Specific adaptation technologies for better cropland management consist of cultivar technology, soil-fertility management, irrigation water management, changes in planting dates, and combined or mixed technologies. These adaptation options, together with supportive public investment policies can enhance food availability and stability and reduce climate risks for food systems while enhancing sustainability.

Further, the AR6 report continues to support the AR5 version that categorized adaptation responses into: technological responses (e.g., development of new crop varieties more adaptable to climate change; improved soil and water management practices; new generation of crop protection); smallholder farmer-support responses (e.g., enhancing access to credit and other critical production resources; diversifying livelihoods); institutional responses (e.g., strengthening institutions at local, national, and regional levels to support agriculture, including community-based organizations, rural enterprises, and gender-oriented policies); and agronomic adaptation responses, like agroforestry and conservation agriculture (IPCC, 2014).

Along this principle, this report aims to develop, analyze and recommend investment and policy options, not only to adapt and counter the effects of climate change, but also to build long-term resilience in Philippine agriculture while exploring the synergies among adaptation and mitigation along with community mobilization for potential decarbonization of the sector.

4.1 Technology, Infrastructure, and Market Responses to Climate Change

Based on the country-specific climate risks the country is facing, *i.e.,* land and water-resource limitations and declining performance of agriculture – that threaten the stability and sustainability of the food systems – two sets of investment programs are presented and simulated as potential adaptation responses to climate change. They are also deemed to build longer-term resilience and sustainability to the sector. Resilient – by remaining efficient and competitive under climate and economic shocks; and sustainable – by minimizing GHG emissions and water footprints as much as possible.

These sets of investment scenarios, defined below – are formulated and implemented in IMPACT-Phil, the suite of biophysical-economic models described in detail in Appendix B on methodology.

The first set of policy options include:

- A technological response of investing agricultural research and development (R&D) for adaptation technology development and promotions suited to the Philippine farming environment – with crop-technology and livestock-technology components. R&D activities in crops and livestock are also independent and separable, but at the farm level, the horizontal integration of crops and livestock has synergies and complementarities from which the farming households and communities can take advantage of and benefit from. Box 1 presents potential crop adaptation technologies that can be applied on farmers' fields.

  Basic assumption of this policy scenario, coded as R&D (Crop-Livestock) includes 20% productivity increase for crops and 10% productivity enhancement and 10% stock increase for livestock with 50% rate of adoption in the next 15 years (2025-2040).

- An infrastructure response of expanding irrigation development coded as Irrigation Devt of investing in irrigating additional lands by expanding 20% of irrigation system in 50% of farm areas, in the next 15 years.

- An institutional response reducing post-harvest losses and waste along the food value chain by 50% – coded as Market & Value Chain scenario. This includes increasing processing, transport and storage efficiencies to minimize waste and losses in the form less food spoilage and quality maintenance, better milling rates, and longer shelf-life, along the food value-chains. Included also in this scenario is the building of more efficient market structures that shorten the food supply-chains, thus minimizing marketing costs and product losses along the supply-chains.

  Since post-harvest losses and waste are estimated to be around 5-10% of production, this scenario is to reduced losses/waste equivalent to 2.5- 5% production. This scenario also runs for the next 15 year to cover 50% of market supply-chains and food value-chains.

Table 14: Description of Selected Technology Options

Technology Suite	Individual Technology	Brief Description
Seed Varietal/ Cultivar Technologies	Heat tolerance	Using improved varieties that allow the plant to maintain yields at higher temperatures.
	Flood tolerance	Seed varieties tolerant to flooding or heavy rainfall conditions. Some varieties withstand excess water and prolong underwater submergence.
	Drought tolerance	Improved varieties that allow better yields than regular varieties because of enhanced soil moisture uptake capabilities and reduced vulnerability to water deficiency.
	Saline tolerance	Development of seed varieties more resistant to saline soil and water, salt-water intrusion and rising sea level due to changing climate.
Soil Fertility Management Technologies	No-till and direct seeding	Minimum or no soil disturbance, often in combination with residue retention, crop rotation, and use of cover crops – retain or enhance natural soil fertility. Direct seed broadcasting is also often used in this technology.

	Integrated soil fertility management	Combination of chemical fertilizers, crop residues, and manure/compost. Includes site-specific soil fertilizer management, soil analysis and nutrient-deficiency fertilizer matching.
	Organic farming, brown and green manuring	Use of only organic sources of fertilizers, pest and weed control. Non-use of chemicals in crop production and crop protection.
	Full and partial intensification	Increased use of inputs to raise and optimize yield level. Usually involves increased fertilizer usage and land spaces to maximize light absorption.
	Precision agriculture	GPS-assisted delivery of agricultural inputs, as well as low-tech agricultural practices that aim to optimize management of crops (this includes effective plant spacing and use of appropriate planting windows). Localized and spot water, chemical and fertilizer application.
Irrigation Water Management Technologies	Water harvesting	Channeling rainwater or run-off toward crop fields through macro- or micro-catchment systems or by using earth dams, ridges, or graded contours
	Laser land leveling	Use of precision laser technology in the construction of bunds and land preparation to efficiently manage water flow and the application of irrigation water.
	Alternate wet and dry system	Water-saving technology that involves efficient application of irrigation water. Includes timing of irrigation to coincide with plant water demand at different stages of plant development. Also, in combination with fertilizer application and weed control.
	Precision water application	Like precision agriculture but limited to site-specific and time-specific application and efficient non-application of irrigation water. Included also are the types of water delivery like drip, sprinkler and hydroponics systems
Crop protection Technologies	Weed protection	Chemical treatment to protect crops against existing weeds and changing weeds regime brought about by changing climate.
	Insect protection	Chemical treatment to protect crops against current and future climate-related onset of insects and arthropod pests.
	Disease protection	Chemical treatment to protect crops against diseases and pathogens related to changing climate.
Stacked Technology Package	Mix of complementary technologies	Combined application in the same farm of complementary technologies from different technology suites. This specifically involves the application two or more complementary technologies – *i.e.,* one from seed varietal suite; another one from either soil-fertility and/or irrigation water suite; and one from the crop protection suite.

Source: Adopted from Perez et al 2021.

These three investment options were simulated with the IMPACT-Phil model determine their individual (i.e.,3 separate scenarios) effectiveness in countering the impact of climate change with changes in yields, production, and net trade as main indicators. Results for respective indicators are presented in Table 15, Table 16 and Table 17.

Yield-effects are limited only to R&D (Crop-Livestock), since this is the only scenario where productivity increases are particularly specified for both crops and livestock. Irrigation can increase yields of rainfed lands, but not beyond the yields of existing irrigated lands – only raise the yields to that level. The Market & Value Chain scenario is not specified for increasing yields, although food available for consumers is increased due to prevented losses and waste along the market's value and supply chains.

As specified in the R&D (Crop-Livestock) scenario, crops have higher yield-response than livestock and poultry, almost uniformly between 6-7% for crops and between 2-3% for livestock and poultry. Oilseeds, however, has the highest potential yield response of 7.02%, followed by corn and all other crops. Yield-responses for eggs and dairy products are highest for the livestock and poultry sector.

Table 15: Potential Yield-Effects of Selected Policy Options on Food Commodities, Philippines by 2050

Food commodities	2020 Values	2050 no CC effects	2050 with CC Effects	Technology, Infrastructure and Market Devt			% change from CC Effects		
				R&D (Crop-Livestock)	Irrigation Devt*	Market & Value Chain **	R&D (Crop-Livestock)	Irrigation Devt*	Market & Value Chain **
Yields	*-------------------------- kg/head or mt/ha ---------------------------------*						*percent*		
All meat products	5	8	8	8	8	8	1.81	-	-
Beef	263	350	350	358	350	350	2.48	-	-
Mutton/Goat meat	13	16	16	16	16	16	2.49	-	-
Pork	79	111	111	114	111	111	2.47	-	-
Poultry meat	2	3	3	3	3	3	2.45	-	-
Dairy	2,346	2,637	2,637	2,703	2,637	2,637	2.49	-	-
Eggs	5	5	5	6	5	5	2.50	-	-
All cereals	2.81	3.63	3.32	3.55	3.33	3.31	6.91	-ns-	-ns-
Corn	2.71	3.11	2.51	2.68	2.50	2.50	6.96	-ns-	-ns-
Rice	2.88	3.95	3.80	4.06	3.80	3.79	6.92	-ns-	-ns-
Other foodcrops	1.30	1.55	1.49	1.59	1.48	1.48	6.95	-ns-	-ns-
Fruits	15.26	20.52	20.18	21.52	20.04	20.10	6.64	-ns-	-ns-
Vegetables	10.70	13.78	14.58	15.56	14.51	14.54	6.71	-ns-	-ns-
Oilseed crops	4.59	5.27	5.04	5.39	5.08	5.04	7.02	-ns-	-ns-
Pulses	0.92	1.06	1.00	1.07	1.00	1.00	6.54	-ns-	-ns-
Roots and tubers	8.16	10.20	10.17	10.88	10.12	10.14	6.93	-ns-	-ns-
Sugar	83.19	88.46	79.93	85.39	80.49	80.11	6.84	-ns-	-ns-

Note: Results are averages of 3 climate models UK-ESM, EC Earth and MPI-ESM under RCP 8.5 and SPP2; NoCC means no climate change that serves as the counterfactual scenario; blank cells have no measurable yield response, while “-ns-“ means no significant yield-effect i.e., yield effects less than 0.05%. SOURCE: IMPACT-PHIL SIMULATIONS.

With respect to the production-effects of the policy options, a different response pattern are presented in Table 16. All three scenarios now exhibit significant production responses – consistently higher for the R&D (Crop-Livestock) scenario, but with relatively higher production response from the livestock and poultry sector than for crops sector. This is due to the combined effects of yield-enhancement and increased stock for animal-source foods. Dairy production is now to increase by 9.3%, poultry by 8.6%, and production of beef by 8.6%, while crop production effects are limited to a percentage point higher – i.e., within 6-7% compared to yield response.

The Irrigation Devt scenario, on the other hand, displays mixed production responses, with both positive and negative production effects for both crops and livestock sectors. This mixed result is explained by farmers land allocation decisions based on crops relative profitability. Similar to farmer's supply response to prices, farmers tend to allocate additional land area to the more profitable crops. With new irrigated lands generated by the Irrigation Devt scenario, this profitability-based allocation is further emphasized in the cropping pattern. Thus, more areas are planted to rice, oilseeds and sugarcane and less for other crops. Similarly, with additional farm water, farmers prefer to raise more dairy cows, broiler chicken and cattle. Consequently, the productions of rice, oilseed crops, and sugarcane are to increase relative to other crops, and dairy, poultry meat and beef production are to increase under the Irrigation Devt scenario.

The Market & Value Chain reveals additional nuances with respect to production response from minimized waste and marketing costs. This scenario does not directly impact farmers' production behavior since prevented waste and losses do not accrue to producers but to processors, aggregators and ultimately to consumers and trade demands. So that in effect, it is creating slight excess supply of foodcrops (and depressing domestic prices), in favor of animal-sourced foods both in the production and land allocation. This is further re-enforced by increases in export demand and declines in import receipts, despite slight declines in farm produce under this scenario.

Table 16: Potential Productions-Effects of Selected Policy Options on Food Commodities, Philippines by 2050

Food commodities	2020 Values	2050 no CC effects	2050 with CC Effects	Technology, Infrastructure and Market Devt			% change from CC Effects		
				R&D (Crop-Livestock)	Irrigation Devt*	Market & Value Chain**	R&D (Crop-Livestock)	Irrigation Devt*	Market &Value Chain**
Production	*--- 000 mt ---------------------------*						*percent*		
All meat products	3,234	5,090	5,016	5,410	5,034	5,090	7.85	0.34	1.48
Beef	345	635	627	681	633	638	8.55	0.95	1.64
Mutton/Goat meat	55	95	95	102	95	96	7.24	-0.27	0.41
Pork	1,909	2,714	2,710	2,907	2,705	2,743	7.27	-0.18	1.20
Poultry meat	926	1,646	1,583	1,720	1,600	1,614	8.60	1.04	1.96
Dairy	15	20	20	22	20	21	9.33	1.63	2.75
Eggs	894	1,738	1,773	1,891	1,761	1,784	6.69	-0.67	0.66
All cereals	19,835	26,476	24,179	25,936	24,751	23,828	7.26	2.36	-1.45
Corn	7,364	8,668	6,798	7,302	6,724	6,704	7.41	-1.09	-1.39
Rice	12,471	17,808	17,381	18,633	18,027	17,124	7.21	3.72	-1.48

Other foodcrops	656	1,001	955	1,025	955	941	7.35	0.00	-1.53
Fruits	20,122	33,524	33,971	36,327	33,605	33,470	6.93	-1.08	-1.48
Vegetables	7,178	11,575	12,629	13,592	12,582	12,469	7.63	-0.37	-1.26
Oilseed crops	16,877	19,809	19,520	20,601	19,996	20,019	5.54	2.44	2.56
Pulses	76	95	86	92	85	84	7.15	-0.93	-2.35
Roots and tubers	3,043	3,922	3,939	4,215	3,912	3,904	7.01	-0.71	-0.89
Sugar	3,002	4,383	4,163	4,364	4,272	4,372	4.82	2.62	5.03

Note: Results are averages of 3 climate models UK-ESM, EC Earth and MPI-ESM under RCP 8.5 and SPP2; NoCC means no climate change that serves as the counterfactual scenario. Source: IMPACT-Phil simulations.

The Philippines is a small food producing country relative to the global food market, so that even substantial gains in production achievable under the R&D (Crop-Livestock) policy scenario – cannot move the world price needles in significant manner. And without declines in food prices, increases in domestic food production do not lead to higher domestic consumption and better nutrition for the population. Instead, they are to boost the trade position of the country – that is decrease in import demand and increase of export receipts.

Table 17: Potential Trade-effects of Selected Policy Options on Food Commodities, Philippines by 2050

Food commodities	2020 Values	2050 no CC effects	2050 with CC Effects	Technology, Infrastructure and Market Devt			% change from CC Effects		
				R&D (Crop-Livestock)	Irrigation Devt*	Market & Value Chain**	R&D (Crop-Livestock)	Irrigation Devt*	Market & Value Chain**
Net Trade	-- *000 mt* -----------------------------------						*percent*		
All meat products	-829	-2,380	-2,418	-2,046	-2,421	-2,203	-15.37	0.13	-8.88
Beef	-391	-926	-931	-880	-927	-903	-5.50	-0.39	-3.02
Mutton/Goat meat	-6	-49	-49	-42	-49	-45	-14.36	0.36	-7.24
Pork	-257	-1,004	-994	-807	-1,007	-883	-18.86	1.32	-11.13
Poultry meat	-174	-402	-444	-318	-438	-372	-28.37	-1.45	-16.31
Dairy	-1,936	-3,094	-3,086	-3,092	-3,094	-3,093	0.20	0.26	0.23
Eggs	317	643	692	803	673	753	16.01	-2.77	8.78
All cereals	-7,320	-16,484	-16,149	-15,865	-16,140	-16,460	-1.76	-0.05	1.93
Corn	516	-4,737	-4,422	-4,766	-4,680	-4,607	7.79	5.85	4.19
Rice	-3,708	-3,476	-3,281	-2,394	-2,871	-3,245	-27.04	-12.50	-1.08
Wheat	-3,792	-7,816	-7,983	-8,234	-8,122	-8,141	3.14	1.74	1.97
Other foodcrops	-139	-150	-164	-109	-179	-164	-33.40	9.13	-0.10
Fruits	6,050	11,555	13,048	15,076	12,390	13,306	15.54	-5.05	1.97
Vegetables	-659	-2,518	-1,376	-474	-1,485	-1,201	-65.51	7.90	-12.70
Oilseed crops	3,248	2,779	2,857	3,230	2,965	2,881	13.04	3.78	0.84
Pulses	-123	-240	-251	-246	-253	-251	-1.87	0.91	0.33

Roots and tubers	**-841**	**-1,430**	**-1,280**	**-1,071**	**-1,360**	**-1,246**	**-16.35**	**6.27**	**-2.64**
Sugar	**-106**	**-561**	**-674**	**-500**	**-591**	**-352**	**-25.84**	**-12.33**	**-47.75**

*Note: Results are averages of 3 climate models UK-ESM, EC Earth and MPI-ESM under RCP 8.5 and SPP2; * NoCC means no climate change that serves as the counterfactual scenario. *Negative values mean either decline in exports or increase in imports, positive values mean either increase in exports or decline in imports. If values are less than -100, there are shifts from net importer to net exporter (or from net exporter to net importer). Source: IMPACT-Phil simulations.*

Increases in production due to R&D (Crop-Livestock) policy scenario, presented in Table 16 are to result in increases in export of fruits by 16%, of egg products by 16% and of oilseed crops by 13%. While increased production of traditionally imported food like rice, vegetables, sugar and meat products are to result to reduced import bills, by as much as 27% for rice, 65% for vegetables, 26% for sugar, and 28% for poultry meat.

Similarly, for Irrigation Devt scenario, any increase in production e.g., for rice, sugar, oilseed crops, poultry meat and beef, there is corresponding positive trade position, i.e., decline in imports for rice by 13% and 12% for sugar, and increase in export of oilseed crops by 4%.

And for Market & Value Chain scenario, where substantial food savings ultimately accrue to consumers and/or trade demand, that even reduction in foodcrops production can increase export volume of fruits by 2% and reduce import volume of vegetables by 13%, and by smaller amount for rice.

4.2 Complementary Investment programs: Technology and Rural Enterprise Development

Among the three investment options presented earlier, investment in R&D (Crop-Livestock) holds greater potential for countering the impact of climate change, as it has the advantage horizontally integrated crop and livestock production. Nevertheless, the benefits of having additional water and land under the Irrigation Devt scenario cannot be ignored, especially in light of worsening land and water scarcity. Modern technologies need irrigation water to maximize yield-potentials, while irrigated lands need modern technologies to achieve higher productivity of the land.

The Market & Value Chain scenario also has the potential of additional 5-15% of food supply without using land and water resources by simply minimizing food losses and waste. And with sound business model, investment in this scenario can augment the income and livelihood of rural communities.

These three policy options can, therefore, be packaged into combinations of 1) R&D (Crop-Livestock) + Irrigation Devt investment program, and 2) R&D (Crop-Livestock) + Irrigation Devt + Market & Value Chain investment program.

The effective operations of these two investment programs on the ground are to be greatly enhanced when implemented with existing framework and structure consistent with climate resiliency objectives of the agricultural sector – the AMIA Program.

4.2.1 The AMIA Plus Investment Strategy: R&D (Crop-Livestock) + Irrigation Devt

This adaptation investment program includes a technological response (R&D Crop-Livestock) and an infrastructure response (Irrigation Devt) to climate change, developed and pre-tested in the previous section. The R&D (Crop-Livestock) is aimed to develop and disseminate adaptation technologies - dubbed as climate-smart agriculture (CSA) or climate-resilient agriculture (CRA) technologies and practices. CRA technologies are more productive, efficient, and resilient to short-, medium- and long-term shocks and risks associated with climate change and climate variability.

Increased Crop Productivity

Although the research community is already in the forefront of climate-resilient technology development suitable for Philippines, additional and more intensive funding for agricultural research, development and extension (RD&E) are needed to adequately address the urgency and the magnitude of climate risks the country is facing. Most of these technologies are still in laboratory and/or in on-farm evaluation phases – but others, on limited basis, are already being implemented by farmers in their fields (selected adaptations options are listed in Box 1).

Increased Yields and Stock of Animal-source Food

Smallholder livestock production in Philippines may be classified as mixed irrigated systems with significant proportion of irrigated cropping interspersed with livestock and fodder crops. Other classifications include backyard (monogastric, ruminant, poultry), grassland-based with minimal or no crop-based agriculture (pastoralism). On average, animal-sourced food provides 39% of protein and 18% of calories in human diets.

The effects of climate change on livestock productivity, however, are not adequately modelled in this report due to limited definitive studies on the topic for the Philippines. Only the indirect impacts on feedstuff are simulated here. Although evidence is accumulating that rising temperatures can lead to heat stress that may significantly affect the productivity of domestic species (Das *et al*., 2016b; Godde *et al*., 2021). Investment in livestock productivity should be part of any adaptation options against climate risks – and thus simulated in this report. Prices of animal-sourced foods are projected to rise steeply so that the combination of crop-livestock can be another source of livelihood for small landholders.

Initial results on productivity indicators (*i.e.,* yield, area and animal number, production) show separability (exclusivity or independence) between crops and livestock scenarios, and with minimal loss of synergies when simultaneously implemented. Therefore, the simultaneous implementation of crop and livestock technology is recommended.

Expanded Irrigation and Increased Water Productivity

On top of this is the Irrigation Devt response, that includes the expanded development of irrigation systems to include different water sources (e.g., surface water, groundwater, and effective precipitation), and various irrigation water delivery system (e.g., gravity, drip irrigation, precision irrigation) and diverse energy sources including solar energy.

Implicit in the strategy is the promotion and cultivation of high-valued, less water-intensive horticulture crops (i.e., fruits and vegetables) over low-value water-intensive cereals like rice, resulting to better irrigation efficiency by reducing flood-irrigated rice areas. Efficiency is further enhanced when drip irrigation systems for fruit and vegetable fields are constructed. A level of environmental sustainability is also attained when methane (CH_4) emissions are reduced with declines in rice areas.

4.2.2 The AMIA Enterprise Investment Strategy: R&D (Crop-Livestock) + Irrigation Devt + Market & Value Chain

The AMIA Enterprise investment program is a notch higher – an investment in community-based rural enterprise development that implements the Market & Value Chain scenario on the ground is added to the AMIA Plus program

This addition is a comprehensive adaptation option is based on institutional response that includes rural mobilization and the strengthening of community-based institutions at local, national, and regional levels to support the triple-win nexus of productivity, livelihood and household income, and the potential of reducing the rate of GHG emissions and water footprints from Philippine agri-food systems.

It is, however, predicated in the restructuring of rural cooperatives into business-oriented community-based rural enterprises, where every farmer or farmer group serves as shareholders with financial stake in the business operations. These community-owned rural enterprises or rural agribusiness enterprises are to operate as business-concerns whose main objectives are to be competitive in the agribusiness industry and to be profitable to every farmer-owner member.

4.3 Comparative Analysis of AMIA Plus and AMIA Enterprise Investment Programs

4.3.1 The Investment Program Scenarios

Both the AMIA Plus and AMIA Enterprise investment scenarios incorporate the R&D (Crop-Livestock) and Irrigation Devt investment options in their investment portfolios.

1. AMIA Plus Investment Strategy is centered in the development, dissemination and accessibility of site-specific and cropping system-specific (e.g., all-crop, all-animal, or mixed crop-animal systems) single or stacked technology packages to smallholder farmers. In its core is an accelerated investment in R&DE (research and development and extension) to support the national agricultural research system (NARS) in collaboration with international agricultural research centers (IARCs) based in Philippines and in the region. Investment in ancillary services like seed industry and other input markets (e.g., fertilizer, chemicals, and farm machinery), veterinary services, IT-based information support, marketing information, weather early-warning system, crop insurance, and credit facilities – are the support components of the AMIA Plus investment program, which need to be put in place to for the investment to be effective.

   In addition, the program includes: (a) the expansion of irrigation system and the modernization of the irrigation delivery systems i.e., drip irrigation for fruits and vegetable crops and sprinkler systems; (b) expansion of the animal industry, inclusive of livestock, dairy, poultry and egg production operations, by 10%.

The rate of adoption is projected at 50% in 15 years with targets of 20% for the first five years (2025-2030) and the other 30% by 2040.

2. AMIA Enterprise Investment Strategy is a more comprehensive investment option that incorporates all the AMIA Plus components and adds a community mobilization component of developing community-based agribusiness industry. It has the potential for higher economic and social benefits by achieving the triple-win nexus of productivity, livelihood and household income, and reductions in GHG emissions and water footprints – which are the indicators of resilience and sustainability in the country's agri-food systems.

   In addition to same R&DE and ancillary support in the AMIA Plus scenario, the AMIA Enterprise investment scenario is to include (a) provision of post-harvest, processing, storage, and marketing infrastructure and facilities to minimize wastes and lower marketing costs – consequently reducing wastes and spoilage and marketing costs by 50%; (b) provision of ancillary input services e.g., seed industry for cereals and horticulture crops; fertilizer and pest control chemicals or technology; crop insurance; early warning weather stations; and IT services for soil and water management.

   On top of these is the development and operation of community-based agribusiness enterprises around the country, where farmers or farmers associations hold ownership and financial stakes.

   The rate of adoption is similarly projected at 50% in 15 years with targets of 20% for the first five years (2025-2030) and the other 30% by 2040.

4.3.2 AMIA Plus vs AMIA Enterprise: Impacts on Productivity – Yield, Production and Area

Climate change is shown to directly affect agricultural productivity, reducing yields of cereals by -8.53%, highest declines for corn (-19.40%) and rice (-3.76%) (Table 6).

However, both the AMIA Plus and AMIA Enterprise investment scenarios are designed to counteract the direct productivity- impact of climate change, so that yields for AMIA Plus are projected to increase for cereals by 7.72% relative to CC scenario; corn by 6.95%; rice by 7.48% (Table 18). For the AMIA Enterprise scenario, positive yield gains are also projected at 7.93% for cereals; 7.22% for corn; 7.69% for rice – all at higher rates due to the additional investments in market infrastructure and rural agribusiness development.

Table 18: Comparative Impacts of AMIA Investment vs AMIA Enterprise Investment Options on Crop and Livestock Yields in the Philippines by 2050

Food commodities	2020 Values	2050 with CC Effects	Technology and Rural Enterprise Development		% change from CC Effects	
			AMIA Plus	AMIA Enterprise	AMIA Plus	AMIA Enterprise
Yield	------------------------- *kg/head or mt/ha* ----------------				*percent*	
All meat products	5.0	8.2	8.3	8.4	1.81	2.01
Beef	263	350	358	358	2.48	2.48

Mutton/Goat meat	13.1	15.6	15.9	15.9	2.49	2.49
Pork	79	111	114	114	2.47	2.47
Poultry meat	1.5	2.7	2.8	2.8	2.45	2.45
Dairy	2,346	2,637	2,703	2,703	2.49	2.49
Eggs	5.4	5.4	5.6	5.6	2.50	2.50
All cereals	2.81	3.32	3.57	3.58	7.72	7.93
Corn	2.71	2.51	2.68	2.69	6.95	7.22
Rice	2.88	3.80	4.08	4.09	7.48	7.69
Other foodcrops	1.30	1.49	1.60	1.60	7.31	7.56
Fruits	15.26	20.18	21.52	21.59	6.65	7.00
Vegetables	10.70	14.58	15.59	15.66	6.91	7.36
Oilseed crops	4.59	5.04	5.45	5.46	8.09	8.37
Pulses	0.92	1.00	1.07	1.08	6.64	7.11
Roots and tubers	8.16	10.17	10.88	10.90	6.89	7.13
Sugar	83.19	79.93	86.19	86.60	7.84	8.35

Note: Results are averages of 3 climate models UK-ESM, EC Earth and MPI-ESM under RCP 8.5 and SPP2; CC means with climate change scenario. Source: IMPACT-Phil simulations.

Both AMIA Plus and AMIA Enterprise scenarios are able to effectively counter the negative productivity-impacts of climate change, except for corn and sugar crops that are severely affected by climate change the most.

Increases in productivity are further translated into better changes in production for both AMIA Plus and AMIA Enterprise. Table 19 shows that most of productivity gains with AMIA Plus are translated into increases in production – positive to all animal products and most foodcrops, except for corn and pulses, whose productivity gains are the lowest, rendering them most vulnerable against crop area competition.

Table 19: Comparative Impacts of AMIA Plus Investments vs AMIA Enterprise Investment Options on Food Production in the Philippines by 2050

Food commodities	2020 Values	2050 with CC Effects	Technology and Rural Enterprise Development		% change from CC Effects	
			AMIA Plus	AMIA Enterprise	AMIA Plus	AMIA Enterprise
Production	--------------------------------------- *000 mt* ---------------------- --------				*percent*	
All meat products	**3,234**	**5,016**	**5,410**	**5,471**	**7.85**	**9.06**
Beef	**345**	**627**	**681**	**685**	**8.55**	**9.29**
Mutton/Goat meat	**55**	**95**	**102**	**103**	**7.24**	**7.97**
Pork	**1,909**	**2,710**	**2,907**	**2,947**	**7.27**	**8.74**
Poultry meat	**926**	**1,583**	**1,720**	**1,735**	**8.60**	**9.59**
Dairy	**15**	**20**	**22**	**22**	**9.33**	**10.54**

Eggs	**894**	**1,773**	**1,891**	**1,917**	**6.70**	**8.12**
All cereals	**19,835**	**24,179**	**26,917**	**26,882**	**11.32**	**11.18**
Corn	**7,364**	**6,798**	**7,327**	**7,331**	**7.78**	**7.84**
Rice	**12,471**	**17,381**	**19,589**	**19,550**	**12.71**	**12.48**
Other foodcrops	**656**	**955**	**1,041**	**1,041**	**9.00**	**8.96**
Fruits	**20,122**	**33,971**	**36,503**	**36,529**	**7.45**	**7.53**
Vegetables	**7,178**	**12,629**	**13,746**	**13,775**	**8.85**	**9.08**
Oilseed crops	**16,877**	**19,520**	**21,251**	**21,975**	**8.87**	**12.58**
Pulses	**76**	**86**	**93**	**93**	**8.91**	**9.10**
Roots and tubers	**3,043**	**3,939**	**4,229**	**4,234**	**7.35**	**7.48**
Sugar	**3,002**	**4,163**	**4,512**	**4,786**	**8.39**	**14.97**

Note: Results are averages of 3 climate models UK-ESM, EC Earth and MPI-ESM under RCP 8.5 and SPP2; CC means with climate change that scenario. Source: IMPACT-Phil simulations.

4.3.3 AMIA Plus vs AMIA Enterprise: Impacts on Access to, Availability and Consumption of Food

Despite huge increases in production projected for both AMIA Plus and AMIA Enterprise investment adaptation options, the influence of a small-country market like Philippines, relative to global trade, is not expected to counter the effects of climate change on the prices of food in any significant way. Consequently, consumption is not expected to significantly increase either. Global cooperation and concerted efforts at adaptation and mitigation are needed to substantially increase global food production and restore the world prices of food.

However, there are lags in the transmission of prices from domestic market to global market due to artificial barriers to trade, with sticky price assumption, increases in domestic production can influence domestic consumer prices – along the wedge between export and import tariffs. Sticky prices are assumed for the succeeding simulations presented in Table 20, Table 21, Table 22 and Figure 8.

Table 18 presents the general decline in consumer prices of food due to AMIA Plus and AMIA Enterprise – with bigger price declines for AMIA Enterprise through additional supply gains from prevented food losses and waste.

The most price declines are projected for oilseed crops (-13%), rice (-7.4%) and rootcrops (-6.9%) (Table 20). Figure 8 further presents the correspondence between production and domestic prices – moving in opposite directions.

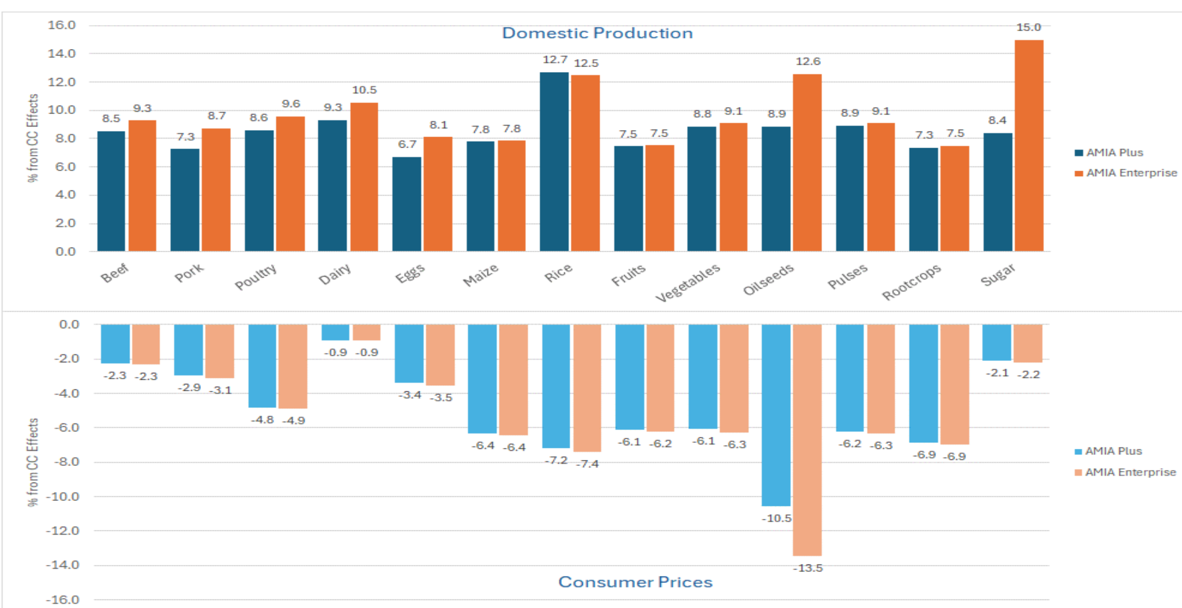
Table 20: Comparative Impacts of AMIA Plus Investment vs AMIA Enterprise Investment on Consumer Prices in the Philippines by 2050

Food commodities	2020 Values	2050 with CC Effects	Technology and Rural Enterprise Development		% change from CC Effects	
			AMIA Plus	AMIA Enterprise	AMIA Plus	AMIA Enterprise

Consumer Prices	-- US$ per mt ----------------------------------				percent	
All meat products	3,908	4,873	4,716	4,712	-3.22	-3.31
Beef	5,269	5,895	5,762	5,759	-2.25	-2.30
Mutton/Goat meat	6,679	6,245	6,164	6,162	-1.29	-1.33
Pork	3,628	4,534	4,400	4,394	-2.95	-3.09
Poultry meat	3,397	4,611	4,389	4,387	-4.81	-4.86
Dairy	722	778	771	771	-0.91	-0.91
Eggs	3,453	4,043	3,906	3,901	-3.39	-3.53
All cereals	452	628	581	580	-7.53	-7.78
Corn	258	394	369	369	-6.35	-6.43
Rice	557	836	775	774	-7.20	-7.40
Other foodcrops	353	434	407	407	-6.29	-6.35
Fruits and Vegetables	1,644	2,080	1,953	1,951	-6.09	-6.20
Vegetables	1,408	1,952	1,833	1,829	-6.08	-6.27
Oilseed crops	85	138	123	119	-10.53	-13.46
Pulses	1,901	2,173	2,038	2,036	-6.23	-6.31
Roots and tubers	472	671	625	624	-6.85	-6.94
Sugar	510	643	630	629	-2.11	-2.20

Note: Results are averages of 3 climate models UK-ESM, EC Earth and MPI-ESM under RCP 8.5 and SPP2; CC means no climate change scenario. SOURCE: IMPACT-PHIL SIMULATIONS.

Figure 8: Comparative Impacts of AMIA Plus Investments vs AMIA Enterprise Investment Options on Domestic Food Prices in the Philippines by 2050



Gains in production are still beneficial to the country and are reflected in substantial decreases in imports and increases in exports of food commodities (Table 21). Higher magnitudes of net trade changes are projected for AMIA Enterprise, on average by 50%, over AMIA Plus scenario, due to huge supply boosts from prevented food losses and waste under this scenario.

Exports of eggs, fruits and oilseeds are to increase respectively by 28%, 26% and 27%. While imports are to declines the most for rice (72%), other foodcrops (-62%), and poultry meat. The country is also projected to turn from net importer to net exporter for sugar and vegetables.

Table 21: Comparative Impacts of AMIA Plus Investment vs AMIA Enterprise Investment Options on Food Trade in the Philippines by 2050

Food commodities	2020 Values	2050 with CC Effects	Technology and Rural Enterprise Development		% change from CC Effects	
			AMIA Plus	AMIA Enterprise	AMIA Plus	AMIA Enterprise
Net Trade	------------------------------------ *000 mt* -------------------------------------				*percent change*	
All meat products	-829	-2,418	-2,046	-1,812	-15.37	-25.05
Beef	-391	-931	-880	-853	-5.50	-8.33
Mutton/Goat meat	-6	-49	-42	-38	-14.36	-22.52
Pork	-257	-994	-807	-674	-18.86	-32.21
Poultry meat	-174	-444	-318	-247	-28.37	-44.33
Dairy	-1,936	-3,086	-3,092	-3,091	0.20	0.17
Eggs	317	692	803	889	16.01	28.41
All cereals	-7,320	-16,149	-14,889	-14,243	-7.80	-11.80
Maize	516	-4,422	-4,732	-4,617	7.03	4.42
Rice	-3,708	-3,281	-1,451	-898	-55.78	-72.62
Wheat	-3,792	-7,983	-8,235	-8,255	3.15	3.40
Other foodcrops	-139	-164	-94	-61	-42.90	-62.64
Fruits	6,050	13,048	15,247	16,415	16.85	25.80
Vegetables	-659	-1,376	-321	146	-76.66	-110.59
Oilseed crops	3,248	2,857	3,484	3,650	21.93	27.73
Pulses	-123	-251	-244	-241	-2.47	-3.72
Roots and tubers	-841	-1,280	-1,058	-921	-17.38	-28.08
Sugar	-106	-674	-352	73	-47.82	-110.84

*Note: Results are averages of 3 climate models UK-ESM, EC Earth and MPI-ESM under RCP 8.5 and SPP2; * CC means with climate change scenario. *Negative values mean either decline in exports or increase in imports, positive values mean either increase in exports or decline in imports. If values are less than -100, there are shifts from net importer to net exporter (or from net exporter to net importer). Source: IMPACT-Phil simulations.*

Annual Per capita food consumption is projected in increase in both scenarios, a little higher for AMIA Enterprise, though still fails to fully compensate for the effects of climate change – prices of food remains high. Daily calorie consumption is to increase slightly by 1%, while the number of undernourished individuals is to decline by 3.78% and number of malnourished children reduced by 1.6% (Table 22)

Table 22: Comparative Impacts of AMIA Plus Investments vs AMIA Enterprise Investment Options on Selected Food Security Indicators in the Philippines by 2050

Food commodities	2020 Values	2050 with CC Effects	Technology and Rural Enterprise Development		% change from CC Effects	
			AMIA Plus	AMIA Enterprise	AMIA Plus	AMIA Enterprise
Annual Consumption	*------------------ kg per capita/year ---------------------------*				*percent*	
All meat products	37.0	49.9	50.0	50.0	0.30	0.31
Beef	6.7	10.5	10.5	10.5	0.16	0.16
Mutton/Goat meat	0.6	1.0	1.0	1.0	-0.06	-0.06
Pork	19.7	24.9	24.9	24.9	0.26	0.28
Poultry meat	10.0	13.6	13.7	13.7	0.50	0.49
Dairy	17.0	19.9	20.0	20.0	0.26	0.26
Eggs	4.8	6.6	6.7	6.7	0.73	0.76
All cereals	170.6	174.9	177.5	177.6	1.49	1.52
Corn	14.3	12.5	12.6	12.6	0.89	0.90
Rice	127.8	118.4	119.9	120.0	1.31	1.35
Wheat	27.9	43.5	44.5	44.5	2.14	2.17
Other foodcrops	4.1	4.1	4.1	4.1	1.54	1.57
Fruits and Vegetables	177.0	206.0	208.2	208.3	1.07	1.12
Oilseed crops	5.4	5.9	6.0	6.0	1.80	1.90
Pulses	1.8	2.2	2.2	2.2	0.43	0.43
Roots and tubers	27.7	26.5	26.8	26.8	1.07	1.09
Sugar	26.1	30.3	30.5	30.5	0.58	0.61
Food Security and Nutrition						
Consumption (*Kcal/day*)	2,721	2,915	2,946	2,947	1.06	1.10
Undernourished (*million*)	9.1	8.8	8.50	8.49	-3.66	-3.78
Malnourished children (*million*)	3.5	2.5	2.47	2.46	-1.20	-1.60

Note: Results are averages of 3 climate models UK-ESM, EC Earth and MPI-ESM under RCP 8.5 and SPP2; CC means with climate change scenario. SOURCE: IMPACT-PHIL SIMULATIONS.

4.3.4 Economic and Environmental Health

The overall impact of the investment options on society's welfare are summarized in Table 22. Society gains in both scenarios – with AMIA Enterprise investment option to have total economic surplus amounting to US$ 63.4 billion for the 25-year period, equivalent to US$2,535 million per year, around 42% higher compared to AMIA Plus. This projected economic gains from AMIA Enterprise investment are much higher than the losses inflicted by climate change. Producers get the most benefits due to increases in productivity, while consumers are slightly benefitted since food prices remain expensive. AMIA Plus investment is projected to gain US$1,773 million per year of total economic surplus, which can fully compensate for losses from climate change.

Table 23: Changes in Society's Welfare Due to Climate Change, World and Philippines, 2025-2050

Climate models	Welfare Measure		
	Producer Surplus	Consumer Surplus	Total Economic Surplus
	net present value (billion US dollars)*		
Impact of Climate Change			
World	**2,968**	**-5,703**	**-2,734**
Philippines	**62.9**	**-80.2**	**-17.2**
Annualized value (US$ million)	**2,517**	**-3,207**	**-690**
Impact adaptation to of Climate Change			
AMIA Plus	**9.2**	**35.1**	**44.3**
Annualized value (US$ million)	**370**	**1,404**	**1,773**
AMIA Enterprise	**27.2**	**36.2**	**63.4**
Annualized value (US$ million)	**1,086**	**1,449**	**2,535**

Note: Results are averages of 3 climate models UK-ESM, EC Earth and MPI-ESM under RCP 8.5 and SPP2. SOURCE: IMPACT-PHIL SIMULATIONS.

5 POLICY RECOMMENDATIONS

The report has shown the urgency of putting in place appropriate policies and strategic investments on making agriculture and the food system more resilient, competitive and sustainable to be able to counter the intensifying effects of climate change and climate shocks, and other potential or unexpected political and economic upheavals, locally or globally, that can disrupt the food systems.

There are two sets of policies and strategic investments this study recommends.

1. to continue, improve, repurpose or rationalize – past and current policies and investments that contributed (or could have contributed to the resiliency, competitiveness and sustainability of the agriculture sector; and
2. to step-up a notch in the next 15 years into a more comprehensive policy and investment framework that includes institutional and market mechanisms and incentives – to prepare the agriculture sector in meeting up future challenges and to remain resilient, competitive and sustainable in the next decades to 2050.

5.1 Key Policy Recommendations from the Study

5.1.1 Step-up Into a More Comprehensive Policy and Investment Framework

To prepare the agriculture sector in meeting up to future challenges and to remain resilient, competitive and sustainable in the next decades to 2050, two alternative investment options were developed and analyzed, and both were shown able to fully compensate for the impact of climate change and similar shocks to the food systems. They both include institutional and market mechanisms and incentives.

Adoption of AMIA Enterprise Investment Strategy

Both AMIA Plus and AMIA Enterprise investment options are able to fully compensate for the impact of climate change and similar shocks to the food systems in the near future. However, the AMIA Enterprise investment option is designed to have stronger institutional mechanisms and more attractive market-based incentive systems.

Whereas the AMIA Plus Investment Strategy

- is based on technological response to climate change to develop site–specific climate-smart agricultural technology packages for smallholder farmers.
- at its core is to enhance the agricultural (R&DE) capability of the national agricultural research system (NARS).
- includes the development of domestic seed industry and other input markets (e.g., fertilizer, chemicals, and farm machinery), veterinary services, IT-based information support, market information, weather early-warning system, crop insurance, credit facilities, and extension services, as its Institutional and market mechanisms.

The AMIA Enterprise Investment Strategy, on the Other Hand

- is an adaptation option based on institutional response to climate change aimed at mobilizing rural communities and the strengthening of agriculture-based organizations and institutions, to complement CSA technology development and extension.
- is the more comprehensive adaptation option that shares most of AMIA Plus components, including agricultural R&DE and the critical ancillary support services, and
- adds the development and operation of community-based agribusiness enterprises around the country, where farmers and farmers associations hold ownership and financial stakes.

(Note that although presented as alternative investment options, the AMIA Plus and AMIA Enterprise options can be both operationalized, as a two-pronged approach, sequentially (AMIA Plus first followed by AMIA Enterprise) or simultaneously (in separate provinces).

5.1.2 Invest in Developing a More Comprehensive and Detailed Roadmap

Although this report includes a *Roadmap* to the implementation of AMIA Plus/AMIA Enterprise investment framework, a more detailed study is needed to prepare a comprehensive investment and implementation "Roadmap Towards Resilient and Sustainable Food SYSTEMS " based on AMIA Plus/AMIA Enterprise investment framework.

This document can serve as basis for:

- Coordinated longer-term planning by the different government Department and Institutes
- Investment planning with international donors and funding agencies.

5.2 AMIA Plus/AMIA Enterprise Implementation Roadmap

The implementation roadmap for AMIA Plus and AMIA Enterprise investment options focuses only on sequential and simultaneous phasing of their respective activities and milestones. Although the phases (i.e., Phases I to III) are arbitrary to coincide with common practice of having plans in 5-year steps (e.g., 5-year short-term plan, 10-year medium-term plan, etc.).

The first phase (Phase I) starts in 2023 to 2025, while Phase II is for the period 2026-2030, and Phase III for 2031-2035 (Table 24). Phase I activities basically include assessments (e.g., assessment of technology stock), soft-implementation of activities (e.g., input industry development, financial and technical support systems), consolidation and strengthening (e.g., of the NARS and extension agencies), pilot testing of new system (e.g., drip irrigation and hydroponics systems, and solar pump). Phase II, on the other hand, mostly involves the start of hard or full-implementation of most activities for both AMIA Plus and AMIA Enterprise options.

The roadmap includes the implementation of four broad categories of activities: 1) technology development; 2) ancillary support; 3) development of institutions and markets; and 4) investment in infrastructure. Activities and milestones under technology development categories include - technology stock assessment, research and technology development, field testing of potential technologies, technology packaging by commodity or cropping system, technology promotion and dissemination, technology adoption and wider application, and maintenance research to sustain and maintain productivity gains of the technology.

The ancillary support system includes the development of input industry, such as seeds, fertilizers, chemicals, and other material inputs; establishment of financial support such as crop insurance and credit facilities; and technical extension services. Development of institutions and markets concerns the strengthening of the national agricultural research system (NARS), the consolidation of extension services from various institutions, and the establishment of rural enterprises.

The establishment of rural enterprises is key in the AMIA Enterprise investment options and distinguishes it from AMIA Plus. Whether from conversion of existing agricultural cooperatives or by creation of new rural enterprises – they are to run as on-going business concerns, owned and managed by farmers, or by farmers-designate management teams. These rural enterprises are aimed to make food production competitive and profitable for smallholder farmers by engaging in various value-adding activities, such as input and output marketing; operation of processing, storage and marketing facilities; contract farming with farmers; and participation in the export-import markets. They can also serve as partners and providers of critical technical extension services, thereby delivering timely and effective technical advice to farmers.

Investment in infrastructure is mostly concerned with the modernization of the country's irrigation system that includes increasing basin efficiency to support the field-level water-use technologies. They also include the pilot testing and subsequent wider implementation of drip irrigation and hydroponics systems and solar irrigation pumps on smallholder farms. However, investment in IT-based infrastructure holds the highest potential as catalysts to the widespread dissemination and adoption of AMIA Plus/AMIA Enterprise technologies.

Table 24: Phasing of Implementation Activities and Milestones of AMIA Plus and AMIA Enterprise Investment Options, 2025-2040

Investment Options, Activities, Milestones, Roadblocks	Phase I - 2023-2025			Phase II - 2026-2030					Phase III- 2031-2035				
	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
AMIA Plus/AMIA Enterprise and AMIA Enterprise only													
Technology Development													
Technology stock assesment													
Technology development													
Field testing of technologies													
Technology packaging													
Technology promotion													
Technology adoption													
Maintenance research													
Ancillary Support System													
Input industry development													
Seed, fertilizer and chemicals													
Financial support system													
Crop insurance, credit facilities													
Technical support system													
Extension services													
Institutions and Markets													
Strengthening of the NARS													
Consolidation of extension institutions													
Establishment of rural enterprises													
Conversion of cooperatives to rural enterprises													
Business operation of rural enterprises													
input and output marketing services													
ownership of processing, storage and marketing facilities													
entering into contract farming agreements													
participation in export-import markets													
Extension partners of government institutions													
Investment in infrastructure													

Modernization of irrigation													
Increasing basin efficiency													
Retrofitting for drip irrigation and hydroponics													
Piloting of drip irrigation system													
Expansion of drip irrigation system													
Piloting of hydroponics system													
Expansion of hydroponics system													
Piloting of solar irrigation pumps													
Expansion of solar irrigation pumps													
IT-based extension infrastructure													

Note: Black texts are applicable to both AMIA Plu and AMIA Enterprise, while red texts are applicable toAMIA Enterprise only

= full implementation

= soft implemetation

Source: Authors' depiction

6 References

Alston, J.M., P.W. Norton, and P.G. Pardey. 1995. "Science under Scarcity: Principles and Practice for Agricultural Research Evaluation and Priority Setting." London, UK, and Ithaca, NY: Cornell University Press for the International Service for National Agricultural Research. https://www.cabi.org/bookshop/book/9780851992990/

Das, R., et al., 2016: Impact of heat stress on health and performance of dairy animals: a review. Vet World, 9(3), 260–268, doi:10.14202/vetworld.2016.260-268.

FAO. 2021. *Global Dialogue on the Role of Food and Agriculture in the Post-2020 Global Biodiversity Framework*.

FAO (Food and Agriculture Organization of the United Nations). 2020. FAOSTAT [database]. http://www.fao.org/faostat/en/#home

FAO (Food and Agriculture Organization of the United Nations). 2020. AQUASTAT [database]. http:// www.fao.org/aquastat/en/#home

FAO, 2019. Developing Sustainable Value Chains for Small-Scale Livestock Producers, Animal Production and Health Guidelines, Rome.

FAO, 2017. Climate-Smart Agriculture Sourcebook, Summary, Second Edition.

Godde, C.M., et al., 2021: Impacts of climate change on the livestock food supply chain; a review of the evidence. Glob Food Sec, 28, 100488, doi:10.1016/j.gfs.2020.100488.

Nelson, G. C., Rosegrant, M. W., Palazzo, A., Gray, I., Ingersoll, C., Robertson, R., Tokgoz, S., Zhu, T., Sulser, T. B., & Ringler, C. (2010). *Food security, farming, and climate change to 2050: scenarios, results, policy options* (Vol. 172). Intl Food Policy Res Inst.

Nhemachena, Charles, and Rashid Hassan. 2007. *Micro-Level Analysis of Farmers Adaption to Climate Change in Southern Africa*. Intl Food Policy Res Inst.

Nin-Pratt, A., H. El-Enbaby, J.L. Figueroa, H. ElDidi, and C. Breisinger. 2018. "*Agriculture and Economic Transformation in the Middle East and North Africa: A Review of the Past with Lessons for the Future*. Food Policy Report. Washington, DC: IFPRI; Rome: FAO. https://doi.org/10.2499/9780896292956

Perez, Nicostrato D et al. 2021. *Climate-Resilience Policies and Investments for Philippines's Agriculture Sector: Sustaining Productivity and Food Security*. Intl Food Policy Res Inst.

Perez, N.D., and M.W. Rosegrant. 2018. "A Partial Equilibrium Approach to Modelling Alternative Agricultural Futures under Climate Change." In *The Future of Philippine Agriculture under a Changing Climate: Policies, Investments and Scenarios*, eds. M.W. Rosegrant and M.A. Sombilla, 450–491. Singapore: ISEAS–Yusof Ishak Institute.

Robinson, S., D. Mason d'Croz, S. Islam, T.B. Sulser, R.D. Robertson, T. Zhu, A. Gueneau, G. Pitois, and M.W. Rosegrant. 2015. "The International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT): Model Description for Version 3." IFPRI Discussion Paper 1483. International Food Policy Research Institute, Washington, DC. http://ebrary.ifpri.org/cdm/ref/collection/p15738coll2/id/129825

Rosegrant, M.W., J. Koo, N. Cenacchi, C. Ringler, R.D. Robertson, M. Fisher, C.M. Cox, K. Garrett, N.D. Perez, and P. Sabbagh. 2014. *Food Security in a World of Natural Resource Scarcity: The Role of Agricultural Technologies*. Washington, DC: IFPRI.http://dx.doi.org/10.2499/9780896298477

Swinnen, Johan, Channing Arndt, and Rob Vos. 2022. "Climate Change and Food Systems: Transforming Food Systems for Adaptation, Mitigation, and Resilience." *IFPRI book chapters*: 6–15.

World Bank. 2020. World Development Indicators [database]. Accessed at https://databank.worldbank.org/source/world-development-indicators

World bank, Data https://data.worldbank.org/indicator/NV.AGR.TOTL.ZS?locations=E.G.,

WorldClim 2.0 Dataset online

APPENDIX AND SUPPLEMENTARY DOCUMENTS

Appendix A: Supplementary Tables and Figures

Table 25: Differential Impact of Technology Package Development Scenarios on Crop Area/Animal in Philippines by 2050

Food commodities	2050 with CC Effects	Technology, Infrastructure and Market Devt			% change from CC Effects		
		R&D (Crop-Livestock)	Irrigation Devt*	Market & Value Chain**	R&D (Crop-Livestock)	Irrigation Devt*	Market & Value Chain**
Area/Number	-------------------000 heads or 000 ha -----------------				percent		
All meat animals	612,392	648,736	618,359	624,132	5.93	0.97	1.92
Cattle	1,794	1,900	1,811	1,824	5.92	0.95	1.64
Sheep/Goat	6,125	6,409	6,109	6,151	4.64	-0.27	0.41
Swine	24,432	25,576	24,388	24,724	4.68	-0.18	1.20
Poultry	580,040	614,851	586,051	591,434	6.00	1.04	1.96
Dairy cows	8	8	8	8	6.67	1.63	2.75
Layers	326,422	339,778	324,238	328,569	4.09	-0.67	0.66
All cereals	7,288	7,312	7,441	7,203	0.33	2.11	-1.17
Corn	2,710	2,722	2,695	2,680	0.42	-0.57	-1.11
Rice	4,578	4,590	4,747	4,523	0.27	3.69	-1.20
Other foodcrops	642	645	643	634	0.38	0.19	-1.24
Fruits	1,683	1,688	1,677	1,665	0.27	-0.38	-1.10
Vegetables	864	872	866	856	0.86	0.17	-0.95
Oilseed crops	3,873	3,819	3,939	3,973	-1.39	1.69	2.59
Pulses	85	86	85	84	0.57	-0.16	-1.93
Roots and tubers	387	387	387	385	0.07	-0.14	-0.59
Sugar	722	708	736	733	-1.89	1.91	1.57

Note: Results are averages of 3 climate models under RCP 8.5 and SPP2; NoCC means no climate change that serves as the counterfactual scenario. SOURCE: IMPACT-PHIL SIMULATIONS.

Appendix B: Methodology - Biophysical and Economic Modeling

This report is tasked to identify and recommend investment policy options for building long-term resilience in Philippines's agri-food system. And in the process highlight opportunities for adaptation to climate change which are highly correlated to mitigation and GHG emission reduction (i.e., decarbonization). Especially in the context of global and national economic recovery post pandemic and regional conflicts. Corollarily, these adaptation policies and investment strategies need to be institutionalized in the national and local units of the government and fully mainstreamed in the development planning activities.

Other subsequent goals in support of the main objective include:

- To provide analytical insights on possible agricultural support measures that could lead to the *triple-win nexus* of productivity, livelihood and household income, and resilience and sustainability) in Philippine agri-food systems.

- To contribute to the ongoing dialogue with the government on green, resilient and sustainable food systems transformation.

- To contribute to the move toward a greener, more resilient, and sustainable development path for reduction in GHG emissions from agriculture, by leveraging the agriculture sector for livelihood and household income opportunities.

- To evaluate policy incentives to scale-up climate-smart technologies and practices in Philippines' agriculture, under a broad theme of food systems assessment.

The key beneficiaries for the proposed policy-focused activity include the (i) the Climate Resilient Agriculture Office of the Department of Agriculture (DA-CRAO) a leading government agency for planning and coordination of high level government policies, including those related to climate change adaptation and mitigation; (ii) the Department of Environment and Natural Re3sources (DENR); (iii) the Local Government Units (LGUs) for coordinating the implementation of climate-resiliency program; (iv) academic and expert community of Philippines interested in the results of climate policy-focused analytics.

IMPACT – A Suite of Linked Biophysical and Economic Models

To facilitate achievement of these objectives, we calibrated a Philippine version of the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT-Phil) that can be maintained and further developed in-house by the DA-CRAO. The simulations of potential investment policy options were implemented with the IMPACT-Phil version depicted in Figure B1. It is the main modeling framework used in this study to: first, estimate the impacts of climate change on the agriculture sector; and next, to determine the effectiveness of adaptation response policies designed to counter them, and promote the building-up of long-term resiliency and sustainability in agriculture.

IMPACT-Phil combines biophysical models (climate, hydrology, and crop growth) with economic models to project water and food supply and demand as well as food trade and prices under climate change. The water models, informed by the climate models, estimate the changes in the supply of water from various sources and allocate available supplies to different users, including households, industry, livestock, irrigation, and the environment. The IMPACT-Phil economic model simulates national and global markets for agricultural production, demand, and trade that are associated with 62 agricultural commodities across 158 countries and regions.

The Core Multi **Market** Model

The core multimarket model simulates the operation of national and international markets, solving for production, demand, and prices that equate supply and demand across the globe. The core model is linked to a number of modules that include climate models (Earth System Models, ESMs), water models (hydrology, water basin management, and water stress models), crop simulation models (for example, Decision Support System for Agrotechnology Transfer [DSSAT] used in this study), value chain models (for example the ADAPTs to be developed in the next phase of the study), and post-processing models of land use (pixel-level land-use, cropping patterns by regions), nutrition and health models, and welfare analysis (see Figure B 1).

In addition, a dynamic computable general equilibrium model for the Philippines (Phil-DCGE) model that covers the entire economy, to complement the partial equilibrium multimarket model in the analysis of long-run trends under climate change, may be added to the IMPACT modules.

Supply and Demand Functions

Although complex in structure with various biophysical and economic modules – at its core, IMPACT-Phil has very simple framework, organized around a global multimarket model of agricultural food production, demand, trade and prices. The multimarket model simulates the operation of national and global markets for agricultural commodities that specifies supply and demand behavior in all markets. Thus, solving for market-clearing prices and quantities, implemented by iterative readjustment of supply and demand at the national levels first and then at the global level – until world supply and demand balance, intersecting at equilibrium world price, where global net trade equals zero.

As core supply and demand functions for food commodities, the component modules serve as either supply shifters or demand shifters. The climate model with crop model, for example, together determine the changes in yield and production due to climate change – and thus serve as supply shifters. The macroeconomic inputs of population growth, income/GDP growth and employment, and changes in preferences for food, on the other hand, serve as demand shifters.

The IMPACT-Phil model system integrates information flows among the component modules in a consistent equilibrium framework that supports longer-term scenario analysis. Some of the model communication is one way, with no feedback links (for example, climate scenarios to hydrology models to crop simulation models), while other links require capturing feedback loops (for example, water demand from the core multimarket model and water supply from the water models must be reconciled to estimate water-stress impacts on crop yields (for details see Robinson *et al.* 2015 http://ebrary.ifpri.org/cdm/ref/collection/ p15738coll2/id/129825).

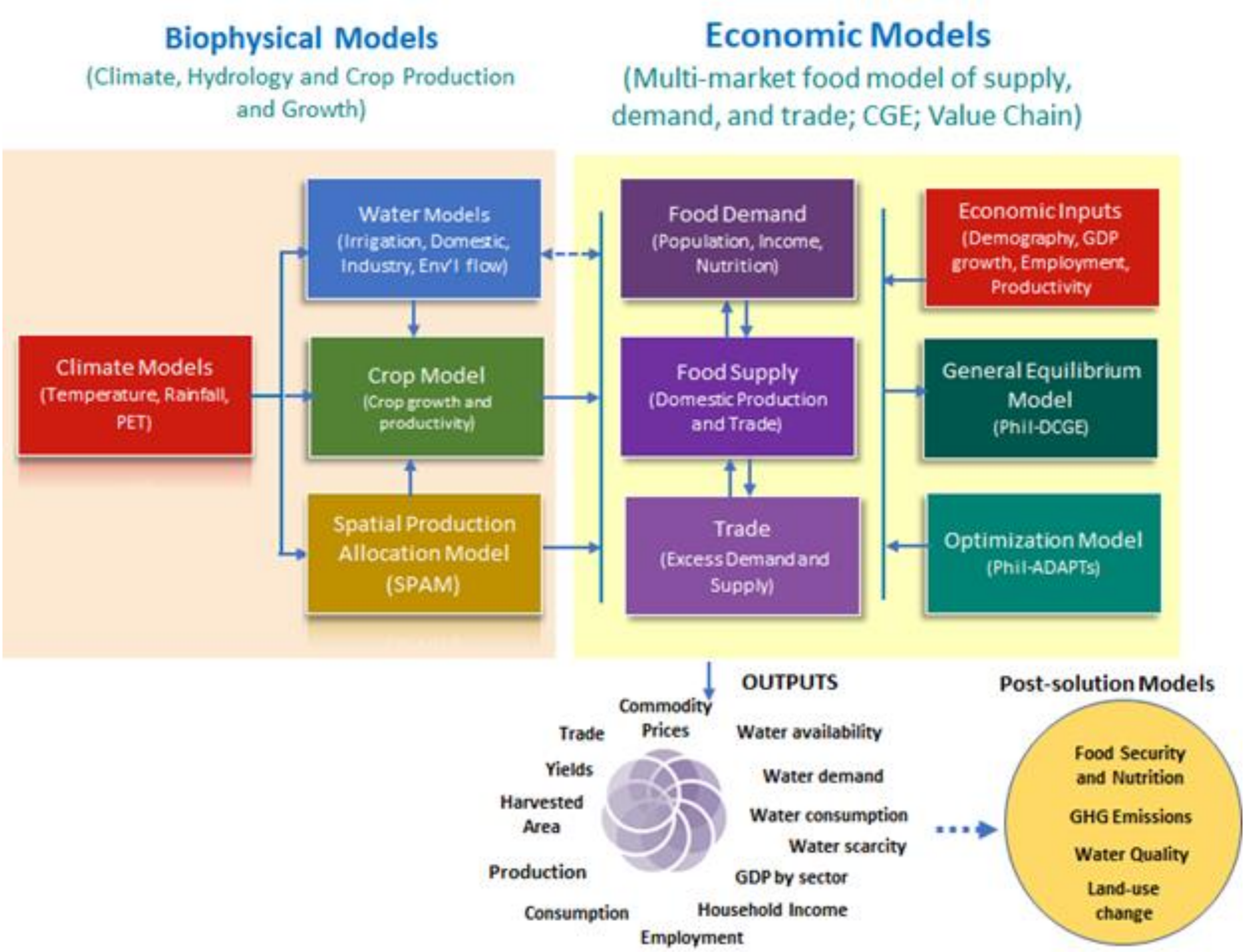
Data and Calibrations

IMPACT-Phil as a global model, requires data sources that provide, at a minimum, comprehensive information about 168 countries and regions, and 62 agricultural commodities. Dataset on food supply (i.e., crop area/ animal stock; production; yields, trade); and food demand (i.e., food and feed demand, other uses [bio-fuel, seeds, industrial], and prices) were mainly from FAOSTAT; while data and projections of population and GDP are based on Shared Socio-economic Pathways (SSPs) assumptions taken from IIASA Database (SSP Database (iiasa.ac.at)) collected from various sources. Projections of spatially (grided) downscaled climate data on precipitation and temperature are from WorldClim.

Since there are no data sources and studies that can provide income and cross- and own-price elasticities for all food items in all countries and regions, they were initially taken (in 1995) from available country studies and meticulously applied to countries and regions with similar income levels and demographics. Backward validations and adjustments were then done to approximate country-level historical data and global closure conditions of zero net trade and one price. In the updated IMPACT-Phil version (2014) especially calibrate4d for the Philippines, the price and income elasticities were validated and oftentimes adjusted by experts from various CGIAR centers until found to be sensible approximations, and that model simulation should also result to sensible country-level and global projections of supply, demand and trade. Same type of expert calibrations were done for country-level crop and livestock productivity growth rates.

Base-year for IMPACT-Phil is 2020 (data are averages of 2019-2021). This is the year where values of endogenous and exogenous variables, parameters, and coefficients populated the model. Area, production, yields, trade and prices are all endogenous to the model, so are demand and consumption.

Figure B 1: Graphic Representation of Suite of Biophysical-Economic Models



Source: Authors' depiction of IMPACT model

For Philippines the model was calibrated to approximate the 2020 values of the endogenous variables by recursively adjusting the relevant elasticities and growth rates – while maintaining the country-level and global integrity of model projections.

Use of IMPACT-Phil in Climate Change Modeling

Changes in temperature and rainfall patterns brought by climate change alter crop yields both directly and indirectly via changes in water availability for irrigation. Livestock productivity is indirectly affected by changes in feed availability. Direct heat stress on livestock is not yet considered in the model. The biophysical and economic effects of climate change were estimated with the UKES, EC Earth, and MPI-ESM climate models (temperature, rainfall, and PET), the DSSAT crop model (yields, temperature stress, water stress), and the IMPACT-Phil water module (availability of irrigation water and water demand). All under the representative concentration pathways (RCP) 8.5 of GHG emissions, and shared socioeconomic pathways, SSP2, population and GDP assumptions (IIASA 2015, 2018).]