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PHILIPPINE CLIMATE CHANGE AND FOOD SECURITY ANALYSIS
STUDY

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Technical Working Group:

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Foreword

Sustainable food systems in the Philippines and the rest of the world are critical now more than ever, as the effects of climate change on water and food security, exacerbated by the economic effects of the COVID-19 pandemic, threatens to reverse years of developmental gains in food and nutrition.

The 2021 Global Food Systems Summit dialogues have underlined the importance of transforming food systems as a critical component in the delivery of all the Sustainable Development Goals. Reaching our collective goal of Zero Hunger by 2030 requires food systems solutions that address systemic inefficiencies, political crises, conflicts and the effects of climate change. This can be achieved by bringing together policymakers, interventions of all stakeholders, linking humanitarian assistance and social protection, developments in infrastructure, and heightened accessibility of innovations and technology — supported by dedicated political leadership and investments.

The United Nations World Food Programme (WFP) in the Philippines embarked on a robust study with the International Center for Tropical Agriculture (CIAT), to aid in the shaping of these policies, resource prioritization, and the crafting of sustainable strategies to mitigate and cope with the effects of climate change on food systems. The Climate Change and Food Security Analysis (CCFSA) analyzes the interconnectedness of climate change and food security, particularly the threats but also to surface the opportunities it presents to food, nutrition, and livelihood in rural and urban areas.

This interconnectedness is extremely important to understand in the context of the Philippines as its geographic position, among other factors, has made it one of the world's most vulnerable countries in terms of climate change impacts and natural hazards. Philippine Government data shows that there are "more Tropical Cyclones (TCs) entering the Philippine Area of Responsibility than anywhere else in the world with an average of 20 TCs in this region per year, and about 8 or 9 of them crossing the Philippines." Meanwhile, the Philippines Statistics Authority data from 2010 to 2019 tallies that the Philippines incurred Php 463 Billion worth of damages due to extreme weather events – 62.7% of that or Php 290 Billion were damages to agriculture. This is a glaring statistic that prevents Filipinos from accessing food and necessary resources for their nutrition and well-being.

The CCFSA study was completed in May 2021. It has produced a set of innovative scenarios that reflect the possible impact of climate change on food security over time – in 2030, 2050, 2070, and 2090. These country-wide scenarios offer stakeholders information and model situations particularly in food production, food accessibility, utilization and consumption patterns, and supply stability.

WFP, together with CIAT and our national government partners, are proud to be able to provide these data sets, for the first time in the Philippines. We have high hopes for providing multi-sectoral stakeholders at all levels – from central government to local governments, actors in the agri-food and fisheries sector, and other industries involved in food systems, including the private sector – key information to introduce adaptation measures that can help to reduce the negative impacts of climate change on the food systems over time.

The analysis utilized WFP's Consolidated Livelihood Exercise for Analyzing Resilience (CLEAR) approach which contains a baseline of major livelihood zones all over the country. CLEAR has provided the backbone to build the Philippines' first livelihood zone maps which aim to provide information for the diversification of economic activities, aimed to ensure that its food systems are secure, peace and hunger are addressed, and that the country is on a continuous path to sustainable development.

Concretely, these products are envisioned to provide government and non-government partners with technical inputs to various development and action plans such as the National and Local Climate Change Action Plans. In addition, the livelihood zone maps that model scenarios in rural and urban settings can assist government and development partners in the targeted mobilization of resources to increase community resilience.

This study's information just scratches the surface of what the data can provide. As more sectors have access to this study, it is WFP's aim that more multi-sectoral interventions aimed at promoting climate change adaptation and livelihood resilience are developed and prioritized.

WFP would like to extend our gratitude to our partners without whom this project would not be a success, namely CIAT and the 10 national government offices that comprise the project's technical working group: the Department of Agriculture, Department of Tourism, Department of Social Welfare and Development, Department of Labor and Employment, Department of Interior and Local Government, Department of Science and Technology, Food and Nutrition Research Institute and Philippine Atmospheric, Geophysical and Astronomical Services Administration, Climate Change Commission, and Task Force Zero Hunger, WFP Philippines research team, led by Juanito Berja, and our colleagues in the WFP Regional Bureau in Bangkok, specifically Katiuscia Fara and her team.

These efforts serve as a testament to our joint commitment of ensuring that the Philippines remains on track to achieve its Sustainable Development Goals, particularly Zero Hunger, in a manner that leaves no one behind.

Brenda Barton
Representative and Country Director
UN World Food Programme, Philippines

A science-driven approach to building climate resilience in the Philippines

Globally, we are challenged by the impacts of climate change. At this rate, it is threatening different segments and aspects of the food system at various scales making food and nutrition security elusive.

This timely work of the Alliance of Bioversity International and the International Center for Tropical Agriculture (CIAT) and the World Food Programme puts forward how climate vulnerability and climate change are affecting livelihoods in the Philippines. We believe that this assessment is key for actors in both the government and private sector to understand the current trends and potential risk of climate change on food and nutritional security in the Philippines and interweave it with key social issues that serve as barriers for effective adaptation.

By mapping the impacts at the municipal level using near-medium and far-future scenarios, the project was able to capture the dynamic impacts of climate change in space and time. This information enables next-users to effectively target and prioritize packages of interventions that increase livelihood resilience and develop proactive plans and programs geared towards adaptation options based on livelihood, socioeconomic conditions, and climate risk information.

The Alliance hopes that the results of the analysis will be able to support initiatives in designing and shaping policies, programs, and climate-proof investments at the local and national level that involve different sectors to mitigate the effects of climate change and subsequently improve livelihoods and the resilience of many Filipinos in the years to come.

Stephan Weise
Managing Director for Asia
Alliance of Bioversity International and CIAT

Executive Summary

Impacts of climate change on water

- Historically, increased rainfall variability has been one of the most significant impacts of climate change in the Philippines. Future projections indicate that seasonal rainfall volumes will exceed historical averages by approximately 40% across the nation.
- Analysis of flood risk and livelihood mapping suggests that rainfall is likely to increase in frequency and severity in many parts of the Philippines from 2020 to 2050, resulting in moderate to high exposure of rice and vegetable production zones under various management types, from irrigated to rainfed to annual crop zones.
- Sea-based hazards, such as sea-level rise (SLR), storm surge (SS), and saltwater intrusion (SWI), will have significant impacts on coastal and freshwater fisheries, especially those located in coastal communities of Visayas and Mindanao that are less accessible and have high incidences of poverty.

Impacts of climate change on crop productivity

- Future climate scenarios show more conducive environments for rice production throughout the country. This is especially true for Luzon, but not for inland pockets in Mindanao.
- The impact of climate change on future maize production is more variable, with some areas seemingly more suitable than others.
- For banana, suitability is quite regionally determined, with enhanced conditions in southern Luzon, Visayas, and southern Mindanao, but poorer conditions in northern Luzon.
- Vegetable production potential is mixed: garlic conditions remain similarly suitable, while the requirements for onion production will be positively affected and eggplant will be negatively affected.

Impacts of climate change on crop diseases

- The areas that depend on rice and vegetable production as the primary livelihood source are the most likely to be impacted by an increased incidence of plant diseases.
- By 2050, the temperature is expected to continue to rise, resulting in heat stress (temperature greater than 30 °C) for most of the areas producing rice and annual crops, which is conducive to the spread of plant diseases.

Impacts of climate change on livestock

- Increased temperature can negatively affect livestock performance, including stunted growth, more deficient good-quality meat and by-products, and decreased reproductive capacity, in addition to diminishing the quality and quantity of feed supply.
- The majority of the livestock sector that will be affected by an increase in temperature is in mainland Luzon and the islands of Mindoro.
- The top three main livelihood zones threatened by climate change associated with livestock farming are pasture mixed with urban zones, pasture mixed with perennial commodity zones, and pasture mixed with vegetable farming zones.

Impact model analysis across key food commodities

- Currently, the diets of urban households constitute a higher demand for rice, while rural households' diets mainly depend on vegetables and root and tuber crops.
- The demand for maize for animal feed is expected to increase significantly from 68% to 89% from 2020 to 2050.
- Livestock in the Philippines is expected to experience major growth from 2020 to 2050 under the RCP 4.5 scenario, while poultry production will increase by a projected 86%, beef by 90%, and pork by 42%.

Impacts of climate change across social sectors

- The Philippines is predominantly rural and dominated by the agricultural and fishing sectors, for which livelihoods are inextricably linked to food production.
- The agricultural sector is the most vulnerable sector in the country to almost all climate-related hazards, rendering rural communities especially vulnerable to climate change.

Climate-sensitive food security zones in the Philippines

- The spatial distribution, incidence, and risk of climate-related hazards in the Philippines vary across geographic areas. To capture this spatial variability, a hazard risk map was developed at the municipal level to match the data on livelihood zones and socioeconomic datasets.
- The results indicate that combined climate hazards such as typhoon, flood, and drought will cause serious threats to food security.
- One of the major risks associated with the occurrence of these climate-related hazards is price volatility of food items, such as an increase in the prices of basic goods, largely due to the disruption of food production in the affected areas.

Climate-sensitive nutrition zones

- The areas exposed to climate hazards that pose the greatest risks to nutrition security were identified based on geographic and demographic information related to food security and nutrition, such as poverty, stunting, wasting, and accessibility.
- The analysis found that, across the Philippines, the very low-density population cluster is characterized by very high poverty with the greatest prevalence of stunting and wasting. These vulnerabilities are likely largely linked to a lack of diversity in sources of income.

1. Context

1.1. Climate change in the Philippines

Climate change poses critical and complex challenges to global food security. However, the potential impacts across the various elements of food security are particularly acute in the Philippines, where hundreds of thousands of households depend on natural resource-based livelihoods such as agriculture, fisheries, livestock, etc. The Philippines has been classified as the third most vulnerable country to climate change across 67 countries and is considered to have the highest sensitivity to extreme weather events vis-à-vis other Asian countries (Paun et al., 2018). The impact of climate change on the incidence and intensity of extreme weather is acutely felt across the country and in particular by the agricultural sector.

Historical trends of change across the region show a general warming (0.14 °C to 0.2 °C per decade), with an increased number of warm days and decreased number of cool days, and varied signals on precipitation trends depending on the location (Hijioka et al., 2014; Manton et al., 2001). A regional study found stronger trends during the last two decades and during summer for warm days and nights (compared with trends for cool days/nights) (Choi et al., 2009). Although historical precipitation trends showed no regional pattern (Choi et al., 2009), data generated from various weather stations in the Philippines have shown decreases in the number of rain days and in fewer cases an increase in total rainfall from extreme events (Manton et al., 2001). Luzon and Visayas showed decreased/increased trends in total annual precipitation and increased average precipitation on wet days and in the annual maximum number of dry days (Endo et al., 2009).

Altered hydrologic regimes can exacerbate the occurrence and intensity of hazards and other extreme weather events; for example, according to Cruz et al. (2007), the frequency and intensity of tropical cyclones originating in the Pacific have increased over the past few decades. Based on the report of OML (2017), typhoons Durian, Babs, and Haiyan had the highest maximum gustiness ever recorded in the world. Moreover, the Emergency Events Database indicates, globally, a steady increase in tropical cyclone occurrences from the 1900s, with a notably higher number of occurrences after the 1990s (although highly variable). This increase in the number of extreme flood and storm events is significantly correlated with increasing atmospheric carbon dioxide (CO_2) (Lopez et al., 2020).

Future climate scenarios (multi-model average by the end of the century, 2080 – 2100) across Southeast Asia (SEA) show higher temperatures (relatively lower increases over coastal areas) and increased total annual precipitation (0-6%) (Collins et al., 2013). Increased precipitation trends are found greater than 50% of the Coupled Model Intercomparison Project 5 (CMIP5) models with anomalies relatively small compared to the historical variability in precipitation across the 21st century and across seasons, except for models showing the largest precipitation increases (models with anomalies above the 75th percentile) under Representative Concentration Pathway (RCP[1]) 4.5 (van Oldenborgh et al., 2013). Under RCP 8.5, precipitation trends are similar but anomalies are larger than the historical variability following a southeast (SE) to northwest (NW) axis (i.e., Indonesia and the Philippines show larger anomalies than their historical variability) (van Oldenborgh et al., 2013). Future scenarios show no significant difference between CMIP3 and CMIP5 temperature changes over the Philippines. They also show increased minimum and maximum daily temperatures and in the number of tropical nights (more than 20 °C) (Collins et al., 2013). Annual maximum 5-day precipitation and the number of consecutive dry days will also increase, although only the former will have significant changes in future scenarios. CMIP5 scenarios show a delayed seasonal cycle across the region models but lack a consistent signal. However, changes in the extent of the dry season show disagreement between models under future climate scenarios (Pascale et al., 2016).

Effects on the annual water cycle for the region include decreased relative humidity and soil moisture decreases vis-à-vis the historical variability only under high-warming scenarios (RCP 8.5, with less than 2 standard deviations). The region shows increases in runoff (0.1–0.5 mm/day) under future scenarios that are 1–2 standard deviations of the historical variability (Collins et al., 2013). Hydrological simulations under future climate change scenarios in the Philippines indicate increased river flow and variability across seasons (Tolentino et al., 2016).

Studies on observed and projected climate change impacts for the SEA region have mostly focused on human settlements, infrastructure, and industry concerns while fewer studies exist for other issues except for major river runoff, coral reefs, health concerns, and rice productivity (Hijioka et al., 2014). Hirabayashi et al. (2013) used a multi-model approach to simulate changes in the return period of flood events under climate change and found a return period of less than 25 years by the end of this century for events with a magnitude with a 100-year return period from 1971 to 2000 (without accounting for the effect of flood regulation infrastructure). Furthermore, the region showed a trend consistency in at least 9 out of 11 future climate model runs. A follow-up study from Arnell and Gosling (2014) using a larger number of climate models, with coarser resolution and without a water flow routing scheme, found similar trends for 2050 and estimated an increase in flood risk (in 4 out of 7 models) for at least 30% of the population and greater than 40% of the cropland areas in SEA.

1.2. Food security, nutrition, and climate change in the Philippines

Food security is a multi-dimensional concept, considering how food can meet individuals' energy nutritional needs, but also its ability to fulfill social purposes and uphold cultural meanings. Although objective indicators of food and nutrition security are important, they do not always correspond to how people subjectively value food and perceive food security. Maxwell and Smith (1992) distinguished four conceptual aspects of food security: (i) sufficiency – defined as the calories needed for an active and healthy life; (ii) access – defined by entitlements to produce, purchase, or exchange food; (iii) security – defined as the balance between vulnerability, risk, and insurance; and (iv) stability – a temporal aspect in which food insecurity can be chronic, transitory, or cyclical. These four aspects apply to food security for a population or individual, whether food is from own production, market purchase, exchange, borrowing, or receipt as a gift. A fifth important aspect is the concept of utilization, or how food is assimilated through an adequate diet, clean water, sanitation, and health care to support a state of nutritional well-being (FAO, 2006). Utilization becomes increasingly significant considering the challenges posed by climate-related hazards to food production, infrastructure and distribution, and consumption.

This study aims to understand the impact that climate-related changes and hazards will have on food security in the Philippines. In doing so, it will be necessary to consider the breadth of agricultural supply chains from production to consumption and across urban and rural sectors, as well as accounting for differences among households and individuals therein. To this end, this project considers the impact of climate-related changes and disasters on food security and nutrition from both the standpoint of food production in rural agricultural communities and food consumption in rural, urban, and peri-urban centers. In this section, we outline several aspects of food systems in the Philippines that are vulnerable to the impacts of climate change.

PRODUCTION SHOCKS: At the production level, the Philippines is vulnerable to the impact of climate change and natural hazards on the production of staple crops, livestock, and fisheries, which generates market disruptions and compromises the availability of food. Several studies have investigated the connection between an increased incidence and intensity of climate-related hazards, namely, typhoons, increased precipitation (rainfall and/or flooding), and increased temperature (drought), and the productivity of key dietary and commodity crops, namely, rice and maize (corn). Although the findings regarding precipitation are less generalizable, the consensus is that climate-related changes have (and are projected to continue having) a negative effect on staple crop yields in the Philippines. One study estimates the total value of agricultural damage to crops, livestock, and fisheries due to typhoons, floods, and droughts in the Philippines from 2000 to 2010 to reach US$219 billion. Considering specific crops, the study estimated annual yield losses from 1995 to 2010 and found losses of up to 5.9% for maize, 4.2% for rice, and 3.0% for high-value cash crops (Israel and Briones, 2012).

Beyond the macroeconomic implications, climate-related productivity losses have far-reaching implications. The impact of climatic changes on agricultural production is experienced by rural households in several ways: (i) in terms of food consumption in their inability to consume the food that they produce; (ii) as producers due to the decreased income from productivity losses; and (iii) as market consumers due to the unavailability and higher prices of food. The yield losses that result from climate shocks lead to scarcity, disrupted supply chains, and food price inflation that are experienced by both rural and urban consumers. Globally, Satterthwaite et al. (2010)

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[1] The Representative Concentration Pathways (RCPs) are used for making projections based on anthropogenic greenhouse gas (GHG) emissions driven by population size, economic activity, lifestyle, energy use, land-use patterns, technology, and climate policy. RCPs describe four different 21st-century pathways of GHG emissions and atmospheric concentrations, air pollutant emissions, and land use. RCP2.6 – stringent mitigation scenario, RCP 4.5 and RCP 6.0 – intermediate scenarios, and RCP 8.5 – very high GHG emissions scenario (IPCC: Climate Change 2014 Synthesis Report: Fifth Assessment Report. Retrieved on 26 May 2021. Accessible online: https://ar5-syr.ipcc.ch/topic_summary.php).

outline the major urban-rural food system linkages, highlighting how climate change impacts on agriculture directly shape urban food systems (e.g., food availability, price), and likewise how the impacts of climate change on the urban sector affect the rural sector (e.g., disruptions in demand, urban service providers, and food accessibility for rural producers).

PRICE SHOCKS: Food price shocks have significant and varied effects on poverty and various aspects of food and nutrition security in the Philippines. A World Bank study (2011) looking at the effects of climate change on food price inflation established linkages between climate disasters and food prices in the Philippines. Fujii (2013) links vulnerability to food inflation to poverty. His study finds that poor agricultural households are particularly vulnerable to food inflation, which has the effect of increasing the depth of poverty, in terms of the gap between household income and the poverty line, and the scale, in terms of the share of the population affected by poverty. Significantly, because of the disaggregated nature of supply and demand markets in the Philippines, the study considers how food price inflation varies across provinces, finding significant differences between provinces and urban and rural populations for major food groups (Fujii, 2013).

Despite this variation, the poor are generally affected by food price inflation, and particularly the rural poor that depend on agriculture as their principal source of income (Fujii, 2013). In a related study, Ahmed et al. (2009) analyzed the potential impact of a “once in 30 years” climate extreme event on the incidence of poverty in the Philippines, finding that the most vulnerable socioeconomic sub-sections of the population are the urban labor and rural labor groups, experiencing a 32.3% and 25.9% increase in the incidence of poverty, respectively. These findings corroborate other studies (Ivanic and Martin, 2008) that find that while rural agricultural populations are greatly affected by staple food price increases, in the short term, price increases tend to worsen poverty for the majority of both the urban and rural poor.

In other studies, price inflation due to production shocks is seen as reinforcing pre-existing price inflation that is attributed to market structures and policies. Considering the impact of domestic policies on the national consumption of fish, Kurien (2005) suggests that the relatively low per-person consumption of fish as a key source of protein in the Philippines is tied to the high costs of fish specifically for domestically produced food more generally. This analysis seems to coincide with the WFP’s findings from a cost of diet study (2018) that a nutritious diet, complete with varied sources of protein, is beyond the purchasing power of most households. Kurien (2004) further explains the importance of small-scale fisheries in contributing to a sustainable, nutritious, and affordable domestic diet, as they are well integrated into small-scale marketing channels that are low-cost, highly efficient, and cater to local food needs (Kurien, 2004).

NUTRITION: The World Food Programme’s (2018) Fill the Nutrition Gap (FNG) Survey report offers a detailed and insightful overview of the state of nutrition in the Philippines, with particular reference to rural, urban, and vulnerable populations across 17 regions. The report finds that the average diet is high in cereals (constituting 73% of the energy), particularly rice, and low in fruits and vegetables, even though these foods are among the most affordable. This suggests that even households that can afford a more nutritious diet are not consuming it. At the same time, the report finds that the cost of a nutritious diet is unattainable for households earning the minimum wage in all regions, even if they were to dedicate 70% of their income to food purchases. This could partially account for the high prevalence of stunting (33%) and wasting (6%) among children and overweight (31%) among the adult population (NNS 2015). The FNG also found that the non-affordability of nutritious food is highly correlated with childhood stunting.

In a study on food insecurity among vulnerable populations in the Philippines, Roa (2007) finds that the most significant factors that influence children’s nutrition include total food budget, nutrient knowledge of the caregiver, and own-food production, among other factors. At the same time, the author finds that among vulnerable rural households that depend both on farming and on off-farm income, children demonstrated higher nutrition adequacy rates than adults, suggesting that preferential feeding of children is a common coping strategy (Roa, 2007). Balatibat (2004) finds significant differences between household income and food availability and the nutritional scenarios of populations of villages located in the lowlands and coastal areas. In coastal villages, livelihood insecurity contributes to food insecurity, with direct links to malnutrition such as stunting and wasting in children. However, in the lowlands, malnutrition occurs in the presence of food security and is more readily attributable to social practices, including breastfeeding and complementary feeding approaches, and morbidity linked to environmental and health conditions (Balatibat, 2004).

Food utilization (the body’s ability to make use of the nutrients in the food that it accesses) is an important aspect of food security and one that can be compromised by various environmental and biological factors, including sanitation and morbidity. Following the occurrence of natural disasters, the sudden displacement of an affected population can result in overcrowding, inadequate water supply and sanitation, and poor access to health services, all of which increase the risk of communicable diseases that affect food utilization (WHO, 2006). In the Philippines, Porio (2011) examines the vulnerability and adaptation of poor urban households living in flood-prone riverine communities in Manila, finding that the effects of flooding are acutely experienced by these populations, rendering them more vulnerable to health, livelihood, and asset loss. These findings complement those of Morin et al. (2016). Climate-related disasters including typhoons, floods, and tidal surges resulted in losses (including of income, infrastructure, health, and assets) for approximately two-thirds of the survey population, and further compounded the livelihood deprivations (such as lack of access to potable water, sewage and sanitation, electricity) of the most vulnerable among them (Porio, 2011).

COPING AND ADAPTATION: Households that experience food insecurity due to climate shocks and their related effects on food availability and accessibility often use different coping strategies to mitigate the impact. A study by the Department of Agriculture in the aftermath of a dramatic El Niño season found that both poor rural and poor urban households adopted negative coping strategies such as decreasing the quality and quantity of food intake (PCARRD/DA, 2001). Zoleta-Nantes (2000) finds that the urban poor in slums and squatter settlements in Manila face food security-related deprivations created by climate hazards by adopting various coping strategies, including cutting down on food consumption and preemptively stockpiling shelf-stable, calorie-dense foods (e.g., candies, canned and processed foods).

Some positive coping strategies adopted to address food insecurity can also be considered adaptation strategies. Income diversification is a significant factor that affects the nutritional status of children: households characterized by solely farm-based livelihoods had poorer childhood nutrition indicators, while households with off-farm or a mix of on-farm and off-farm income sources had better childhood nutrition (Roa, 2007). A World Bank (2003) study confirms that post-disaster coping mechanisms that combat unemployment and inflation often include diversification of livelihood strategies. For example, following the 1997 - 1998 El Niño season, many households diversified their on-farm income by introducing new crops (vegetables and root crops) and off-farm income by engaging in alternative and additional activities, such as sewing, carpentry, and construction (World Bank, 2003).

Alternatively, Pajaron (2014) considers the impact of increased precipitation (rainfall shocks) on agricultural productivity and how that affects income for rural Filipino households. The study finds that households depend on their networks of family and friends to ensure approximately 27% of their lost income, with international remittances from migrant family members replacing about 11% of income declines, while domestic transfers replace about 14% (Pajaron, 2014). The study likewise finds that informal loans decrease as rainfall shocks increase, suggesting that borrowers and lenders may be experiencing similar shocks, which would diminish the effectiveness of local risk-sharing arrangements (Pajaron, 2014). This is crucially important for understanding how communities farming heterogeneous crops, livestock, and/or fish will be able to cope with the impact of climate-related hazards that affect entire areas or regions.

> In a more formalized context, the implementation of state-organized disaster risk management, emergency response, and social protection programs is an important component of ensuring food and nutrition security in the face of disaster.

An important approach in the Philippines is Shock Responsive Social Protections (SRSPs). For example, in the aftermath of the devastation caused by Typhoon Haiyan (Yolanda) in central Philippines in 2013, the Pantawid Pamilyang Pilipino Program (referred to here as Pantawid) social protection program, with its core focus on social welfare and poverty reduction, including a conditional cash transfer program, was implemented and vertically expanded in scope by numerous aid agencies (WFP, UNICEF) to transition at least in part from in-kind to cash assistance (Smith et al., 2017). Two independent impact studies on the effectiveness of conditional cash transfers as a form of emergency disaster relief that supports coping for the most vulnerable suggest that the scaling of the success of these programs was contingent on the pre-existing network, efficiency, and accessibility of the Pantawid network that allowed for a quicker and more efficient dissemination of resources to households that were most predisposed to food and nutrition shocks

(Smith et al., 2017). Following the success of the social protections scaling approach, stakeholders, including the government of the Philippines, NGOs, the United Nations, and donors, found consensus on the potential for a National Emergency Cash Transfer program augmenting Pantawid for natural disasters (Smith et al., 2017).

1.3. Objectives and purpose

With the increasing food security risks caused by climate change in the Philippines, the World Food Programme (WFP) is pro-actively engaged in identifying climate-resilient interventions as a strategic approach to exploring the co-benefits of adaptation and mitigation measures that support food security. In the Philippines, WFP supports the national government to initiate, invest in, and implement climate adaptation and food and nutrition security initiatives through various channels: (i) mobilizing technical expertise on demand, (ii) knowledge-brokering among relevant institutions and groups, (iii) building partnership within and among countries, and (iv) enhancing access to a global pool of knowledge and experiences, including cutting-edge scientific tools and information.

This project seeks to provide strategic guidance for the WFP's current effort to develop a long-term national food security and nutrition agenda with an enhanced climate resilience perspective for the Philippines. Furthermore, this project seeks to provide insightful, actionable information that can be used by the Philippine government to foster climate-adaptive food systems and, in doing so, fulfill its commitments to the Philippine population, the United Nations, and other international agreements.

To this end, the project assesses the impacts of climate variability and climate change on food security and nutrition, and livelihoods in the Philippines for different timescales under various emissions scenarios. Specifically, this project considers impact models for the 2030, 2050, 2070, and 2090 time horizons, under both low and high global greenhouse gas emission scenarios (RCP 8.5 and 4.5), with sensitivity to social and geospatial attributes. In this way, the project aims to determine which populations will be most vulnerable to the impacts of climate change, including characterizing the types of livelihoods that will be most affected, by which climate hazards, to what extent, and where. Central to this analysis is the consideration of the potential consequence of climate change on the drivers of food and nutrition insecurity, such as production and market shocks, and how these might affect nutrition outcomes, such as the availability of, accessibility to, affordability of, and utilization of a nutritious diet. In addition to identifying risks and vulnerabilities, the project focuses on adaptation, proposing different adaptive approaches that can be taken to mitigate and overcome the impacts of climate change.

Taken together, the findings from this project will constitute a base of science-driven evidence that can be used to support decision-makers as they create policies, programs, and initiatives for disaster risk reduction and agricultural adaptation that strive to ensure food security in the light of climate change in the Philippines.

2. Methodology

2.1. Mapping of livelihood zones

Critical to this project's approach to determining the potential impacts of climate change on the food security of specific populations was the classification into livelihood categories. To that end, the project team developed a system for mapping livelihood zones at the city and municipal level across the country. The Livelihood Zones Map exercise (Figure 1) was developed in an iterative process, beginning with online meetings and consultations with experts from several national agencies that would eventually form the Technical Working Group (TWG). Following a recommendation by the TWG to link the impacts of climate change and food security with specific livelihoods, the project team set out to develop a comprehensive Livelihood Zones Map by overlaying several existing datasets, which would then be validated by experts with first-hand knowledge of the areas.

In total, six different national datasets were used to build the Livelihood Zones Map, including land cover map (NAMRIA, 2015), Agro-Ecological Zones (DA-AMIA, 2016), MODIS-derived rice land cover extension (GRiSP, 2013), tourism areas (Philippine Geoportal), mining locations (Department of Environment and Natural Resources, Mines and Geosciences Bureau (DENR-MGB)), and the land classification maps from the Philippine Local Government Units (LGUs). In order to combine the information from these six independent datasets, a geographic information systems (GIS) overlay analysis was employed.

LIVELIHOOD ZONES (LLZ) - HOW THE MAP WAS DEVELOPED

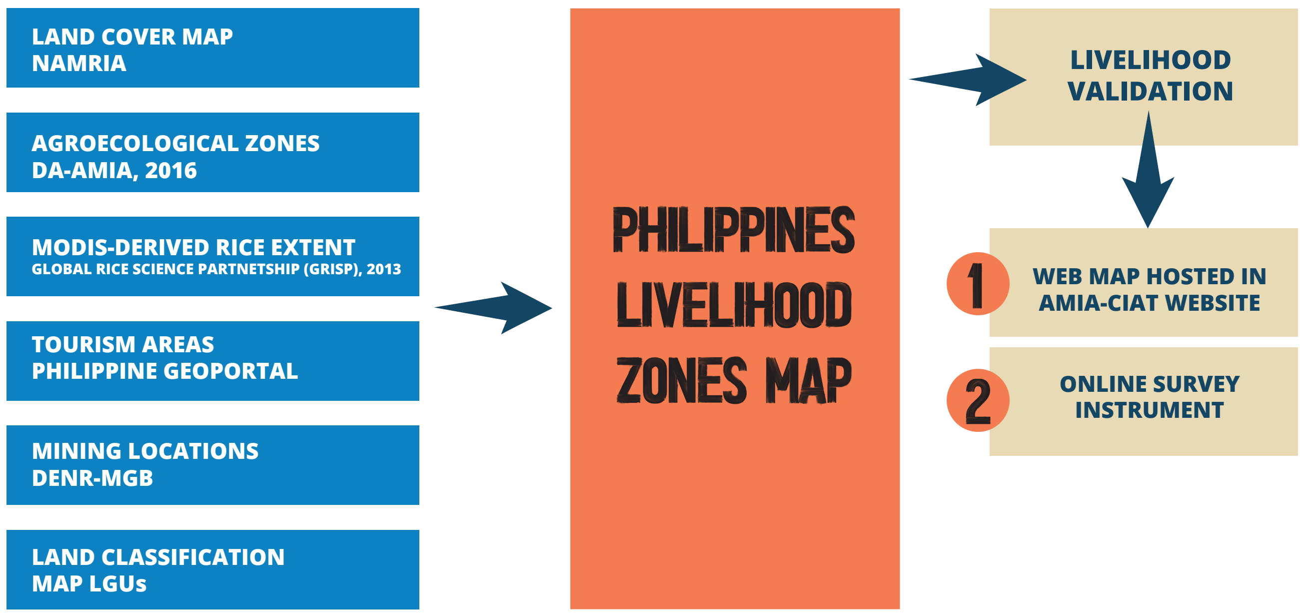


FIGURE 1. Chart depicting the design of the Livelihood Zones Map exercise in the Philippines.

Based on the GIS analysis, the proportion of total land area of each of the livelihood zones in each city or municipality was calculated. The livelihood zones that comprise the greatest proportion of each city or municipality were assumed to be the predominant sources of livelihood for that area, and hence that city or municipality was classified under that livelihood zone. However, "tourism" was included in the livelihood description in any municipality in which it was present, regardless of the geospatial extent of the endeavor. Similarly, mining operations were included in the livelihoods description based on the complete list of existing mineral production as of June 2015 from the DENR-MGB and validation of its present-day status by experts.

After the initial Livelihood Zones Map was developed, it was presented to the members of the TWG. Because of the COVID-19 pandemic and mobility restrictions, the TWG co-created a methodology to virtually validate the map and characterize each major livelihood zone and sub-zone. The initial Livelihood Zones Map was hosted on the AMIA-CIAT website, and an online survey questionnaire was developed and deployed using an online survey tool (KOBO). In total, 26 experts from different Regional Field Offices of the Department of Agriculture (DA-RFOs), national government agencies (NGAs), and state universities and colleges (SUCs) participated in the online survey, providing validation and enhancement of the original Livelihood Zones Map. The breakdown of expert participants included

- Six experts from four different NGAs
- Three experts from three different SUCs
- Seventeen experts from 11 different DA-RFOs

Out of the 81 provinces in the Philippines, 32 were validated by the survey, providing a sample group that covers approximately 39% of the nationwide total. The final livelihood zones database has a total of 2,306 records, comprising 1,646 unique cities and municipalities in the Philippines. The final Livelihood Zones Map is composed of 9 major zones and 74 unique sub-zones (see Table 1).

TABLE 1. Major livelihood and sub-livelihood zones in the Philippines.

MAJOR ZONES		DESCRIPTION	SUB-ZONES (No.)
(1)	Aquaculture/ Freshwater Zone	Activities related to raising and breeding freshwater aquatic animals and plants for economic purposes with ponds, reservoirs, lakes, rivers, and other inland waterways (brackish water).	5
(2)	Aquaculture/ Coastal Zone	Activities related to fisheries and seaweed farming in coastal and marine areas.	9
(3)	Irrigated Rice Zone	Activities related to rice farming in bunded fields wherein water supply is reliable using irrigation system. Rice grows once or twice a year and sometimes mixed or intercropped with vegetables.	4
(4)	Rainfed Rice Zone	Activities related to growing of rice in upland and/or hilly areas wherein water supply is dependent on rainfall. It is usually mixed with maize, cassava, and other vegetables.	4
(5)	Annual Crops Zone	Activities related to growing of vegetables and root crops that are harvested seasonally and have a life cycle for a year.	13
(6)	Perennial Crops Zone	Activities related to growing of a more permanent plant such as coconut, banana, cacao, coffee, rubber, abaca, calamansi, mango, and other fruit-bearing trees, which requires several growth cycles before its fruit is produced and/or harvested.	13
(7)	Cool Environment Zone	Consists of a combination of activities unique in terms of temperature ranges in the area (e.g., highland crops such as broccoli, cauliflower, lettuce, etc., can be grown only in this zone).	8
(8)	Pasture Zone	Activities related to raising livestock, swine, poultry, and other domesticated animals, such as goats, cattle, cows, etc., and growing of plants and/or grasses used for feeding animals.	9
(9)	Urban Zone	Activities related to commerce, industry, and non-agricultural jobs.	9

LIVELIHOOD ZONES

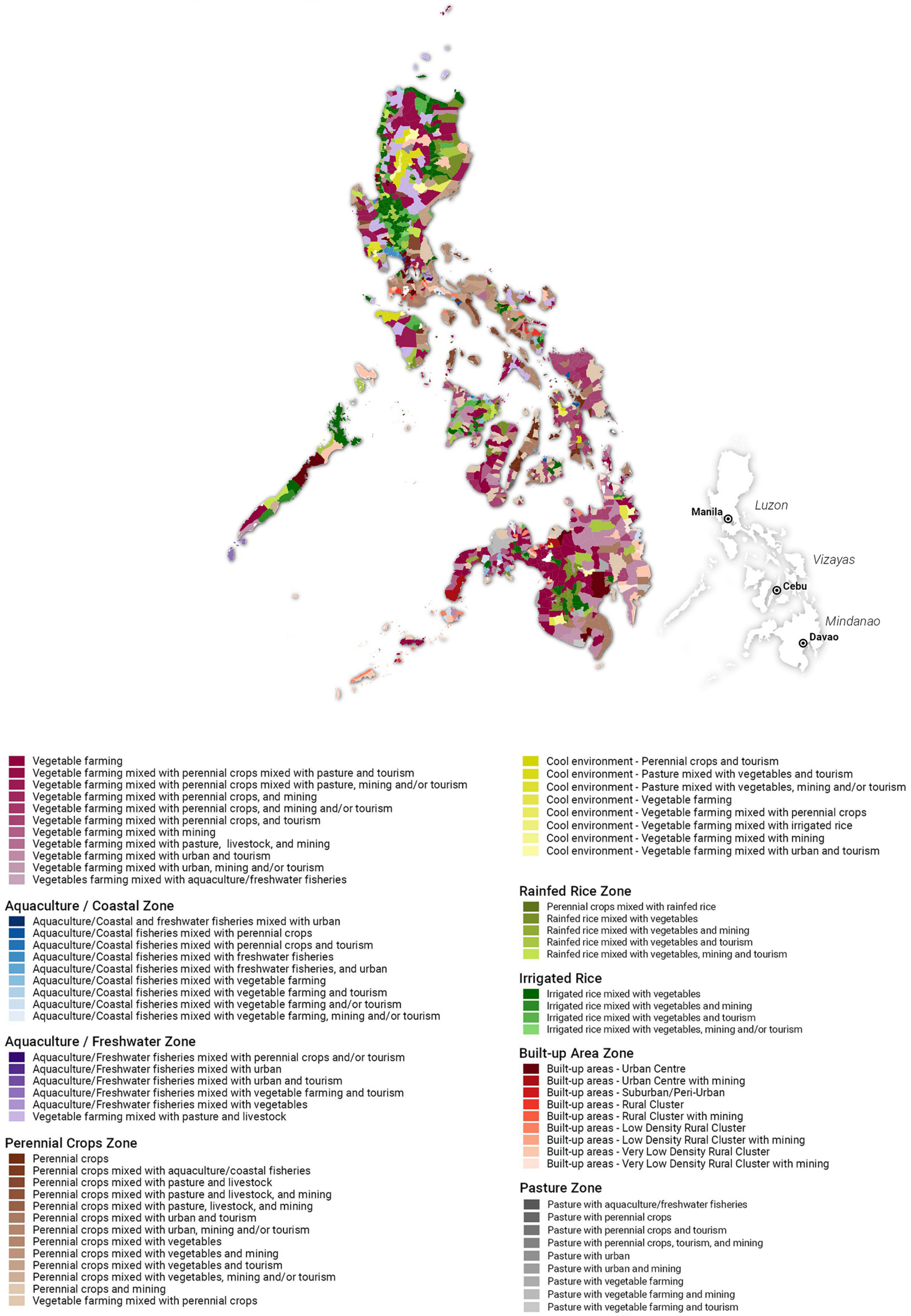


FIGURE 2. Map of livelihood zones in the Philippines.

2.2. Assessment of climate change impacts

2.2.1. CROP SUITABILITY METHODOLOGY

For the climate-based suitability assessment of selected crops, the project used Species Distribution Modeling (SDM) to estimate where changing climatic conditions will render a current food production region as no longer viable, or less suitable, or becoming suitable for the introduction of a different crop. The analysis helped identify where negative impacts are very high so as to possibly consider a shift to new crops or a new livelihood source.

Six commodities were selected for the assessment based on their food security and nutritional value, current contribution to livelihood income of farmers, potential to drive the local and national future economy, and inclusion in government priority programs and the private sector (Table 2). The selected crops are rice, banana, maize (corn), onions, eggplant, and garlic. Rice and maize farming are the most common livelihood of most agricultural populations in the Philippines. These two crops have enjoyed support from the Department of Agriculture through its banner programs.

TABLE 2. Selection criteria for prioritized crops.

COMMODITY	REMARKS
Rice	Main staple crop cultivated in both lowland and upland areas in the whole country. Irrigated and rainfed, cultivated year-round.
Banana	Supplemental crop to rice and corn in rural and/or upland areas. Harvested year-round.
Maize (corn)	Alternative to rice as staple food in large parts of the country, especially in Visayas, Mindanao, and northern Luzon. Cultivated in lowland and upland areas, and during non-typhoon season.
Vegetable, includes eggplant, onion, and garlic	Main ingredients in many food delicacies (fried rice, sausages, sautéed food, fried nuts, etc.). Represents the root crops. Cultivated during dry season.

Finally, we overlay the results of the crop suitability model on the relevant livelihoods in the Philippines in order to gain additional insights regarding crop-specific future risks (i.e., changes in rice suitability will be overlaid with irrigated rice and rainfed rice only).

2.2.2. CLIMATE RISK MAPPING

To identify and qualify the major climate change-related risks that were prioritized for this project, six datasets on hazards were used to characterize the Philippines' exposure to climate variability and extreme weather events (Table 3). The prioritized climate risks are typhoon, flood, drought, saltwater intrusion, storm surge, and sea-level rise. The selection of hazards was based on their potential impact on livelihood, food security and nutrition, and data availability. The hazard maps represent the current risk and exposure of crops, people, and institutions. Each of these risks is then used to describe the exposure level of populations based on the livelihood zones. To build a historical narrative and better understand the impact of hazards on livelihoods, government and open-sourced spatial databases were used to characterize susceptibility and hazard risks in the country.

TABLE 3. Overview of hazard datasets.

PARAMETER	SOURCE	UNIT OF MEASUREMENT, SPATIAL AND TEMPORAL RESOLUTION
TYPHOON	UNEP/UNISDR (2013) (https://preview.grid.unep.ch/) WFP-PH	1-km pixel resolution. Estimate of tropical cyclone frequency based on Saffir-Simpson scale category 5. (> 252 km/h) from 1970 to 2013; typhoon tracks
FLOODING	Mines and Geosciences Bureau, Department of Environment and Natural Resources (DENR-MGB)	1:10,000 scale. Susceptibility of flood risk for Philippines from the past 10 years.
DROUGHT	TerraClimate (Abatzoglou et al., 2018); Palmer Drought Severity Index (PDSI) from 1950 to near present	PDSI, Standard Precipitation Index
STORM SURGE	AMIA multi-hazard maps/baseline data from Disaster Risk and Exposure Assessment for Mitigation, Department of Science and Technology (DREAM, DOST)	1:100,000 scale (resampled). Exposure of an area to storm surge
SALTWATER INTRUSION	AMIA multi-hazard map/baseline data from the NWRB	1:100,000 scale (resampled). Risk of saltwater intrusion
SEA-LEVEL RISE	AMIA multi-hazard map	1:100,000 (resampled). 3-meter sea-level rise

A set of climate layers (gridded data) from Worldclim (https://www.worldclim.org/) with a spatial resolution of about 1 km^2 is used as baseline condition while climate data for future conditions are based on RCP 4.5 and 8.5 scenarios using CMIP5 Global Climate Models (GCMs) downloaded from CCAFS (Climate Change, Agriculture and Food Security – http://www.ccafs-climate.org/data_data_spatial_downscaling/). Changes in annual precipitation and temperature in the Philippines for both RCP 4.5 and 8.5 were computed (Pang et al., 2021). Then, the results of change analysis of the two climate variables were superimposed on the current risk maps in the country. This analytical process enabled the team to identify livelihood areas where there are expected substantial increases in precipitation and high susceptibility to flood risk in the future. Moreover, the team examined the consecutive number of dry months to explore the changes in the amount of rainfall to assess the likelihood of increased incidence of drought in the future, generating a qualitative discussion on future trends of these extreme events.

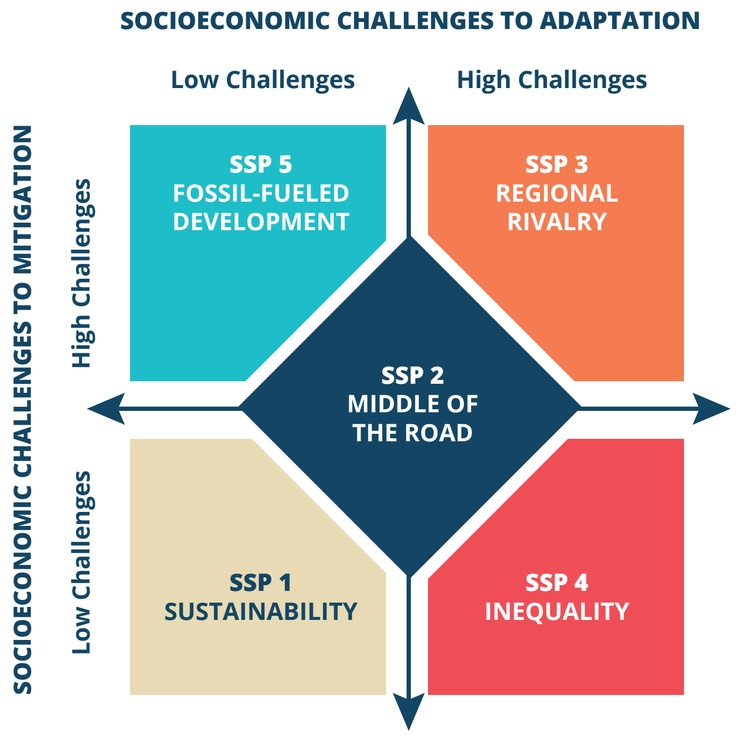
TABLE 4. Overview of socioeconomic data and link to food security and nutrition.

VARIABLE	DESCRIPTION	DATA AVAILABILITY, TEMPORAL RESOLUTION, SPATIAL SCALE
POVERTY INCIDENCE	Mapping of climate-sensitive livelihood zones/overlay with climate risk maps	PSA (2015). Municipality level
NUTRITION	Operation Timbang (OPT) is the weight and height measurement among preschoolers or <5 years old. It provides insights into the prevalence of stunting and wasting in the community.	National Nutrition Council (2019). Operation Timbang. Municipality level
ACCESSIBILITY	Distance of livelihood zones to urban zones as indicator for market access	Nelson et al. (2019). A suite of global accessibility indicators. Sci Data 6, 266. https://doi.org/10.1038/s41597-019-0265-5.
HUMAN SETTLEMENT	Disaggregation of urban and rural areas	GHS SMOD POP2015 (2015). 1-km resolution
LIVELIHOOD DIVERSITY AND GENDER ANALYSIS	Dependency on agricultural livelihoods. Gainful workers >15 years old by major occupation group, 2015	OCHA (2015). Humanitarian Data Exchange (HDX)

2.2.3. IMPACT MODEL

In the present study, climate change is modeled using the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) (Robinson et al., 2015). The IMPACT model is an exploratory tool that is used to assess linkages between agricultural policy, climate change, and technologies in agricultural systems. The model covers more than 50 agricultural commodities and comprises several interacting modules that simulate different climate, crop growth, land use, and trade scenarios. The climate and economic scenarios used in the IMPACT model were developed to give policymakers and researchers a series of useful scenarios that can be used to test how the world would respond to future demographic, economic, and climatic changes. These scenarios are defined by two major components: Shared Socioeconomic Pathways (SSPs) and Representative Concentration Pathways (RCPs). The SSPs are global pathways that represent alternative futures of societal evolution. Each SSP presents unique challenges to society for mitigating and adapting to climate change (O'Neill et al., 2014). On the other hand, the RCPs represent potential greenhouse gas emission levels in the atmosphere and the subsequent increase in solar energy that would be absorbed (radiative forcing).

SSPs: SSPs are scenarios of global development and each describes a development path the world might take and how this path would affect society's ability to respond to climate change. Figure 3 shows how the five SSPs were envisioned with respect to society's ability to deal with climate change. Although all of the SSPs can be simulated in IMPACT, **SSP 2 has been used as the primary reference scenario** to calibrate the model. The alternative SSP scenarios are currently used to do sensitivity testing to assess potential effects of different socioeconomic trends.



SOURCE: based on O'Neill et al. (2014, Figure1)
Note: SSP= Shared Socioeconomic Pathway

FIGURE 3. Five SSPs with defining characteristics and relative relationships. Source: Robinson (2015).

RCPs: RCPs describe alternative future climates depending on the levels of GHG emissions that may be observed in the 21st century. There are four RCPs, which are named according to the approximate level of radiative forcing in 2100, which ranges from 2.6 watts per square meter (W/m^2) to 8.5 W/m2. The RCP 2.6 scenario is similar to a baseline showing the effects of no further climate change and provides a useful counterfactual to isolate the effects of climate change from other assumptions, while the RCP 4.5 and 8.5 scenarios are more closely related to our current trajectory with some mitigation or little mitigation. Table 5 provides temperature and sea-level rise levels for two-time horizons under different RCP scenarios.

TABLE 5. Likely temperature and sea-level change under RCPs. Source: Robinson (2015)

RCP	MID-CENTURY[a]		END OF THE CENTURY[b]	
	TEMPERATURE INCREASE	SEA-LEVEL RISE	TEMPERATURE INCREASE	SEA-LEVEL RISE
2.6	+0.4–1.6	+0.17–0.32	+0.3–1.7	+0.26–0.55
4.5	+0.9–2.0	+0.19–0.33	+1.1–2.6	+0.32–0.63
6.0	+0.8–1.8	+0.18–0.32	+2.2–3.1	+0.33–0.63
8.5	+1.4–2.6	+0.22–0.38	+2.6–4.8	+0.45–0.82

SOURCE: International Panel on Climate Change (2013).
Note: The no climate change scenario assumes no change in temperature or sea levels. Temperature in degrees Celsius and sea-level rise in meters. RCP = Representative Concentration Pathway. [a]Mid-century represents the 20 years from 2046 to 2065. [b]End of century represents the 20 years from 2081 to 2100.

Based on these assumptions, the IMPACT model simulated the global agricultural market for the selected time horizons: 2030 and 2050. The model showed a wide range of parameters nationally, including food price, area and yield, demand, and food security indicators among others. Food security is modeled in terms of kcal/capita available from each commodity as well as the population at risk of hunger and the number of undernourished children. In addition, import and export trends can be included in the analysis to offer insight into future food security concerns that are affected by trade. The study focused on key food commodities, including rice, maize/corn, vegetables, pork, poultry, beef, and some additional staples and vegetables for context. In doing the analysis, the parameters included were production area, yield, demand, diet, number of malnourished children, and import dependence.

3. Presentation of the main findings

3.1. Threats of climate change to aspects of food security and nutrition

3.1.1. IMPACTS OF CLIMATE CHANGE ON WATER

CONTEXT

The Philippines is endowed with immense natural resources, not least of all its abundant water resources. In total, the Philippines is home to 119 watersheds, 412 principal river basins, and more than 100 inland lakes, swamps, and marshes. The island nation is surrounded by oceans and seas that catalyze the rain events that supply these freshwater bodies, including replenishing groundwater reservoirs. Despite this natural abundance, the country has long experienced clean water supply shortages, which are becoming more acute due to anthropogenic activity and the effects of climate change (Greenpeace, 2009).

The freshwater demand of the Philippines totals approximately 30.65 billion cubic meters (bcm), which is currently met by the supply of groundwater and surface water, constituting approximately 20.20 bcm and 125.80 bcm, respectively. Surface water from lakes, artificial reservoirs, rivers, and streams accounts for 98.1% of the total water extracted, while the remaining 1.9% is extracted from groundwater reservoirs (PSA, 2016). The Philippines currently uses approximately 21% of its total water resource potential, although nearly one-quarter of the country's municipalities (332 of 1,488 total) do not have access to piped water (Tecson-Mendoza, 2004). In addition to surface-water sources, groundwater accounts for approximately 15% of the total water resource potential of the Philippines. The regions with the most abundant groundwater potential compared with surface-water potential are Regions I and VII, in contrast to Region X, which has the lowest potential groundwater reserves (State of Water: Philippines, n.d.). Potential groundwater reserves are particularly important for domestic consumption, considering that 86% of the piped water originates from groundwater sources, and half of the population depends on groundwater as its principal source of drinking water.

The simultaneous growth of the population and the economy has generated additional freshwater demand distributed across the agricultural (74% of total demand), domestic (17%), and industrial (9%) sectors. This has directly contributed to the precipitous decline in the per capita renewable water resources in the Philippines in the past half century. From 1962 to 2017, the total annual internal renewable water resources per capita decreased by nearly 75%, from 17,060 bcm to just 4,554 bcm (AQUASTAT, n.d.).

Unfortunately, overextraction caused by indiscriminate unregulated withdrawal is systematically depleting groundwater supplies. In the past decade, water abstraction increased by 12.3%, from 194.1 bcm in 2010 to 218.0 bcm in 2019. An estimated 60% of groundwater extractions are made without the required regulatory permits, thus undermining monitoring and public allotment efforts. In addition to complicating the management of a precious shared resource, overextraction can have long-term effects on the ability of groundwater systems to recharge. Although current estimates are elusive, a decade-old study by the Philippine Statistics Authority connected a 5.3% annual increase in groundwater withdrawal nationwide from 4.3 bcm in 1988 to 5.8 bcm in 1994 to a 3.7% annual decline in groundwater recharge from 1.9 bcm in 1988 to 1.5 bcm in 1994 (PSA, 2016). Considering the significant increase in groundwater demand since the time of the study, there is reason to believe that recharge levels may already be significantly lower.

This decline in terms of the quantity of renewable water resources is coupled with the continuous decline in water quality brought about by the growing population, urbanization, and industrial development. A recent report by the DENR titled "Progress of Water Environment Governance in the Philippines" highlights several indicators of freshwater quality (Tuddao, 2019). For example, at present, nearly half of the Philippines' major rivers (180 of 421 in total) are classified as relatively polluted or degraded (Tuddao, 2019). In addition, an estimated 7,465 million cubic meters of wastewater are produced annually by the municipal and agricultural

sectors, and an undisclosed amount is generated by other sectors such as industry and energy (Tuddao, 2019). Approximately 10% of this total wastewater volume is treated, whereas the rest contributes to runoff and seepage that can contaminate groundwater, surface water, and marine water. Perhaps unsurprisingly then, 18 of the 19 bathing beaches in Manila Bay exhibited fecal coliform counts below the sanitary threshold (200 MPN/100 mL) (Tuddao, 2019).

The scarcity and contamination of water resources directly affect food production by the agricultural and fisheries sectors, with potential consequences for nutrition and health. The Philippine food systems that are intensively farmed with synthetic fertilizers and pesticides often introduce nitrates and chemical contaminants into the water systems through runoff and leaching (Bouman et al., 2002; Tirado, 2007). Studies in intensive agricultural areas in the Philippines found elevated levels of nitrates in groundwater, exposing farming communities that consume well water to both acute and long-term health effects (Greer et al., 2005). At the same time, runoff and leaching of contaminated soil and surfaces can contaminate domestic water sources in urban and peri-urban areas, such as Metro Cebu (Galarpe, 2012). Moreover, toxins present in contaminated groundwater, such as arsenic, can accumulate through the food chain, potentially compromising meat and dairy (Rahman, 2009). For freshwater and marine fisheries, nitrogen pollution from runoff causes eutrophication that can result in the death of fish and invertebrates and the creation of toxic and overabundant algae blooms (Tirado, 2007). These studies and other anecdotal evidence help to illustrate the existing challenges to the Philippines' water resources, many of which are compounded or exacerbated by climate change.

CURRENT IMPACT OF CLIMATE CHANGE ON WATER RESOURCES AND SYSTEMS

The Philippines' precious water resources are vulnerable to climate-related hazards such as floods, droughts, and tropical cyclones. Along with other effects of climate change in the Philippines, these climate-related hazards are expected to increase in frequency and severity as a result of climate change. In the past decade alone, climate hazards have manifested themselves as the increased occurrence and variability of heavy rainfall, resulting in floods and landslides; drought and drought-like conditions, including high temperatures and low rainfall that have contributed to agricultural losses, freshwater shortages, and forest fires; and major typhoons that have brought unprecedented ruin to several parts of the country (see Table 6), particularly in the Visayas and Mindanao regions.

For example, in November 2020, back-to-back typhoons Goni and Vamco devastated eight regions across the Philippines. These events resulted in 98 deaths, the destruction of more than 97,000 homes, and the displacement of 155,000 households. Damage to critical infrastructure and the agricultural sector was especially dramatic in Catanduanes and Albay provinces, while in Cagayan Province landslides and deep floods submerged 336 *barangays* (Gutierrez, 2020; ReliefWeb, 2021). The increased incidence and severity of extreme weather events such as these in the country are indicative of the broader global pattern of climate variability and hazards over the past two decades (Seneviratne et al., 2012). Table 6 depicts the major climate-related events that severely affected people's livelihoods, the environment, and the economy in the Philippines in the past decade.

TABLE 6. Extreme weather events in the Philippines, 1990 to present.

EXTREME WEATHER EVENT	YEARS	LOCATION	CASUALTIES	COST OF DAMAGE (PHP)	REMARKS
Drought	1997 - 1998	Nationwide	-	8.46 billion	Most intense drought recorded in history caused primarily by El Niño phenomenon
Prolonged rainfall	2006	Southern Leyte	1,221	200 million	Rainfall-induced landslide buried an entire village in Guinsaugon, Saint Bernard, southern Leyte
Flooding	2009	Northern Luzon	465	27.30 billion	Typhoon Pepeng
Flooding	2009	Metro Manila, southern Luzon	464	11 billion	Typhoon Ondoy
Flooding	2011	Cagayan De Oro	1,268	2.07 billion	Typhoon Sendong
Flooding	2012	Mindanao	1,067	36.95 billion	Typhoon Pablo
Storm surge	2013	Central Visayas	6,300	89 billion	Super Typhoon Yolanda
Super Typhoon	2020	Bicol	31	17.9 billion	Typhoon Goni
Super Typhoon	2020	Luzon, Cagayan	111	20.3 billion	Typhoon Vamco

SOURCE: Climate Change and the Philippines: Executive Brief, 2018.

One of the most significant impacts of climate change in the Philippines has been the increased variability in rainfall. Several longitudinal studies have identified significant changes in rainfall patterns across the nation from the 1950s to 1990s. The studies reveal evidence of increased frequency and intensity of rainfall events, resulting in higher rainfall volumes in more recent decades (Thomas et al., 2012; Pajuelas, 2000 as cited in Cruz et al., 2017). Increased temporal variability coincides with geospatial variability across climatic zones: rainfall trends have increased in western Luzon along with a decrease in eastern Luzon, Visayas, and Mindanao. Other studies have identified greater seasonal variability, such as an increasingly prolonged dry period and decreased rainfall events during the southwest monsoon season, particularly in western Luzon, from 1961 to 2010 (Cruz et al., 2013).

Future projections indicate that seasonal rainfall volumes will exceed historical averages by approximately 40% across the Philippines, with decreases over central sections of Mindanao (CCC, n.d.). Likewise, from 1993 to 2015, the sea level has risen at nearly double the global average in some parts of the Philippines and is expected to increase by another 20 cm by the end of the century (CCC, n.d.). Higher sea levels will likely intensify storm surge impacts on coastal communities and may further intensify storms nationwide. In addition to flooding, the more intense and sporadic rainfall creates surface runoff and standing water that are linked to agricultural losses, infrastructure damage, and health and safety risks (PAGASA, 2021). Water-related climate hazards such as flooding, typhoons, and droughts affect nearly every stage of the hydrologic cycle, and hence, directly and indirectly, shape agriculture and food security (European Environment Agency, 2020). Beyond the immediate devastation to productivity and supply chain infrastructure, the far-reaching impacts of water-related hazards on the agricultural sector include waterlogging and standing water; soil runoff, infiltration, percolation, and leaching; and the amount and quality of groundwater recharge.

Groundwater storage is likewise projected to be negatively affected by climate change in the Philippines. Recent research indicates that the impact of climate change on global groundwater storage does not necessarily reflect long-term trends in precipitation, but rather is indicative of a confluence of factors, including enhanced evapotranspiration and decreased snowmelt. The amalgamation of these various climate-induced changes can lead to divergent groundwater storage scenarios in different aquifers (Wu, 2020). In the Philippines, research suggests that groundwater recharge is affected by rising temperatures that increase evaporation over land and thus decrease the amount of water available to replenish groundwater (Jose and Cruz, 1999).

Relatedly, a prolonged dry season and decreased rainfall are known to affect the water supply within watersheds and dams. A 1996 assessment of the effect of long-term temperature and rainfall trends on hydrologic parameters in major multipurpose dams in Luzon and Mindanao suggests that increasing annual temperatures are associated with decreasing water inflows into dams (Jose et al., 1996). These water infrastructures fulfill the major water requirements for farm irrigation, energy production, and domestic and industrial operations.

MODELING: PROJECTED IMPACT OF CLIMATE CHANGE ON WATER AND FOOD SECURITY

Results of flood risk and livelihood mapping corroborate the findings from the prevailing literature on the projected impacts of climate change on precipitation in the Philippines. To illustrate the impact of flooding on livelihoods, an overlay analysis of flood susceptibility mapping and livelihoods mapping was conducted. The Flood Susceptibility Index (FSI) was derived by computing the aggregated areas within the municipality with medium to very high flood risk over the total land area per municipality. The FSI map was created using the existing flood map of the Philippines and NAMRIA's municipal administrative map. The resultant index is useful for approximating the extent of land area affected by flooding per city or municipality, although it does not indicate specific flooding locations within a given city or municipality. As a measure of the geographic extent of flooding per city or municipality, the FSI value of 0 indicates no flooding, while the value of 1 indicates total submergence of the geographic unit in the event of flooding.

The FSI makes it apparent that flooding is a burgeoning problem that will likely increase in frequency and severity in many parts of the Philippines from 2020 to 2050. This increased susceptibility to floods will strongly affect agricultural livelihoods, particularly farming and fishing, which will have knock-on effects on the national food supply. Figure 4 depicts how the areas across the three island groups of Luzon, Visayas, and Mindanao that are largely devoted to agricultural production are the same areas that are expected to experience significant climatic variability and a heightened susceptibility to flooding.

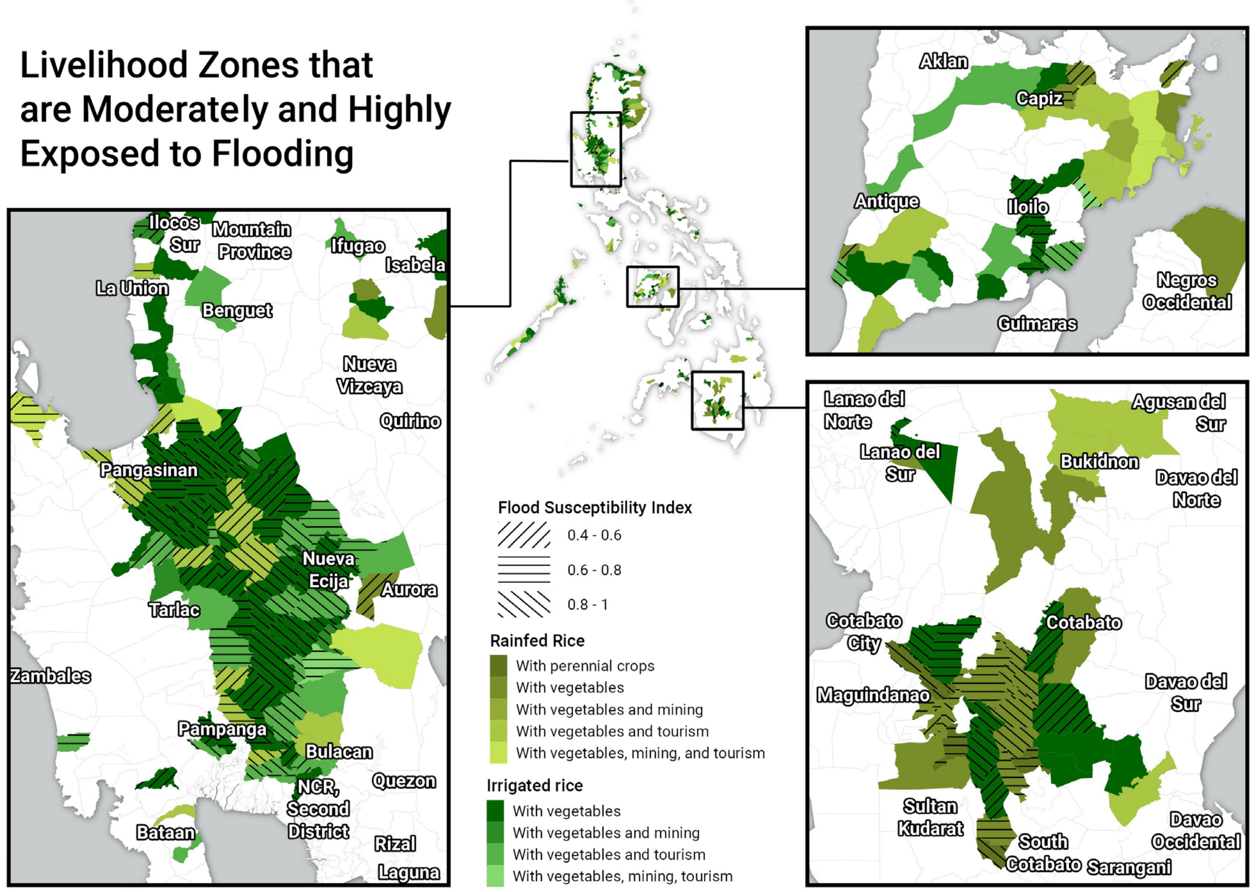


FIGURE 4. Livelihood zones that are moderately and highly exposed to flood.

Significantly, rice and vegetable production areas across the country are expected to be among the hardest hit by climate-related changes. In the north, both the irrigated and rainfed rice and vegetable systems in Pangasinan and Nueva Ecija provinces have extremely high FSI ratings (0.8-1.0). Likewise, those livelihoods areas plus the mixed fishery and perennial crop farming (coconut, banana, mango) livelihood zones in Pampanga and Bulacan are highly susceptible (0.8-1.0 FSI rating). In the south, parts of Maguindanao, Cotabato, Sultan Kudarat, and South Cotabato provinces are expected to be highly susceptible to flooding, rating from 0.8 to 1.0 on the FSI. In those areas, the livelihood zones dominated by irrigated and rainfed rice and vegetable production as well as those areas producing perennial commodity crops such as coconut, mango, and banana are among the most vulnerable.

In addition to being affected by flooding, several food systems that are critical for food security in the Philippines are expected to be impacted by the duration and temporality of the wet seasons. Key staples such as rice and maize as well as many types of vegetables are affected by either a shortened or prolonged rainy season. Accordingly, the key livelihood zones that are greatly affected by changes in rainfall pattern (Figure 5) such as prolonged rainfall include built-up urban areas and areas with vegetables and mixed perennial farming. In Luzon, selected municipalities under the urban zones will be affected by prolonged rainfall, including Divilacan in Isabela Province and Pasil, Lubuagan, and Tabuk City in Kalinga Province. At-risk areas under irrigated rice mixed with vegetables are Cordon and Echague in Isabela Province and Santa Ana, Santa Teresita, Santa Praxedes, Claveria, Sanchez-Mira, and Pamplona in Cagayan Province. At-risk areas under vegetable farming mixed with pasture and livestock include Bagabag, Nueva Vizcaya, and Lacob, Abra, while areas under perennial crops mixed with urban, mining, and tourism include Dumalneg, Adams, and Vintar in Ilocos Norte Province. In the Visayas, areas under irrigated rice mixed with vegetables that are affected by prolonged rainfall are found in the municipalities of Dagohoy, Pilar, and Ubay in Bohol Province.

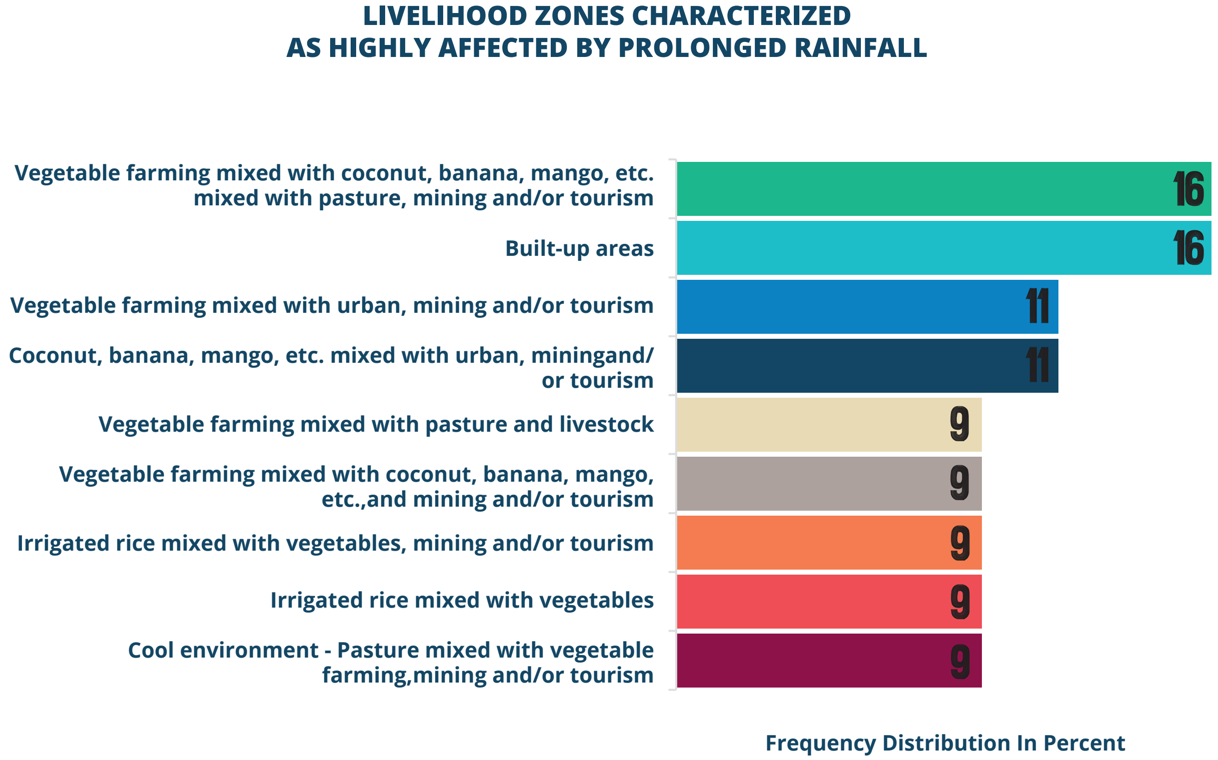


FIGURE 5. Livelihood zones that are mostly affected by prolonged rainfall, based on findings from the TWG survey.

On the other hand, several areas and livelihood zones will be impacted by shortened rainy seasons as a result of climate change (Figure 6). The livelihood zones that are greatly affected by changes in rainfall pattern such as shortened rainfall are vegetables with perennial crops (21%) under the annual crops zone and irrigated rice mixed with vegetables (21%). Among the provinces expected to be most affected are: Luzon Province, including Ilocos Norte, Ilocos Sur, La Union, Pangasinan, Tarlac, Nueva Ecija, Pampanga, and Isabela that are all dominated by irrigated rice mixed with vegetables or annual crops. In the Visayas provinces, Negros Occidental and Negros Oriental are dominated by vegetables with perennial crops, and the Mindanao provinces of Maguindanao, Cotabato, and Sultan Kudarat are dominated by irrigated rice mixed with vegetables or annual crops.

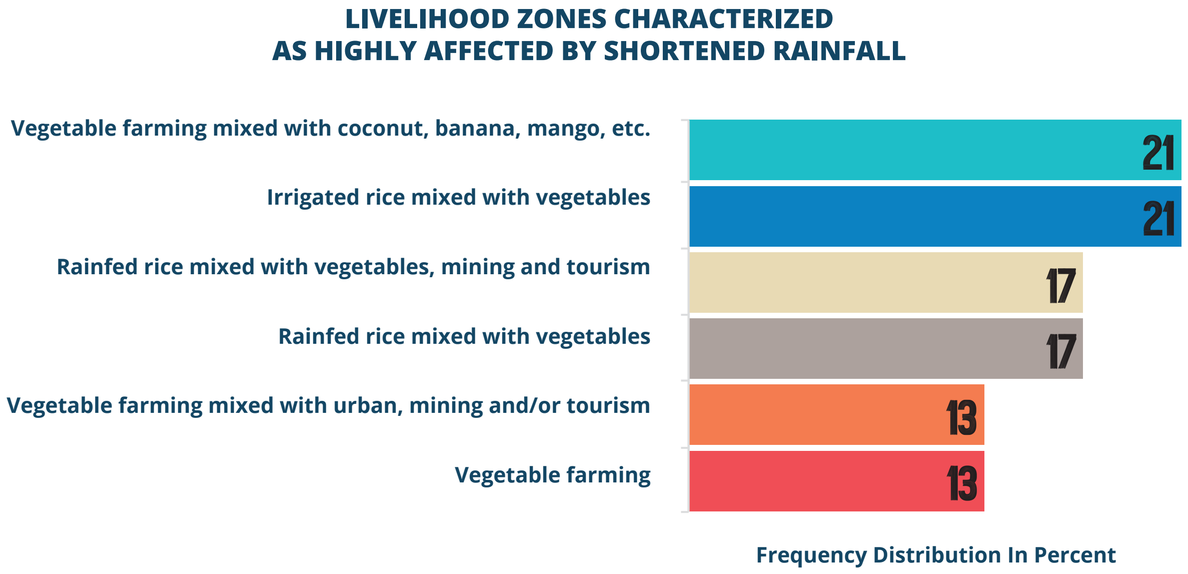


FIGURE 6. Livelihood zones mostly affected by shortened rainfall.

The Philippines is also highly susceptible to climatic hazards that affect fisheries and other ocean-based food systems as well as inland freshwater aquaculture. In general, sea-level rise (SLR), storm surges (SS), and saltwater intrusion (SWI) are among the most significant sea-related hazards that affect the Philippines. A combination of climatic factors and anthropogenic activities plays an important role in the degree of exposure to sea-based hazards such as SLR, SS, and SWI. Coastal fisheries are mostly affected by sea-level rises and storm surges, while freshwater fisheries are likely to be affected by saltwater intrusion.

Human-induced changes, particularly in modifying coastlines in order to create livelihoods for coastal communities and concentrate human-made structures for low-lying areas, make these zones more vulnerable to climate change. Although the Philippines is generally considered to have a low susceptibility to these sea-based hazards based on its location, the risks are magnified by the population and characteristics of the majority of municipalities located along the coasts and low-lying areas.

In terms of accessibility, areas that are prone to sea-based hazards are generally more remote and less accessible and are therefore more vulnerable to disasters and less capable of coping (Figure 7). Comparing the hazard risk map to the poverty incidence map, Visayas and Mindanao have more poor people located in coastal areas. In Luzon, Catanduanes, Camarines Norte, and Sorsogon under perennial crops and vegetable farming are at risk. In Visayas, this includes the whole island of Samar and a large portion of the island of Leyte, where the majority of the livelihoods also depend on perennial crops and vegetable farming and aquaculture and marine ecosystems. In Mindanao, the provinces of Davao Occidental, Sarangani, South Cotabato, Sultan Kudarat, Maguindanao, and Zamboanga del Norte are the areas that are less accessible and have high poverty incidence. These areas that are high in poverty and have a high risk of sea-based hazards are also areas that are prone to flooding due to high tides and storms. These areas are generally under perennial crops and vegetable farming, except for Zamboanga del Norte that is dominated by pasture areas.

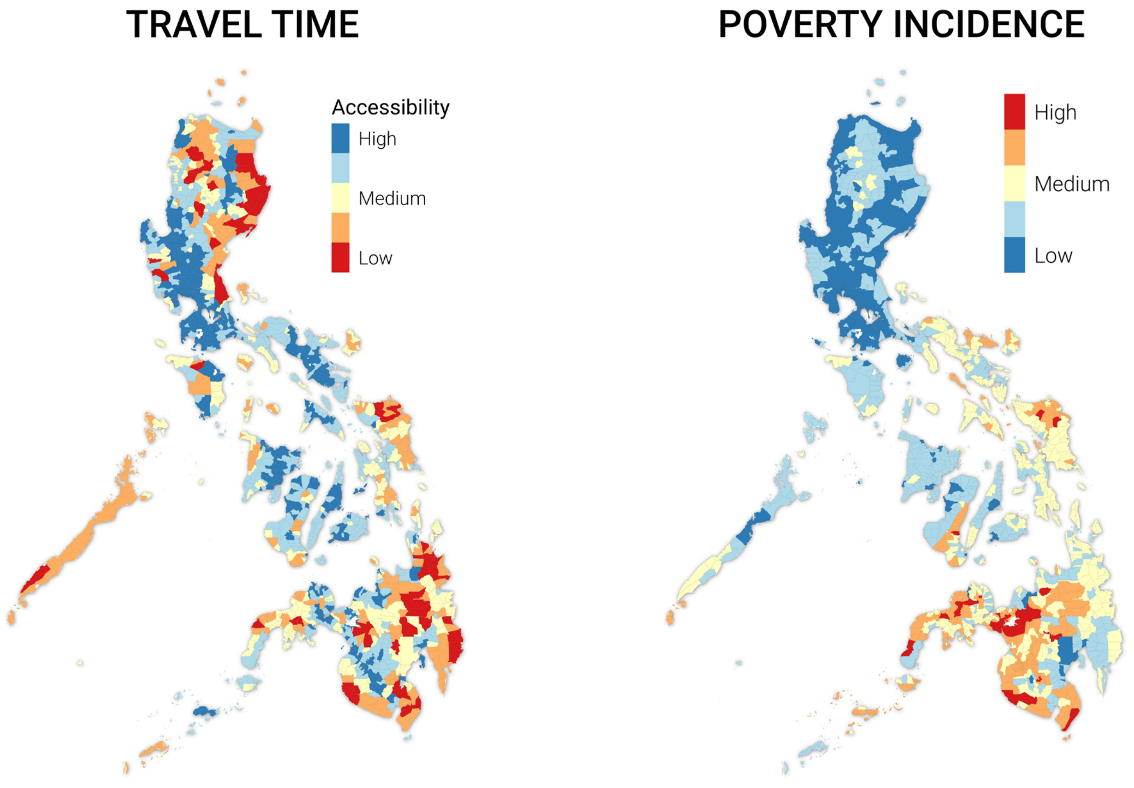


FIGURE 7. Maps comparing incidence of poverty and accessibility based on estimated travel time index.

ADDRESSING THE IMPLICATIONS

As outlined above, the impact of climate change on precipitation has direct and multifaceted effects on the value chains identified by the FSI as being the most vulnerable. For both irrigated and rainfed rice, increased precipitation and flooding can impede productivity, facilitate the establishment and spread of virulent pathogens, and debilitate infrastructure that is necessary for processing or distribution, such as rice processing and storage facilities, among other impacts. As discussed in the literature, the projected increased incidence and severity of flooding in rice- and vegetable-producing areas increases the risk for groundwater contamination from the leaching of nitrates and chemicals (Rahman, 2009). This in turn could increase the risk of toxicity of rice and vegetables consumed by humans as well as fodder consumed by livestock (Rahman, 2009). The impacts on commodity crops and vegetables are similar, with particular challenges arising from perishability during the postharvest processing and transportation phases.

Again, the impact on coastal fisheries and aquaculture value chains can be extremely detrimental. Compounding the impact of incremental sea-level rise caused by global warming, excessive rain and monsoon events can damage infrastructure and pollute fishery ecosystems. The mapping exercise also predicts significant vulnerability to flooding in certain urban areas, especially Cotabato City (0.6-0.8 FSI rating). In general, the disaggregated infrastructure of domestic supply chains in the Philippines complicates the distribution of fresh food; however, in post-disaster times, this is especially pronounced as few mechanisms are in place to distribute food across and within regions (WFP, 2018). Furthermore, storage capacity in local areas of production contributes strongly to postharvest losses when distribution is slowed post-disaster (WFP, 2018). All of these issues compound the risks of water-related hazards to food and nutrition security in the Philippines.

3.1.2. IMPACT OF CLIMATE CHANGE ON CROP PRODUCTIVITY

CONTEXT

Climate change can generate a variety of impacts on food production, including creating temperature and moisture levels that are more suitable for certain crops or crop varieties. However, a review of the existing literature on the impacts of climate change and related hazards on the production of staple crops, livestock, and fisheries in the Philippines suggests that, overall, climate change will negatively affect production. In addition to compromising growing conditions, climate-related hazards often generate market disruptions that impede access to required inputs or prohibit effective postharvest processing or storage. Several studies have investigated the historically negative connection between an increased incidence and intensity of climate-related hazards, namely, typhoons, increased precipitation (rainfall and/or flooding), and increased temperature (drought), and the production of key dietary and commodity crops, in particular rice and corn, in the Philippines. For example, the rice sector incurred losses equivalent to an estimated 3.3% of the total rice production volume as a result of the typhoons, floods, and droughts experienced from 1991 to 2000 (World Bank, 2003). For the following decade (2000 to 2010), one study placed the total value of agricultural damage to crops, fisheries, and livestock due to typhoons, floods, and droughts in the Philippines at approximately US$219 billion (Israel and Briones, 2012). This included estimated annual yield losses of up to 5.9% for corn, 4.2% for rice, and 3% for high-value cash crops (Israel and Briones, 2012).

Studies on the impact of climate change on future grain production suggest an overall negative effect for both corn and rice production. One study finds a consistent decrease in yield and production volume for corn, with both increases and decreases for rice production and yield, which the study attributes to a shorter maturity period, faster evapotranspiration, and waterlogging (Buan et al., 1996). A complementary study analyzing the current and projected future suitability of corn production throughout the Philippines finds that increasing rainfall patterns will compromise production suitability for 8 of the 12 months of the year: in April, as much as 17% of the current growing regions (from the north to the southwest) will be considered moderately to entirely unsuitable for corn production (Salvacion, 2017). Likewise, the study found that increasing temperatures will diminish production suitability for 10 months of the year, with the most significant decreases experienced from April to July (approximately 15%).

Focusing on typhoons, Israel and Briones (2012) find that typhoons, as exemplified by Ondoy and Pepeng in 2009, have a significant negative impact on food production and household food security in directly affected areas. Using the 2009 typhoons as a framing event, a World Food Programme (2010) report considers post-climate disaster food security in terms of food production and distribution. The report highlights production challenges, including a decrease in harvestable land and percentage of planted land that was harvested (approximately 63% of households surveyed), destruction of fish pens and ponds, disrupted food storage, and a loss of productive and livelihood assets, among other challenges. The report also found that the greatest impacts on food production was experienced by populations that were already highly asset poor prior to the event, namely, staple crop farmers (WFP, 2010). Beyond land preparation and cultivation, the postharvest storage and processing phases of crop production are affected by climate-related hazards. The lack of crop storage capacity in local areas of production contributes markedly to postharvest losses when distribution is slowed or aggregation points are inaccessible post-disaster (WFP, 2018).

MODELING AND FINDINGS

In order to assess the likely impacts of climate change on the production and productivity of key crops in the Philippines, both crop suitability modeling to understand the geospatial components of crop production and expert surveys were used to contextualize that analysis through the lens of livelihood zones. Based on findings from the TWG's Livelihood Zones Survey, several key crops were identified, ranked by their economic importance as a key source of income and livelihood as well as their importance to the diet as a staple and for their contribution to nutrition and dietary diversity. Aside from the nation's most important staple - rice - the key crops include corn, cassava, lowland vegetables, and banana. Moreover, these crops had excellent accessibility as they were considered nearly always or always available in the market.

Using these prioritized crops, models were developed using RCPs, which represent potential greenhouse gas emission levels in the atmosphere and the subsequent increase in solar energy that would be absorbed (radiative forcing), at RCP 4.5 and 8.5 thresholds for the years 2030 and 2050. Maps of key crop production livelihood zones were generated for the selected future scenarios to indicate how crop suitability will likely be affected by climate change.

For rice production, the models largely align with the literature in that future climate scenarios may actually provide environments that are more conducive to rice production throughout the country, particularly in Luzon and except for inland pockets in Mindanao (Figure 8). This trend is due to some key climate-related hazards, particularly extreme rainfall events and droughts experienced by Mindanao's agricultural sector. Rainfall from 2001 to 2010 shows a positive deviation of 8 mm per month, which could result in an approximately 35% increase in the frequency of extreme rainfall events, adding one every three years (Thomas et al., 2012). On the other hand, Mindanao is identified as a drought-prone region in the country that recently experienced a high severity of drought in the 2015 - 2016 El Niño event, which affected an estimate of 224,834 ha of agricultural land (IFRC, 2016).

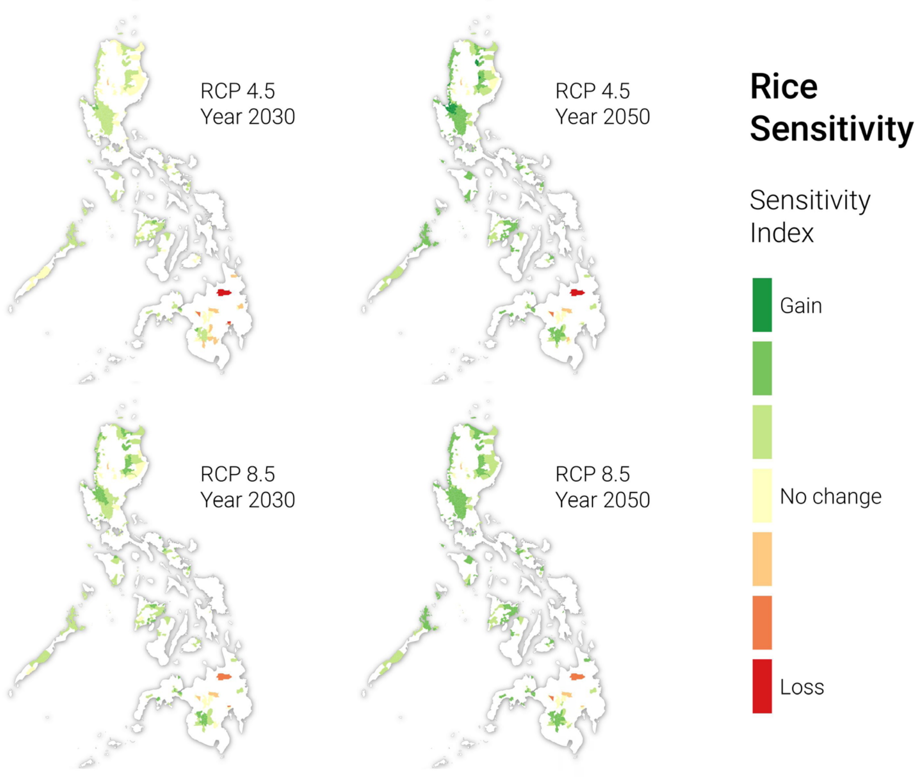


FIGURE 8. Future crop suitability models for rice under RCP 4.5 and 8.5 for years 2030 and 2050.

The same exercise for maize returns results that likewise align with the literature: the impacts on maize suitability are less dramatic and more variable, with some areas seemingly more suitable and other areas less so, with more pronounced division in the longer term (Figure 9).

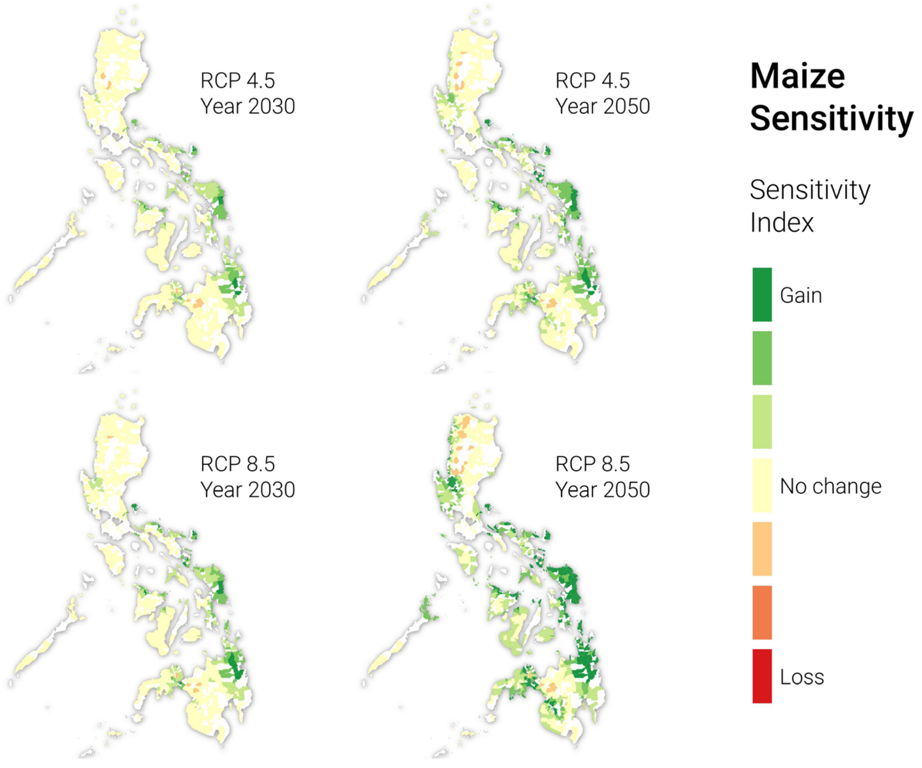


FIGURE 9. Future crop suitability models for maize under RCP 4.5 and 8.5 for years 2030 and 2050.

For banana, suitability is quite regionally determined, with enhanced conditions in southern Luzon and Visayas and poorer conditions in northern Luzon (Figure 10). For some of the most important vegetable production livelihood zones in the Philippines, the models depict very different future crop suitability scenarios. For garlic, there is very little change from the current production suitability (Figure 11). However, the future climatic conditions across both scenarios and timeframes show overwhelmingly positive changes for onion production and overwhelmingly negative changes in suitability for eggplant (Figures 12 and 13).

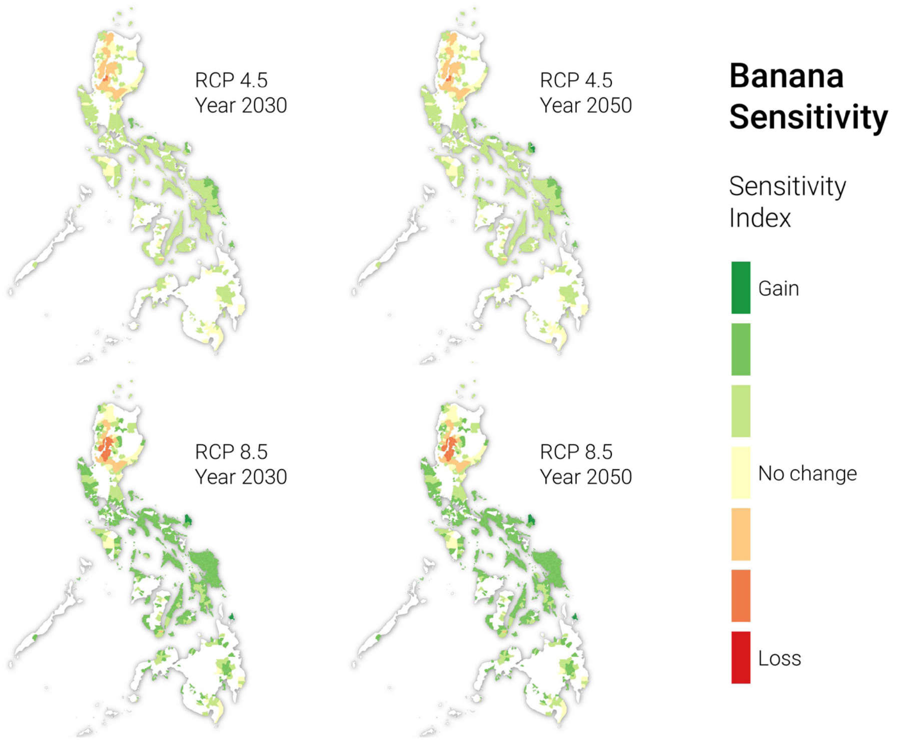


FIGURE10. Future crop suitability models for banana under RCP 4.5 and 8.5 for years 2030 and 2050.

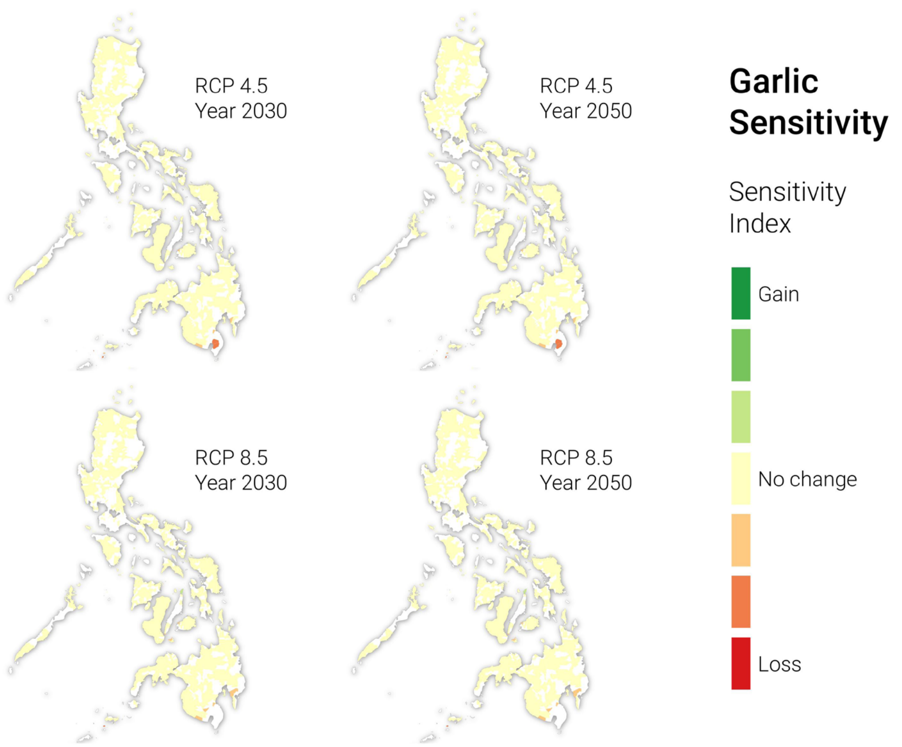


FIGURE11. Future crop suitability models for garlic under RCP 4.5 and 8.5 for years 2030 and 2050.

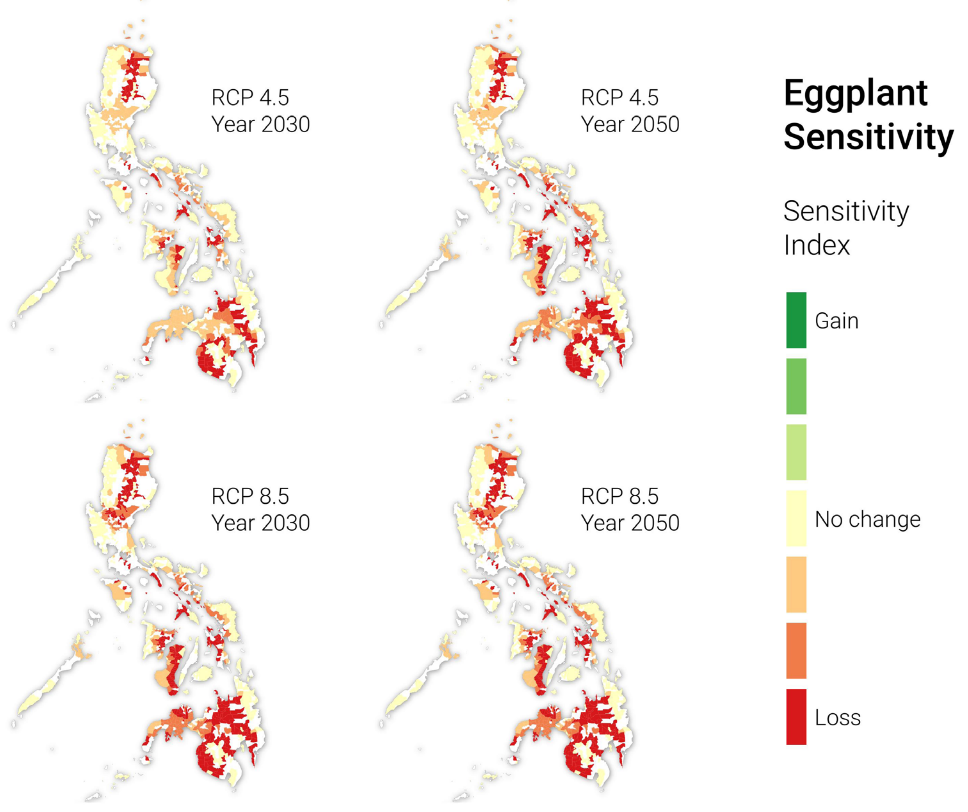


FIGURE 12. Future crop suitability models for eggplant under RCP 4.5 and 8.5 for years 2030 and 2050.

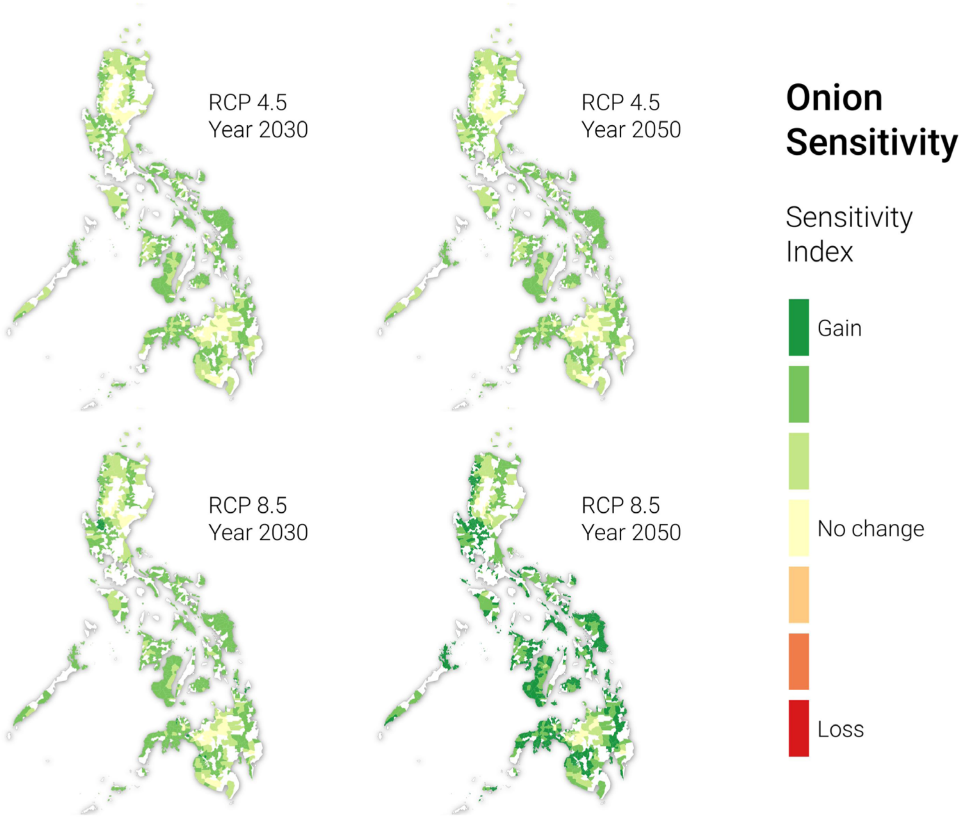


FIGURE 13. Future crop suitability models for onion under RCP 4.5 and 8.5 for years 2030 and 2050.

Using data generated by the TWG's Livelihood Zones Survey, which asked experts to identify the climatic changes that were experienced by different livelihood sub-zones, one can see if and to what extent the changes projected by the future suitability models are being experienced currently in different livelihood zones. It is found that one of the most significant impacts on staple crop production at present is rainfall variability, including rainy seasons that are either longer or shorter than the historical average. An extended rainfall season is considered to have an impact across all nine livelihood zones, but especially in the rural vegetable farming livelihood zone, where vegetables and perennial crops (coconut, banana, and mango) in conjunction with mining and tourism provide the basis of the household economy.

Interestingly, the vegetable and commodity fruit livelihood zones are also among the most susceptible to a shortened rainfall season. Six of the livelihood zones were particularly affected by shortened rainfall, namely, rainfed rice and vegetable systems, with different sub-zonal configurations. For Luzon, these livelihood zones are mostly found on the eastern side consisting of Cagayan and Isabela; on the western side consisting of Ilocos Norte, Ilocos Sur, and La Union; and in the central portion consisting of Pangasinan, Tarlac, Nueva Ecija, and Palawan Island. For Visayas, these zones are located on the eastern seaboard of Eastern Samar, some coastal municipalities of Leyte and Cebu, Bohol, Antique, Aklan, Capiz, and Iloilo, and almost the whole island of Negros. For Mindanao, almost all are distributed in the western region. Again, the results of the survey corroborate the findings from the crop suitability models: variable rainfall is likely to provide more favorable conditions for some crops while disadvantaging others.

3.1.3. IMPACTS OF CLIMATE CHANGE ON CROP PESTS AND DISEASES

CONTEXT

Changing climatic conditions, including temperature, rainfall, extreme weather events, and increasing atmospheric carbon dioxide levels, can result in an increased incidence and severity of outbreaks of crop pathogens (Porter et al., 2014). By creating optimal conditions for the reproduction of pests and diseases, climate change is likely to affect the existing temporal and geographic distribution of plant pathogens globally, with specific ramifications in the Philippines. The expected impacts include the emergence of diseases in new regions, variations in host physiology that change the host-pathogen relationship, and increased disease resistance (Ghini et al., 2008; Ho Won Chung et al., 2009). Climate change might also affect pathogen population dynamics such as the overwintering, survival, and number of generations of polycyclic pathogens (Juroszek and von Tiedemann, 2013). This environmental variability might also influence gene flow, thus increasing the diversity of pathogen populations and thereby causing changes in host resistance, pathogen virulence, and host-pathogen interaction (Cairns et al., 2012). Finally, climate change will likely also render existing plant disease control measures less effective or ineffective (Chakraborty et al., 2000; Ghini et al., 2008).

For all of these reasons, climate change is likely to induce the outbreak of disease in many crops that are considered dietary and livelihood staples in the tropics, including in the Philippines (Boonekamp, 2012). Although changing rainfall patterns, hotter and more humid conditions, and more regular monsoon and flood events have far-reaching implications for most crops in the Philippines, this study will focus on the impact of climate change on pests and diseases for three key value chains: rice, maize, and banana. These three value chains are among the most important in the Philippines from both a dietary and economic perspective as they are widely consumed and their production is a key source of income for farmers and agricultural laborers.

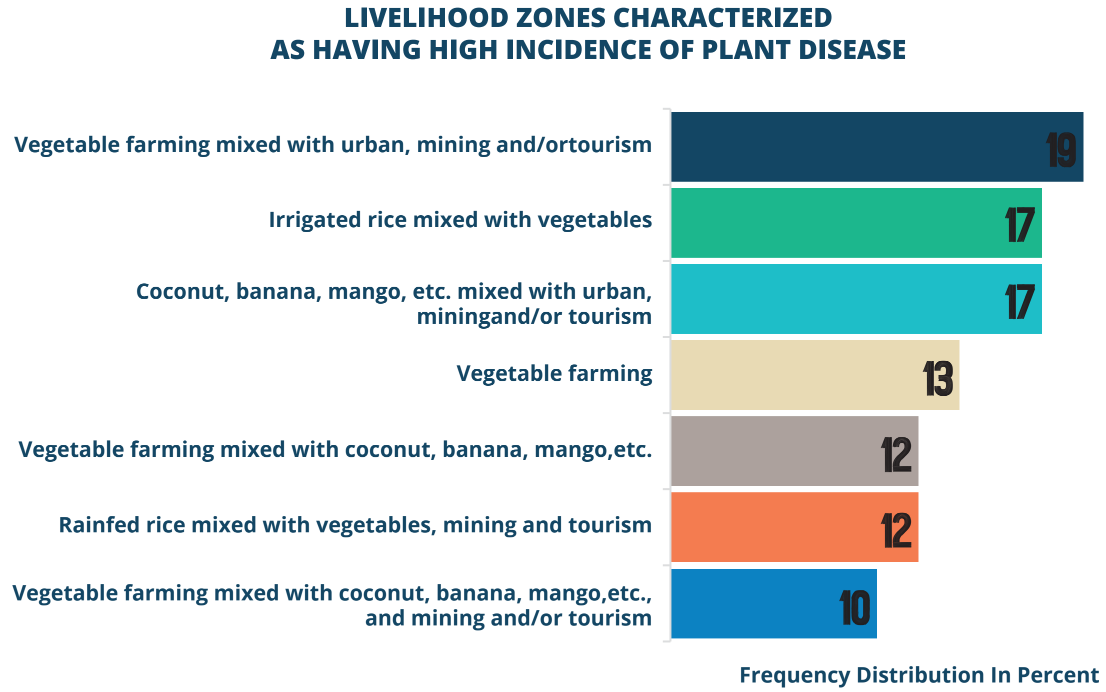


FIGURE 14. This graph indicates the livelihood sub-zones that are reported to have the highest incidence of plant pests and diseases at present according to the Livelihood Zones Survey.

Findings from the Technical Working Group (TWG) Livelihood Zones Survey suggest that, at present, climate change is already having an impact on the occurrence and severity of pests and diseases for key crops in some of the major livelihood categories nationwide. The livelihood zones and sub-zones that are attributed to have the highest incidence of pests and diseases at present are vegetable farming (mixed with urban, mining, and tourism zones), perennial commodity crops (coconut, banana, and mango mixed with urban, mining, and tourism zones) and irrigated rice mixed with vegetables (Figure 14). As indicated in Figure 15, this would suggest that grains, fruits, and staple crops are all already exposed to the occurrence of harmful pests and diseases across the country.

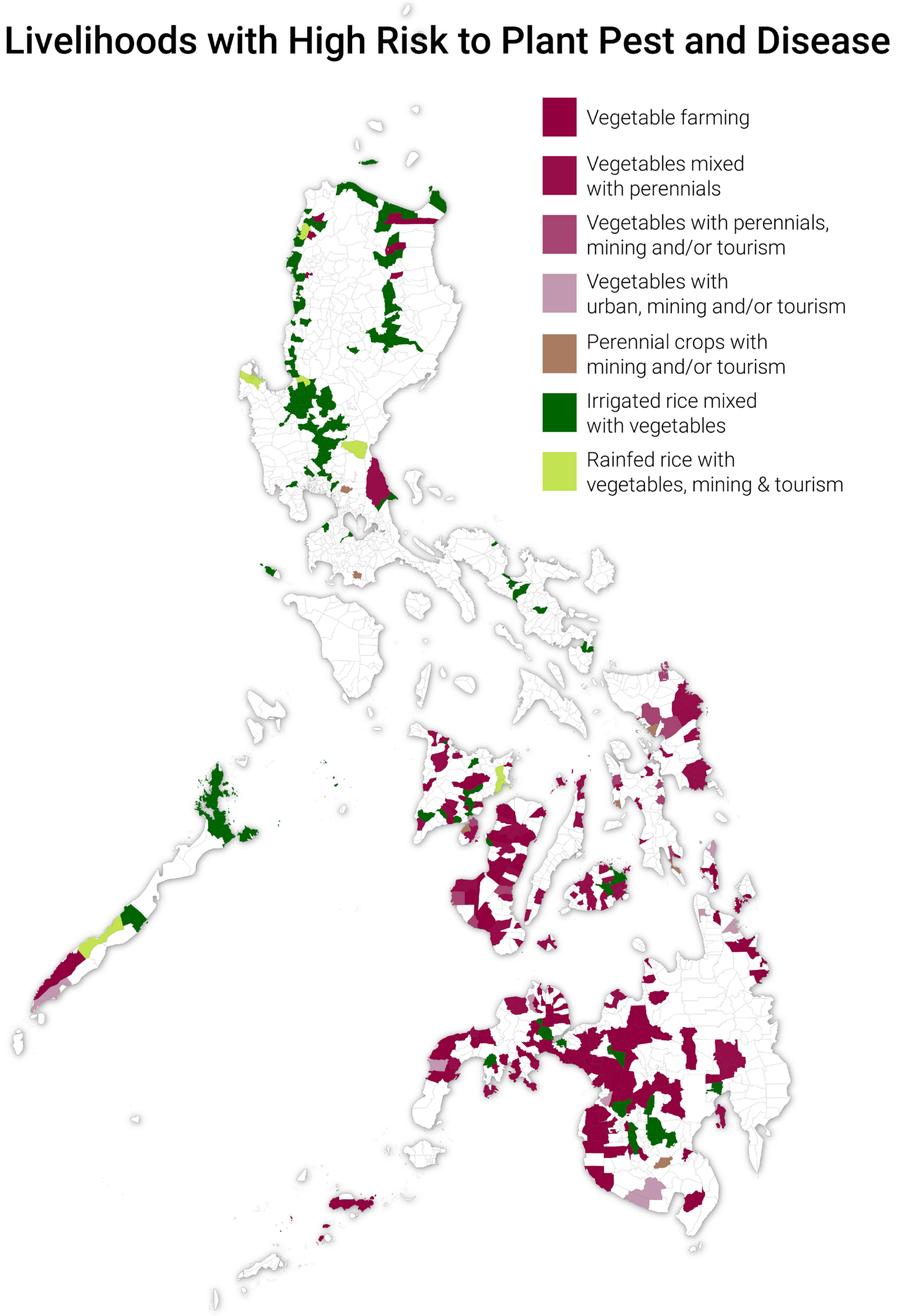


FIGURE 15. Livelihood zones that are at high risk for plant pests and diseases, using results from the TWG survey from regional stakeholders.

CURRENT SCENARIO AND FUTURE MODELING PROJECTIONS

RICE

Rice production in the Philippines is projected to be significantly affected by climate change. Increased temperatures and precipitation will result in more humid environmental and soil conditions. These will likewise lead to increased incidence and duration of flooding, which will consequently cause waterlogging and will create opportune environments for the proliferation of pests and diseases. Based on future climate modeling, the diseases that are projected to experience the greatest proliferation and invoke the most damage to the rice sector are rice sheath blight, bacterial sheath blight, and rice blast.

Rice sheath blight, caused by the pathogenic fungus *Rhizoctonia solani*, is a soil-borne disease that favors high temperatures, high rates of nitrogen, and canopy humidity ranging from 80% to 100% (IRRI Rice Knowledge Bank, 2020). Studies analyzing the correlation among meteorological parameters and disease incidence find that sheath blight incidence and severity are highly governed by temperature, with disease establishment and spread favoring air temperatures in the range of 26°C to 34 °C (Kaur et al., 2015). In addition, studies suggest that elevated atmospheric carbon dioxide concentrations increase the proliferation of sheath blight at the same time that they encourage tillering. The impact is thus twofold as the additional tillers likewise have higher incidences of blight due to the adherence of sclerotial bodies to the leaf sheath (Kobayashi et al., 2006).

The spread of rice sheath blight linked to climate change in the Philippines is projected to have the greatest impact on farmers whose livelihoods depend on irrigated rice production. According to our modeling, the populations that are considered the most vulnerable to rice sheath blight by 2050 (RCP 8.5) are irrigated rice farmers in Luzon in the provinces of Ilocos Sur, Ilocos Norte, Cagayan, Isabela, La Union, Pangasinan, Tarlac, Nueva Ecija, Pampanga, Zambales, Bataan, Bulacan, Cavite, and Laguna (Figure 16). There is also a strong likelihood of increased disease incidence in the irrigated rice zones on the islands of Oriental Mindoro and Palawan.

In Visayas, high incidence of the disease is projected in the provinces of Capiz, Iloilo, and Antique as well as in Negros islands specifically in the municipalities of Manapla, Cadiz City, Villadolid, San Enrique, Pontevedra, and Hinigaran. In Mindanao, the municipalities that are under this condition are Bonifacio (Misamis Occidental); Molave, Tambulig, and Ramon Magsaysay (Zamboanga del Sur); Kapatagan and Lala (Lanao Del Norte); Northern Kabuntalan, Kabuntalan, and Datu Piang (Maguindanao); and Midsayap (Cotabato). However, in terms of crop climate suitability, these irrigated rice zones in Visayas are expected to have a favorable condition by 2030, 2050, 2070, and 2090 under the RCP 8.5 scenario.

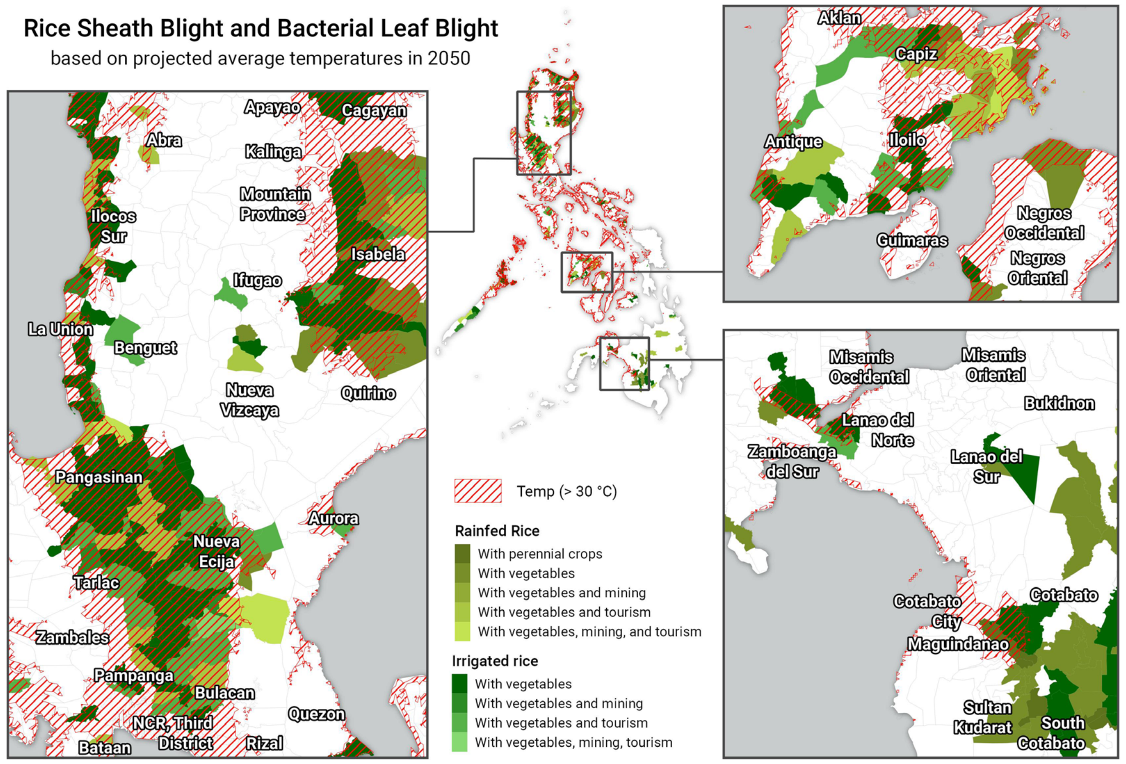


FIGURE 16. Rice sheath blight map based on projected average temperatures in 2050.

Similarly, **bacterial leaf blight** (caused by *Xanthomonas oryzae pv. oryzae*) is currently considered one of the most significant diseases affecting rice production in Asia, and its destructive capacity and high epidemic potential make it a pressing imminent threat in the light of changing climatic conditions. Rice plants become infected through the remnants of seeds, stems, and roots that remain after harvesting as well as through alternative weed hosts. The bacterium lives on dead plant matter and is transmitted through paddy water by irrigation or flooding; hence, crops that are more susceptible to flooding and standing water are more vulnerable to infection. The hotter temperatures and wetter conditions associated with climate change are predicted to accelerate disease development in several regions of the Philippines, as establishment and spread peak from 25 °C to 34 °C with more than 70% relative humidity (IRRI Rice Knowledge Bank, 2020). The great majority of the irrigated rice farming regions in the Philippines will fall under these conditions by 2050, with the exceptions being areas with a maximum temperature of 24 °C, such as Benguet, Ifugao, and Lanao del Sur provinces.

Rice blast (caused by *Magnaporthe oryzae*) is one of the most destructive and widespread fungal diseases globally. It is a result of the interaction between the virulent fungal isolate, particularly in susceptible rice genotypes, and favorable ambient conditions. Climate change highly affects rice blast development; however, additional research is needed to establish quantitative parameters of the effects in terms of temperature, precipitation, and humidity (Luck et al., 2011; Bevitori and Ghini, 2015). It is expected that in several wet, warm, and humid subtropical regions of Asia that are not currently favorable to the occurrence of rice blast, including parts of China, the Philippines, and Thailand, changing climatic conditions could trigger rice blast epidemics (Bevitori and Ghini, 2015). In the Philippines, the most vulnerable areas would potentially overlap with those irrigated and non-irrigated rice-producing regions found to be susceptible to rice sheath blight and bacterial leaf blight.

MAIZE

The development of diseases in maize, as in other crops, is highly dependent on the interaction of several factors, including the pathogen itself, the susceptibility of the variety planted, and the existing environmental conditions. In Philippine maize production, several environmental factors that will be enhanced by climate change are known to favor disease development and could potentially trigger an outbreak (Figure 17). The diseases considered most threatening under future climate models are mycotoxins, northern corn leaf blight, and southern corn leaf blight.

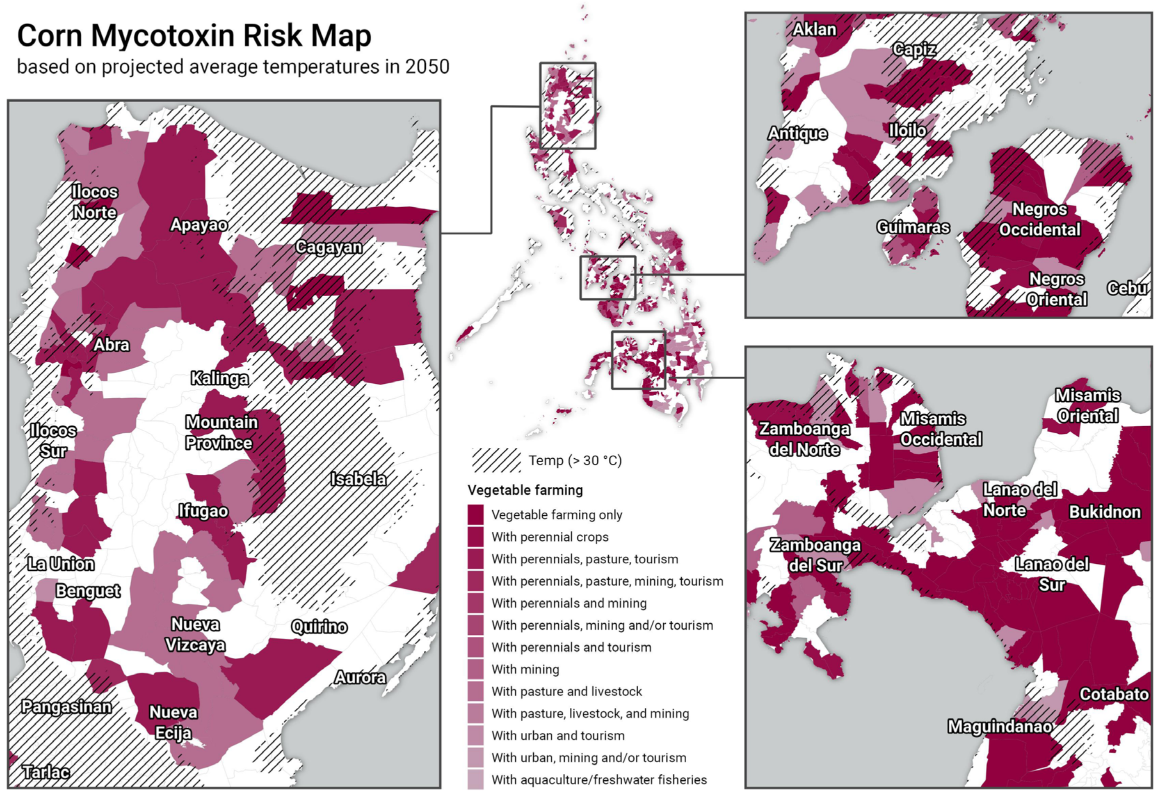


FIGURE 17. Maize mycotoxin risk map based on projected average temperatures in 2050.

A 2015 study of maize production in the Philippines noted changes in **mycotoxin risk** related to climate change. Warm and humid conditions (25 °C to 42 °C) are particularly favorable to the growth of Fusarium mycotoxins in maize, which would designate most regions that currently farm maize in the Philippines at high risk of this disease by 2050 (RCP 8.5). The predicted impact of this change in climate on the spread of this disease can be translated into appreciable yield losses resulting in lower income of most farmers that use maize as a main or complementary crop. Moreover, studies show that mycotoxins can also affect the health of humans and animals that consume maize and maize-based feeds through acute toxicosis, immune suppression, and several other effects.

Both northern and southern corn leaf blight are fungal infections that initially cause leaves to turn a grayish-green to tan color and later produce dark gray or black fungus, which can decrease yield by 30% or more. Under conditions of high humidity, the fungus will produce new spores at the leaf surface, which are then spread by rain or wind to create secondary infections. **Northern corn leaf blight** can be found in regions that are relatively wetter and cooler throughout the year. In the context of livelihood zones in the Philippines, this disease is expected to produce the most significant damage to maize production in irrigated and rainfed rice zones where maize is simultaneously planted. These areas are found in the northern provinces of Abra, Apayao, Mountain Province, Ifugao, and Benguet, and the southern provinces of Surigao del Sur, Bukidnon, and Lanao del Sur. Future projections showing an increase in temperature by 2050 under the RCP 8.5 scenario suggest that the following areas are most likely to be exposed to this disease: in the northern province of Abra (Luzon); in Capiz, Antique, and Iloilo (Visayas); and in the southern province of Maguindanao (Mindanao) (Figure 18).

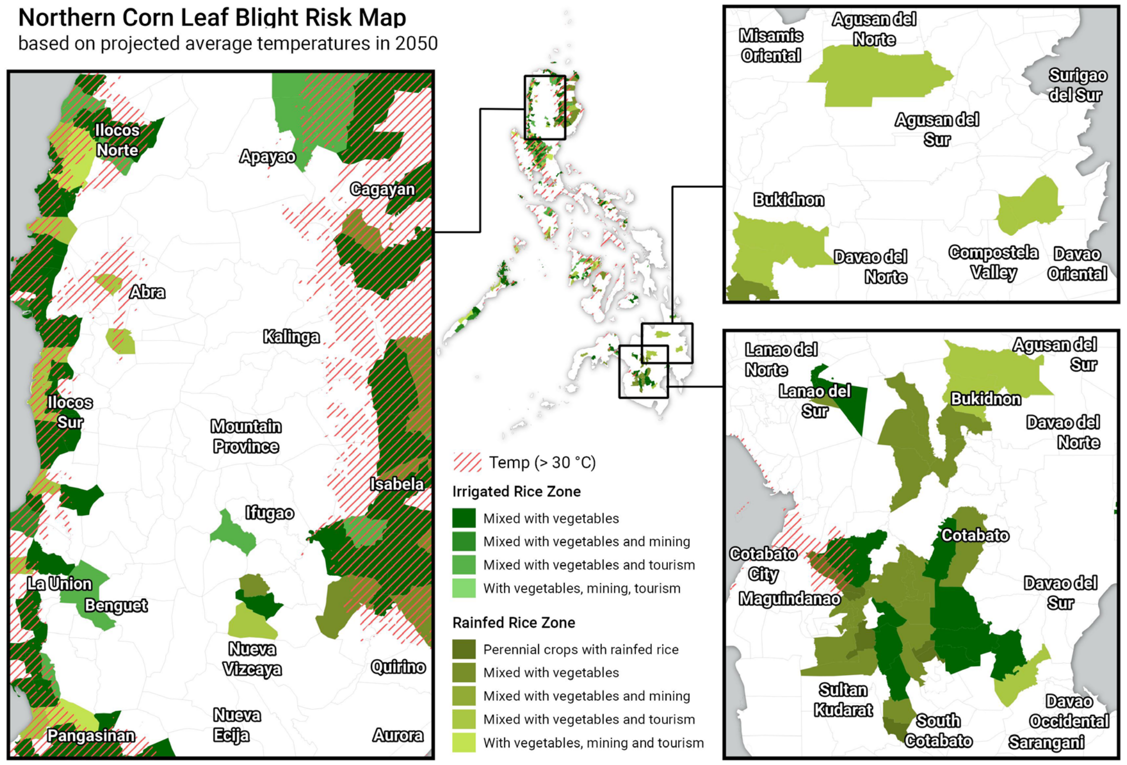


FIGURE 18. Northern corn leaf blight risk map based on projected average temperatures in 2050.

Conversely, **southern corn leaf blight** spreads widely in regions with high temperatures ranging from 25° C to 42 ° C. According to the projected temperature for 2050, the maize-producing zones that will exhibit ideal temperatures for the proliferation of southern corn leaf blight are the provinces of Cagayan, Isabela, Ilocos Norte, Ilocos Sur, La Union, Pangasinan, Tarlac, Nueva Ecija, Pampanga, Bulacan, Oriental Mindoro, and Occidental Mindoro, as well as the northern portions of Palawan (Luzon); Camarines Sur, Sorsogon, Capiz, Antique, Iloilo, Negros Occidental, and Bohol (Visayas); and finally in Mindanao the provinces of Agusan del Sur, Misamis Occidental, Zamboanga del Sur, Lanao del Norte, Cotabato, Maguindanao, Sultan Kudarat, South Cotabato, and Davao del Norte (Figure 19).

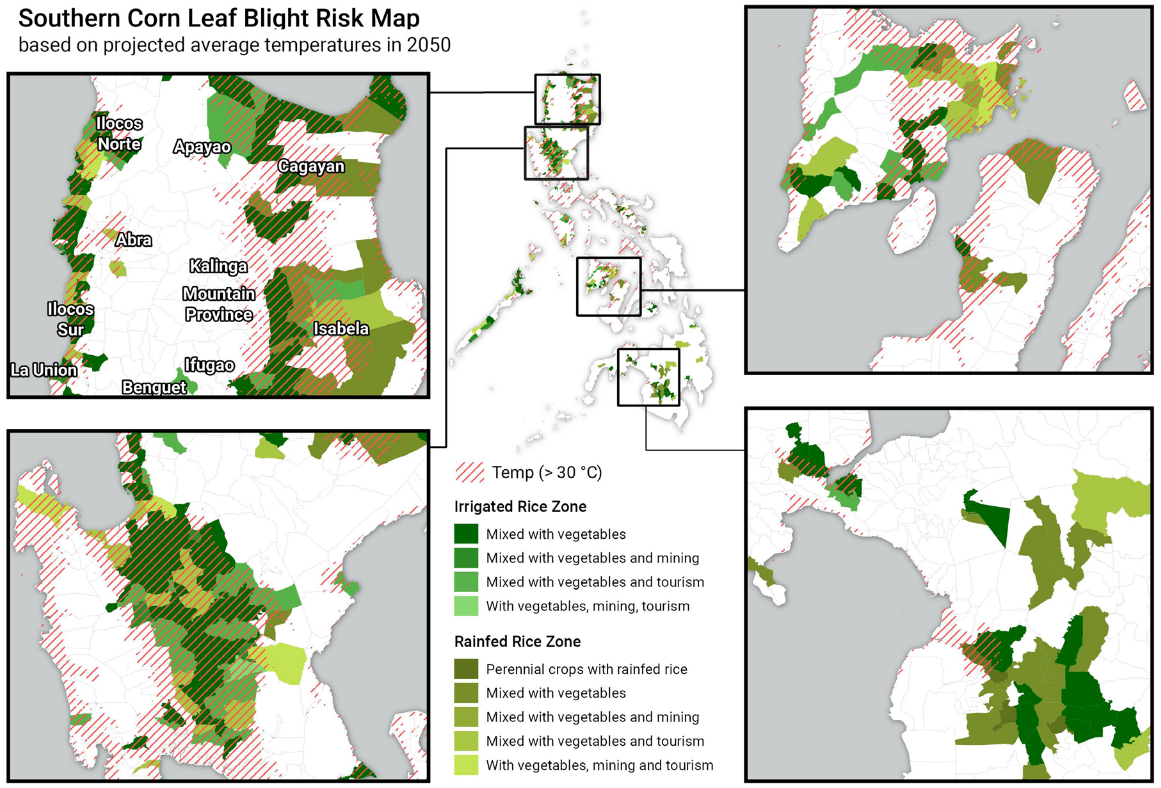


FIGURE 19. Southern corn leaf blight risk map based on projected average temperatures in 2050.

BANANA

Banana is an important dietary staple and source of income in the Philippines; however, the crop is highly susceptible to pathogens that are expected to become more virulent and common in the light of climate change. Among the key diseases that are expected to challenge banana cultivation in the country under changing climate scenarios are Fusarium wilt and black sigatoka.

Fusarium wilt, or Panama disease, is a destructive pathogen that is present in most banana-growing areas in the world and is widespread across Asia (Ploetz, 1994; Mostert et al., 2017). Fusarium is caused by *Fusarium oxysporum* f. sp. *cubense*, which is transmitted through chlamydospores that survive in the soil and attack the root system of the host, eventually causing it to wilt and die (Ghag et al., 2015). Several environmental factors related to climate change might influence the incidence of outbreaks. In the Philippines, increased precipitation during the warmest season is predicted to increase fungal activity, including Fusarium wilt, in the coming decades (Salvacion et al., 2019). Climate change will provide conducive conditions for spore germination and colonization in about 21% of the country, an area that covers approximately 67% of the total banana-growing regions.

Fusarium wilt is widely distributed in the northern part of the country, but it also threatens the southern regions that serve as the departure point for the majority of Philippine produce that is bound for export (Salvacion et al, 2019). With reference to the Livelihood Zones Map, large areas of annual and perennial crop zones, which include banana production in the northern part of Luzon, are expected to be highly susceptible, specifically in the provinces of Isabela, Quirino, Aurora, Sorsogon, and Masbate (Figure 20). In Visayas, annual and perennial crop zones with banana production are also projected to be affected by this disease in the whole island of Cebu. Susceptible provinces in Mindanao include Zamboanga del Norte and the whole region of Davao, which is renowned for large banana plantations in the country.

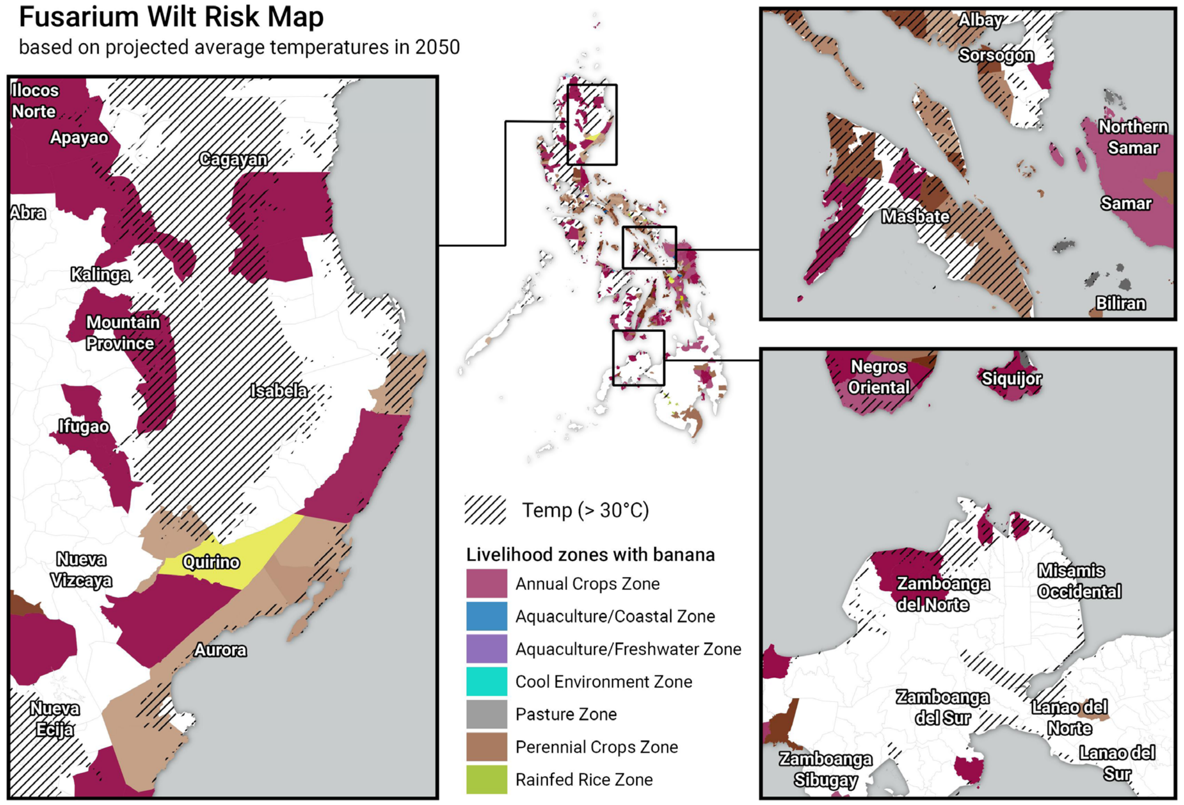


FIGURE 20. Fusarium wilt risk map based on projected average temperatures in 2050.

Another pathogen that may become increasingly threatening to banana production in the Philippines is **black sigatoka**, a foliar fungal disease caused by *Pseudocercospora fijiensis*. This disease penetrates the host through the stomatal opening and spores are disseminated by wind and water (Busogoro et al., 2004). The disease purportedly originated in Papua New Guinea and the Solomon Islands; however, it is now common throughout Asia and found in countries around the world (Stover, 1978). Presently, the incidence of black sigatoka is increasing globally, generating high economic losses in the international banana market (Churchill, 2011). The climatic characteristics that favor the occurrence of black sigatoka are high relative humidity greater than 90%, significant precipitation, and temperatures from 25 °C to 28 °C. (Bebber, 2019). Statistical modeling in the Caribbean and Latin America suggests that climate change will intensify the distribution of P. *fijiensis* by causing favorable weather conditions for spore colonization and survival (Bebber, 2019).

With reference to the Livelihood Zones Map highlighting all the areas in the country with presence of banana, an increase in temperature to greater than 30 °C by 2050 might lead to wide spread of this disease but only on the island of Luzon. These provinces are generally under annual and perennial crop zones, located in the provinces of Aurora, Bulacan, Rizal, Laguna, Quezon, Cavite, Batangas, and the islands of Marinduque and Mindoro.

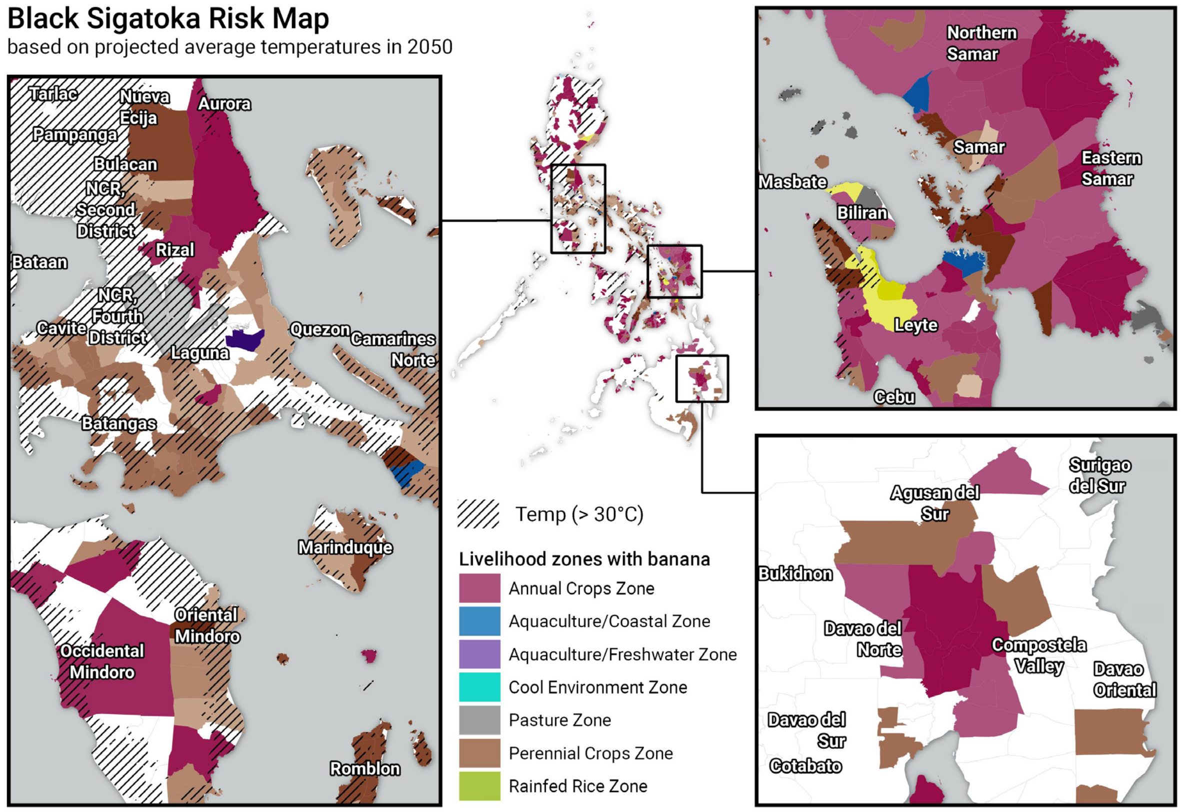


FIGURE 21. Black sigatoka risk map based on projected average temperatures in 2050.

3.1.4. IMPACTS OF CLIMATE CHANGE ON LIVESTOCK

CONTEXT

Changing climatic conditions pose challenges to the livestock and poultry sector, both in terms of animal health and in terms of the viability of pasturelands and fodder crops that are used as animal feed. Both ongoing climatic changes, such as temperature and moisture, and acute climate hazards, such as typhoons and storm surges, can have detrimental impacts on livestock's growth and weight, reproductive performance, and susceptibility to pests and diseases. In the Philippines, there is a relatively limited thermoneutral zone, an area with a range of temperatures in the surrounding environment where adult animals can maintain a normal body temperature without using much energy. This zone provides the appropriate temperature and humidity levels for all domesticated animals, which include goats, cows/cattle, poultry, and swine. In that respect, sudden, seasonal, or prolonged changes in environmental temperature, relative humidity, and photoperiod (sunlight exposure) can expose animals to chronic stress, particularly heat stress.

Direct effects of the changes in microclimatic factors on swine and poultry behavior include increased panting, reduction in voluntary feed intake, and increased water consumption which could, in turn, result in depressed growth, lower meat quality, lower immune functions, and lower reproductive performance of both male and female breeders (Lara and Rostagno, 2013). For example, heat stress related to high temperatures can be very detrimental to the poultry sector in terms of both meat and egg production. Generally, a decrease in feed intake and increase in water consumption are direct effects of acute and chronic heat stress, leading to decreased growth and carcass quality, feed efficiency, gamete formation, egg production, mating behavior, immunity, egg fertility, and hatchability (Sohail et al., 2012; Kim et al., 2020; Quinteiro-Filho et al., 2012; Lara and Rostagno, 2013; Ahaotu et al., 2019). Laying hens' productivity is moderately affected by temperatures that exceed 27 °C, while temperatures surpassing 32 °C can have a severe impact on both laying capacity and quality, such as shell thickness and breaking strength (Mahmoud et al., 1996; Lin et al., 2006; Kim et al., 2020).

The Philippines had a total of 11.27 million pigs in the third quarter of 2020, of which conventional farms represent 68% of the total swine inventory, with the remainder of swine raised on household farms (31%) (PSA, 2020). The thermoneutral zone for rearing and finishing pigs is at a temperature from 21 °C to 24 °C provided that the relative humidity is 70% or lower (Lass, 2019). For sows, a temperature not more than 22 °C should be maintained (Hörtenhuber et al., 2020) to not negatively affect conception rate. Animals in a hot environment tend to diminish feed intake to decrease metabolic heat production, resulting in inferior growth performance (Rauw et al., 2020; Secor, 2009). Changes in the environmental temperature and relative humidity above the thermoneutral zone of pigs could result in poor performance and poor health.

Since intensive swine and poultry production relies heavily on cereal grains, the implications of climate change on the production and distribution of staple grains used in animal feed across the Philippines can likewise affect the health and nutrition of livestock and poultry. As discussed in the preceding sections, climate changes may contribute to higher temperatures and variable rainfall that may weaken or expose crops to pests and diseases, thus decreasing the quantity and quality of important feed crops. In terms of natural fodder and pasture for grazing, climatic changes can contribute to resource competition among plants and weeds and a biodiversity loss that further exacerbate the problem.

MAPPING AND SURVEY FINDINGS

Analysis of the surveys completed by the Technical Working Group indicates that several of the projected impacts of climate change are already affecting the livestock sector in a manner that could have repercussions for regional and national food security (Figure 22). According to the surveys, at present, temperature changes are associated with the greatest impacts on the livestock sector. Temperatures are currently observably higher, more variable, and with increased incidence of hot days, which experts associate with the major impacts currently experienced in the livestock sector. In 8 of the 11 regions considered, poorer reproductive performance was cited as an impact of climate change, accounting for 34% of the total responses. Decreased food supply was the second most cited impact (24% of the total responses), occurring in 9 of the 11 regions and constituting half or more of the responses in 3 regions. Relatedly, stunted growth was cited as a significant impact by 21.1% of the total responses and is often directly related to the decreased availability of fodder and lower food intake of heat-stressed animals. Lower feed quality was also an important impact (15%).

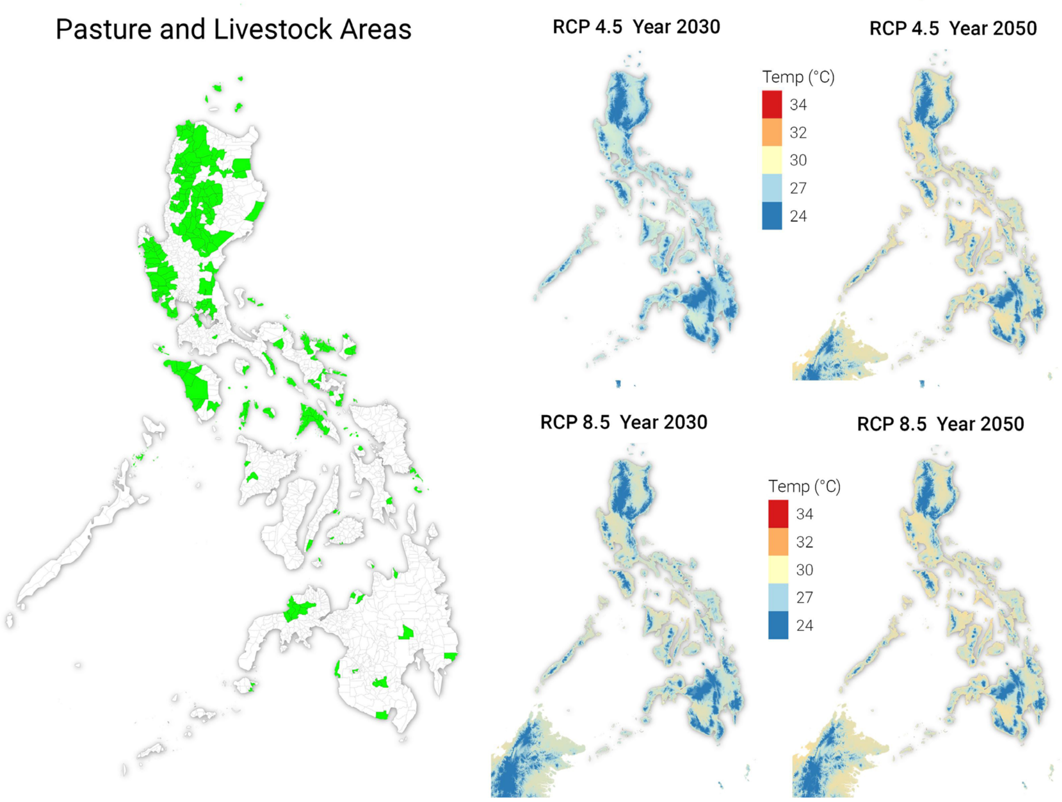


FIGURE 22. Pasture zone and other livestock areas that are most likely to be affected by heat stress; map showing the projected temperature in livestock zones by 2050 under the RCP 8.5 scenario.

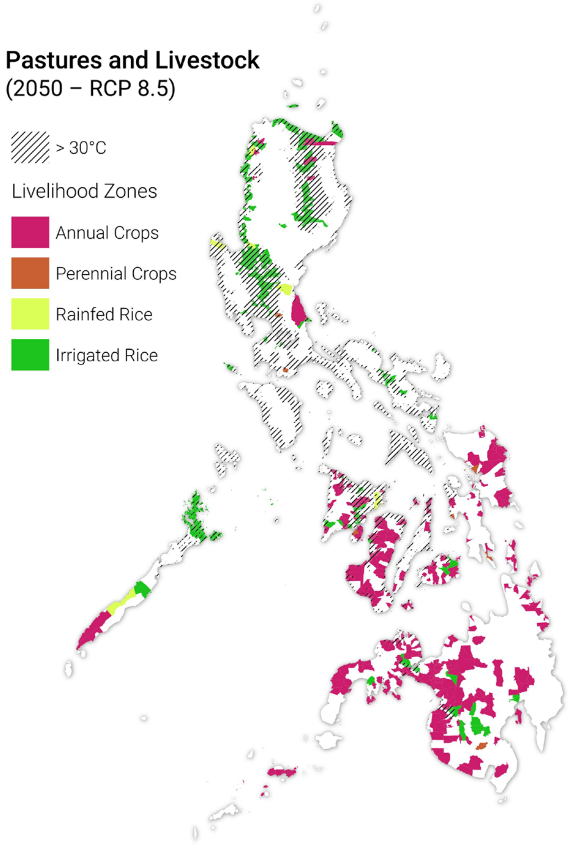


FIGURE 23. Livelihood zones with presence of livestock and pasture projected to be under heat stress under the RCP 8.5 scenario, year 2050.

Mapping exercises that overlay livelihood zones and climate change models help to identify where some of the impacts of climate change that are currently underway will likely become more pronounced by 2050. In Figure 23, the municipalities where the predominant livelihoods involve livestock and poultry farming (referred to as "pasture zones and livestock areas") are compared against a temperature map indicating the average temperature for 2050 (under the RCP 8.5 scenario). The three main livelihood zones that are dominated by livestock are pasture mixed with urban zone (26%), pasture mixed with perennial commodities (coconut, mango, banana) (19%), and pasture mixed with vegetable farming (17%). These LLZs are concentrated in provinces where pasture and livestock are expected to be at risk of heat stress and other climate-related hazards due to projected ambient temperatures of 30 °C or more by 2050, including Apayao, Abra, Kalinga, Mountain Province, Ifugao, Benguet, and Nueva Vizcaya.

IMPLICATIONS FOR ADAPTATION

By 2050, global demand for meat and eggs is estimated to increase by 76% and 65%, respectively, due to a growing human population and increasing demand for higher quality protein foods (Alexandratos and Bruinsma, 2012). In the Philippines, demand is already growing for meat protein, including swine, poultry, other meat, and fish. However, the consumption of these meat protein sources varies significantly across social groups. A 2018 WFP study on nutrition in the Philippines found that the wealthiest quintile of the population consumes six times as much meat and five times as much poultry as farmers in the poorest wealth quintile (WFP, 2018). According to the Philippines National Nutrition Survey (2015), the daily intake of poultry was around 50 grams for the wealthiest quintile and less than 10 grams for the poorest quintile (WFP, 2018). Unsurprisingly, food costs play a major role in the ability of the non-wealthy to access a nutritious diet, complete with animal protein sources. Although studies have not yet been carried out to quantify the impact of climate change-related hazards on the price of meat for consumers, it can be inferred that good-quality meat protein is already too costly for the majority of Philippine families who spend more than 40% of their income on food, and that any price shocks would only worsen that situation. The sensitivity of the Philippine meat product market is demonstrated by the recent episode of African swine fever: the sudden supply shortage caused the price of swine meat products to increase by nearly double and drag other food prices up as well (SciDev.Net, 2020).

The livestock and poultry sectors must revisit their production and management systems and identify mitigation and adaptation strategies to address the challenges of changing climatic conditions for bird welfare, farm sustainability, and profitability (Tabler et al., 2020). Different adaptation strategies include the use of locally bred chickens, which have a slower growth rate and are more tolerant of high temperature; this is gaining popularity in the developing countries with tropical climate (Pawar et al., 2016; Liverpool-Tasie et al., 2019; Cole and Desphande, 2019). The use of naked neck and frizzle genes in poultry strain development is also being explored (Wasti et al., 2020). Selection for heat tolerance bred in animals is usually based on body temperature, respiration rate, and heart rate, and some biomarkers associated with heat stress (Carabaño, 2019). Specific management practices are also being implemented on animal farms such as feed withdrawal or temporary feed restriction during the hottest time of the day (Jasmine and Shyama, 2019), timed stocking so that laying or farrowing will commence during the colder months, and frequent mixing and changing of litters especially during summer months to prevent heat buildup and accumulation of methane and heat conditioning (Pawar et al., 2016; Rodrigues et al., 2019). Although large commercial farms could easily adapt to climatic changes with the use of tunnel-ventilated or climate-controlled houses, small- and medium-scale operators might be more vulnerable because of limitations of resources to adapt to these changes.

3.1.5. IMPACT MODEL ANALYSIS ACROSS KEY FOOD COMMODITIES

MODELING

In order to complement the biophysical insights generated from the analysis of crop suitability and climate change hazard mapping exercises, the IMPACT model was used to identify potential vulnerabilities to key crops, livestock, and fishery systems from a global market systems perspective. The IMPACT model offers findings in terms of commodity supply and demand, import dependence, and related health indicators, such as food and nutrition security. Comparison of climate change scenarios against a "no climate change" benchmark (SSP1) scenario provides insight into how vulnerable food systems are to the effects of climate change. The market forces modeled by IMPACT can either exacerbate or offset biophysical production loss due to climate change. In some cases, certain food systems may even exhibit higher production capacity with climate change than without it. For the purposes of this study, the commodities in focus are staples (rice, maize, and roots and tubers), livestock (pork, beef, and poultry), fish, and vegetables. The selected modeling variables were production, area, yield, demand, import dependence, diet, and the number of malnourished children.

In terms of crop production, the IMPACT model analysis indicates that, in the Philippines, cereals exhibit vulnerability to climate change, whereas vegetables and roots and tubers exhibit relative resilience. This divergence is especially pronounced under a more extreme climate change scenario (RCP 8.5), in which the output of vegetables and roots and tubers is actually higher than under the "no climate change impacts" benchmark (Figure 24). Among the cereals, rice production and productivity are projected to increase steadily over time, from approximately 32% to 47% of current values by 2050, regardless of the modeling scenario used. For roots and tubers, both production and yield are expected to increase rather uniformly across all scenarios by approximately 20% to 35%. Vegetable production will likely increase, with an expansion of area dedicated to vegetable production and significant yield gains expected, regardless of the scenario. On the other hand, maize is especially vulnerable to the impacts of climate change, with production and yield values for 2050 projected to be from 10.9% to 16.5% less under scenarios

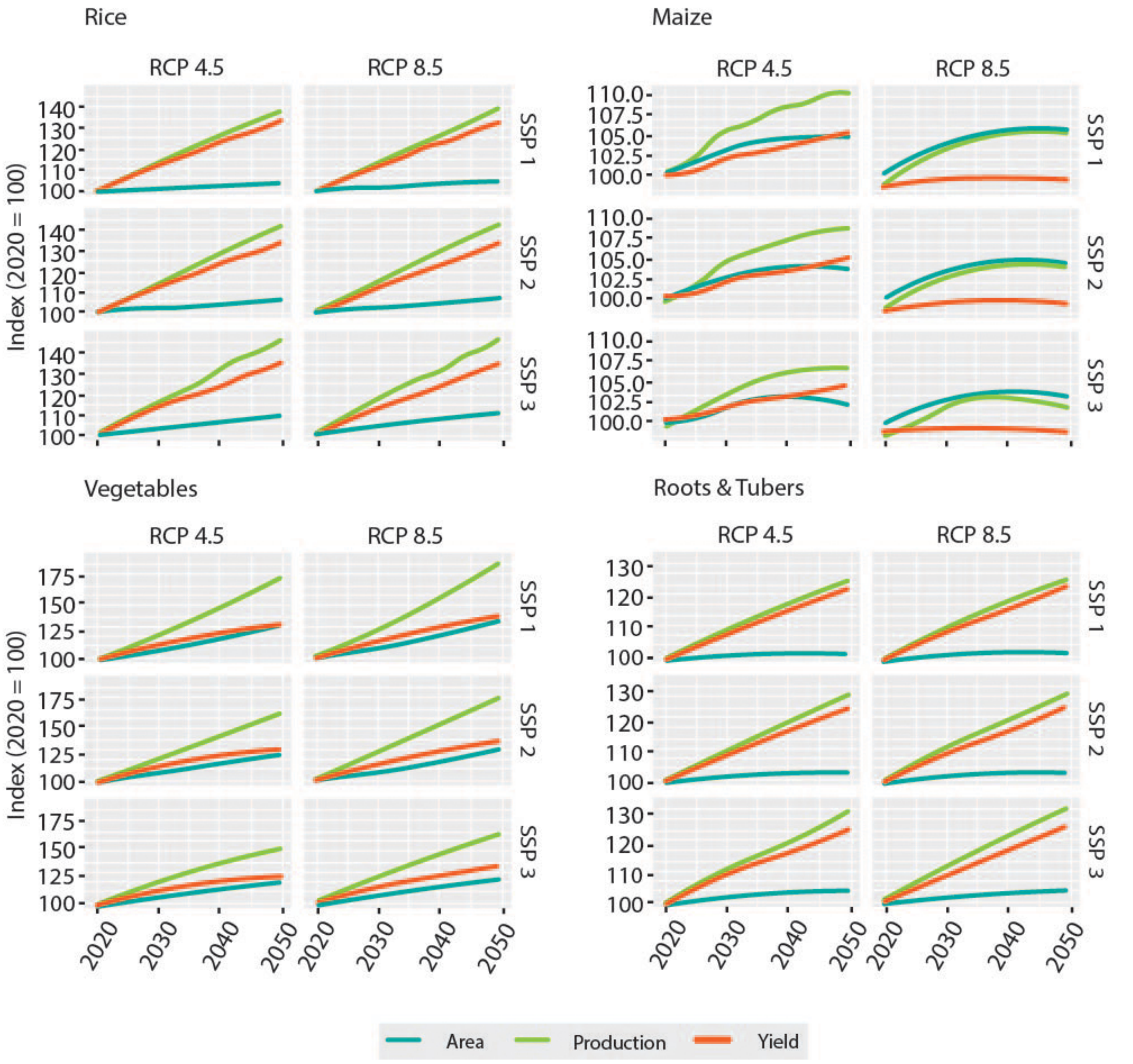


FIGURE 24. IMPACT 2020 - 2050 projection of yield, production, and area for rice, maize, roots and tubers, and vegetables in the Philippines, expressed as an index, with the 2020 value set to 100.

that include climate change impacts versus scenarios that include no climate change impacts.

At the same time, the IMPACT model analysis demonstrates that the demand for key crops will likewise shift over time, with an increase in demand for cereal staples for human consumption, and even more significantly for livestock feed. Urban households currently constitute the greatest demand for rice, and that demand is projected to continue growing from 2020 to 2050, across scenarios. Conversely, the demand for vegetables and roots and tubers is mostly in the form of rural household demand, and it is projected to continue growing across scenarios. Most interestingly, the greatest demand for maize is for livestock feed, which is expected to increase significantly from 68% to 89% depending on the scenario from 2020 to 2050.

For livestock, the Philippines is likely to experience major growth across the poultry, beef, and pork sectors (Figure 25). In terms of production, the middle of the road scenario (RCP 4.5, SSP2) projects that poultry production will increase by 86% from 2020 to 2050, while beef will increase by 90% and pork by 42% in the same period. Importantly, animal yields are expected to increase

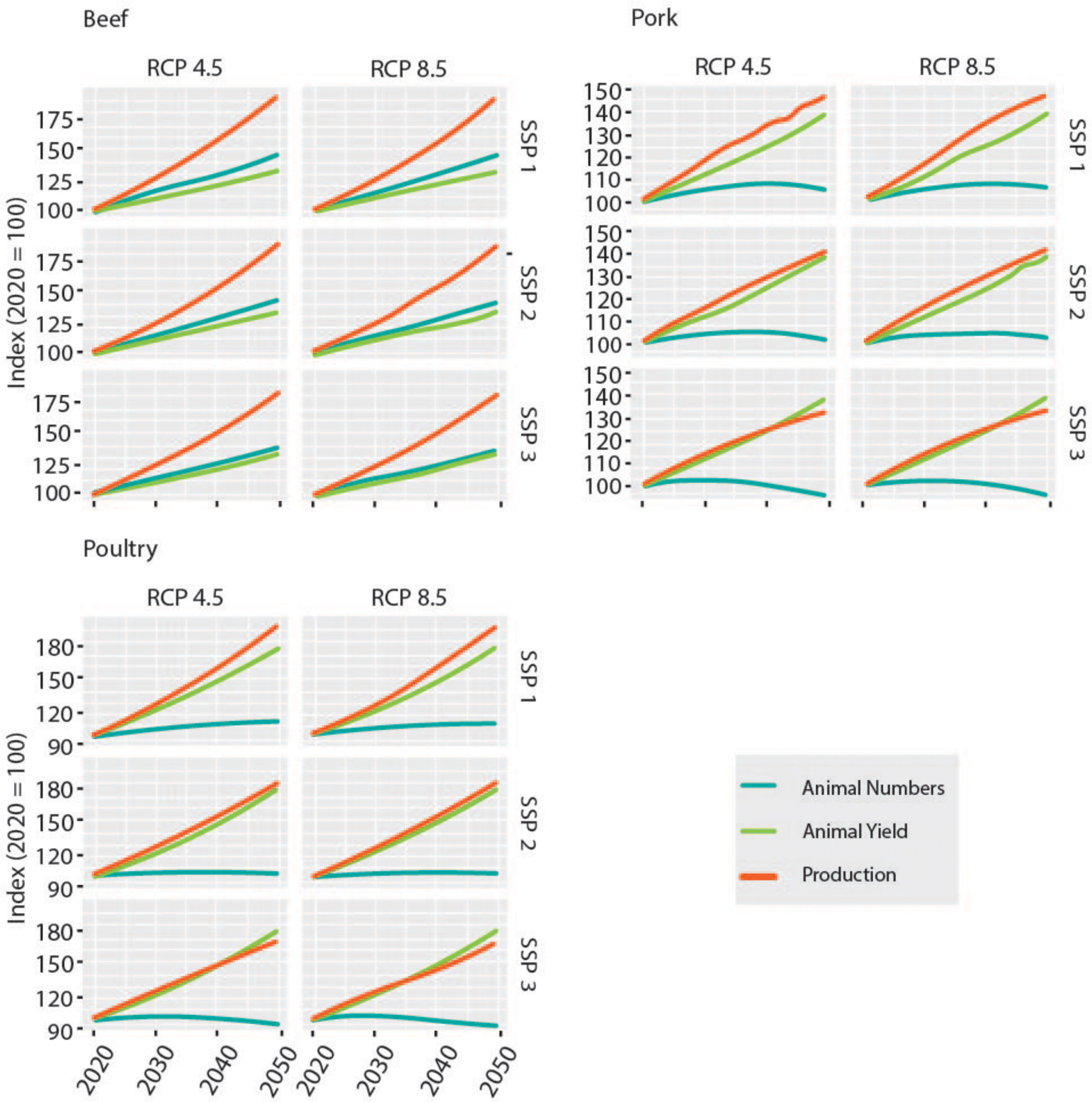


FIGURE 25. IMPACT 2020 - 2050 projection of animal number, yield, and production for beef, pork, and poultry in the Philippines, expressed as an index, with the 2020 value set to 100.

significantly, helping to explain the discrepancy between the relatively steady or even decreasing animal numbers and the significant gains in terms of production value.

The fish IMPACT model is currently under development to be integrated into the latest versions of the crop and livestock models, considering specific biophysical and socioeconomic factors for fisheries and aquaculture and fish management and production targets defined by national governments (for more information, see Annex 1). A stand-alone module by WorldFish and the International Food Policy Research Institute (IFPRI) using the most updated model currently available provides insights for the Philippines' fisheries sector through 2050 (Figure 26). The model suggests significant growth in fish consumption, with per capita consumption doubling from 20 kg in 2020 to 40 kg in 2050 (under SSP2). This increase could at least partly be explained by the rising incomes in the country and the generally high-income elasticities of demand for fish, which indicate that seafood is highly preferred. Along with population growth, the increased ability to purchase fish will result in a significantly higher national consumption in terms of total volume by 2050.

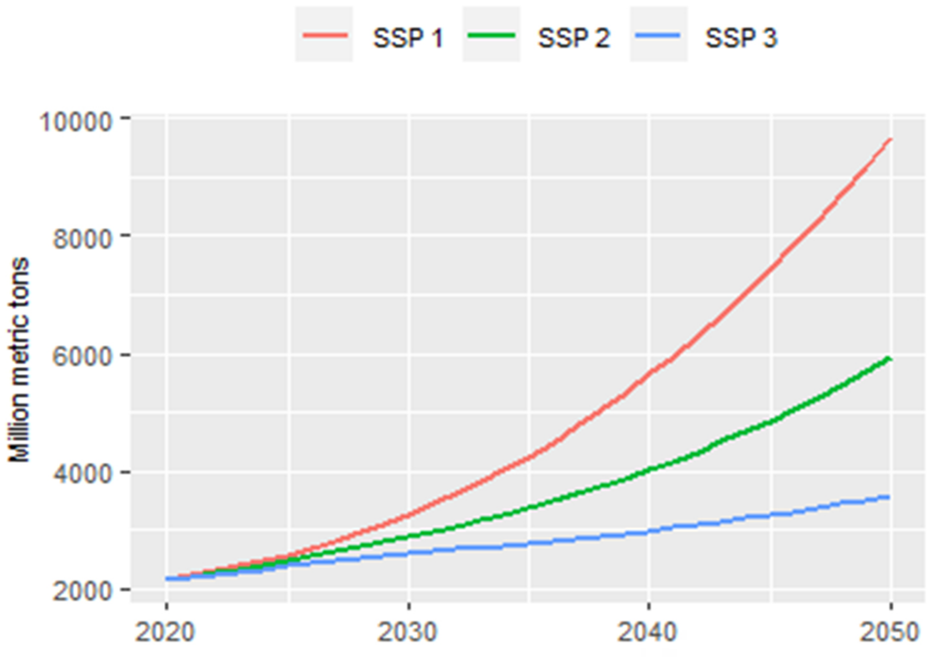


FIGURE 26. IMPACT projection of total fish consumption in the Philippines, 2020 - 2050.

These demand trends are in line with the projected changes in the dietary composition of the Philippine population (Figure 27). IMPACT projects that the per person daily consumption of rice, maize, and roots and tubers will decrease slightly over time, compensated by a corresponding increase in consumption of animal products, pulses, fruits and vegetables, and sugary foods, as is consistent with Bennett's law. The modeling also suggests a slight decrease in per capita consumption of rice in terms of caloric value; however, rice is and will remain the largest calorie source in the standard Philippine diet. There will be a more significant decrease in maize consumption; however, this will not significantly affect demand since maize will become an increasingly important commodity for livestock feed.

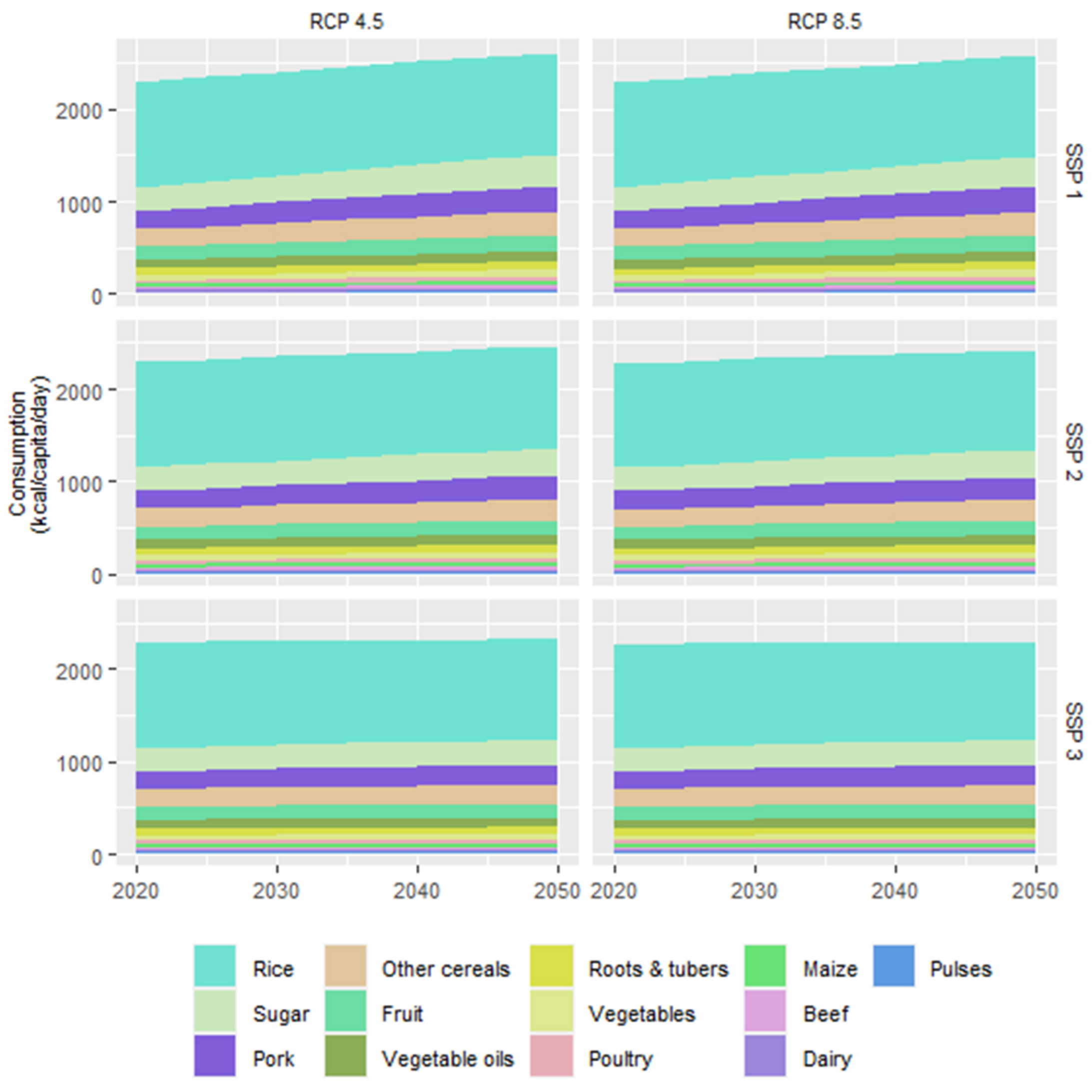


FIGURE 27. Projections on the dietary profile in the Philippines, 2020 - 2050.

In terms of the nation's dependence on food imports, the Philippines is projected to become less reliant on rice imports by 2050 under the more middle of the road scenarios (SSP1 and SSP2) and is projected to hold relatively steady at about 10% of domestic demand under the more extreme regional political scenario (SSP3) (Figure 28). On the other hand, maize import dependence is projected to increase steadily under all scenarios, with imports required to meet about 50% of domestic demand by 2050. Vegetable import dependence is projected to hold steady from 10% to 20% of domestic demand under SSP1 and SSP2, whereas, under SSP3, the share of imports could increase to constitute up to 35% by 2050.

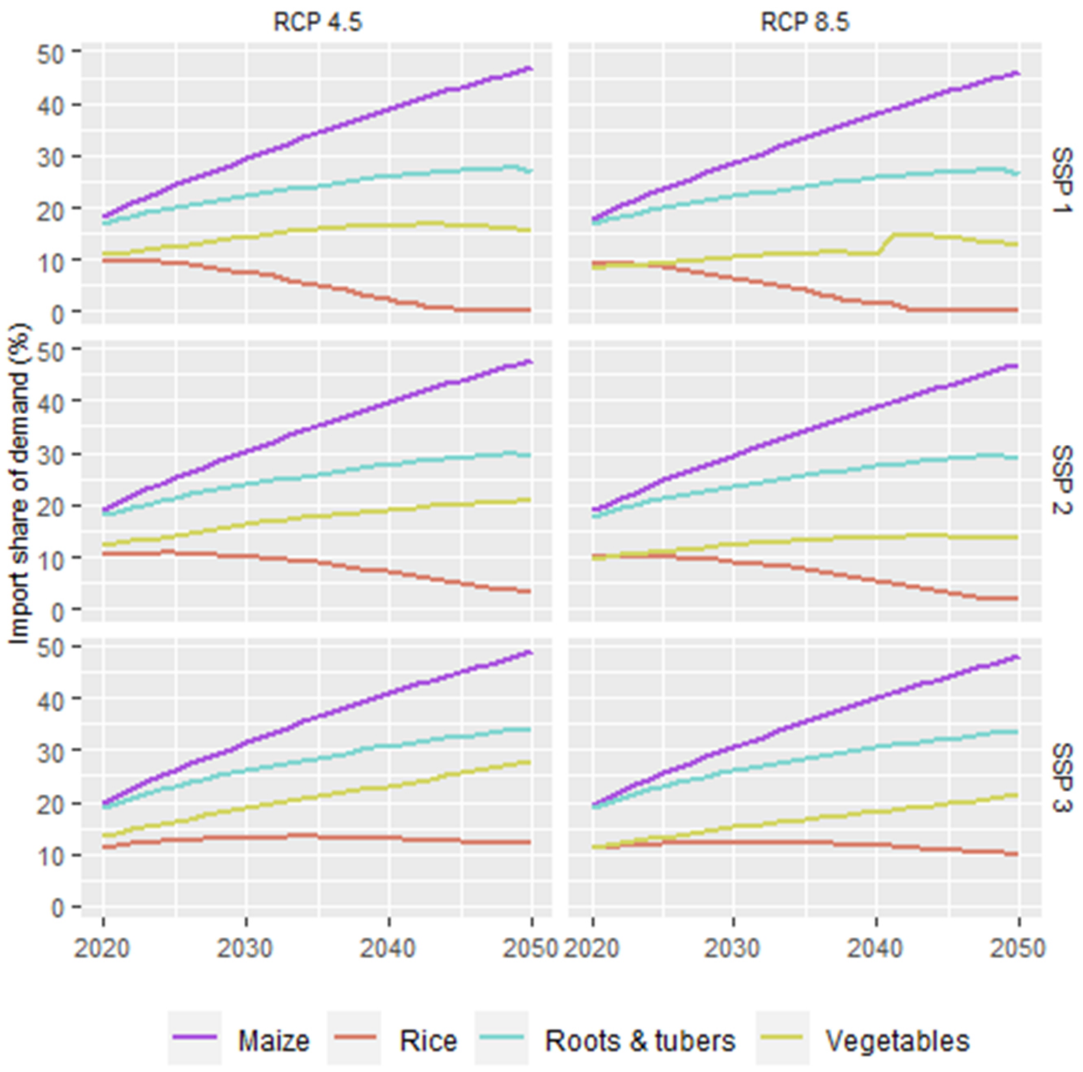


FIGURE 28. Import share of demand for key crops.

The combined impact of these changes, in terms of projected productive capacity, changing dietary preferences, and import dependence, will have an effect on food security and nutrition, particularly for the most vulnerable populations. When considering childhood nutrition, the IMPACT model projects that the total number of malnourished children will decrease over time; however, the significance of this decline varies widely across scenarios. For the more middle of the road scenario (RCP 4.5, SSP 2), the number of malnourished children decreases by almost one-third, from 3 million children at present to just over 2 million by 2050. That decline is even more promising under the less severe scenario (RCP 4.5, SSP 1), but is almost insignificant in the more extreme scenario (RCP 8.5, SSP 3), in which approximately 2.75 million children will still lack proper nourishment.

3.1.6. IMPACTS OF CLIMATE CHANGE ACROSS SOCIAL SECTORS

CONTEXT

The impacts of climate change on the productive capacity of agricultural and fishery systems can create scarcity and generate food price shocks, which in turn have implications for various aspects of food and nutrition security in the Philippines. Although the impacts are far-reaching, with different fallouts across rural and urban landscapes and socio-economic groupings, in general, climate change is shown to disproportionately affect poor and vulnerable populations.

Both urban and rural Philippine populations are affected by climate-related impacts on food systems, in different ways and to different degrees. In general, the production losses that result from climate shocks lead to scarcity, disrupted supply chains, and food price inflation that are experienced by both rural and urban consumers. Globally, Satterthwaite et al. (2010) outline the major urban-rural food system linkages, highlighting how the effects of climate change on agriculture directly shape urban food systems (e.g., food availability and price) and likewise how the impacts of climate change on the urban sector affect the rural sector (e.g., disruptions in demand, urban service provision, and food accessibility in the rural sector).

In the Philippines, a World Bank study (2011) looking at the effects of climate change on food price inflation established linkages between climate disasters and the price of food in both urban and rural markets. Because of the disaggregated nature of supply and demand markets in the Philippines, food price inflation varies across provinces and between urban and rural populations; however, in the short term, price increases tend to worsen poverty for the majority of both the urban and rural poor (Fujii, 2013). For example, Ahmed et al. (2009) found that the socioeconomic sub-sections of the Philippine population that would be most impacted by an extreme “once in 30 years” climate event in the Philippines are the urban labor and rural labor groups, which they estimate would experience a 32.3% and 25.9% increase in the incidence of poverty, respectively (Ahmed et al., 2009).

Focusing on rural households, the impacts of climatic changes are experienced on three levels: first, in terms of food consumption tied to their inability to produce sustenance food; second, in terms of livelihoods, as their income suffers from productivity losses; and third, in terms of market consumers who are vulnerable to limited food availability and price shocks. For example, among the most significant self-reported challenges facing Luzon farmers following the 2009 typhoons were the loss of productive assets and land, financial losses tied to unrepayable debt and reconstruction, and the increased risk of hunger due to market price spikes and debt (WFP, 2010). Poor agricultural households, particularly those that rely on agriculture as their principal source of income, are especially vulnerable to food inflation, which has the effect of increasing the depth of poverty, in terms of the gap between household income and the poverty line, and the scale, in terms of the share of the population affected by poverty (Fujii, 2013). Because the implications of climate shocks for rural households are threefold, their adaptation and coping strategies are often multi-faceted, including diversifying sources of income; sharing, borrowing, or exchanging food, goods, and services; and relying on social networks for loans, including immediate family and friends, international remittances, and domestic transfers (Pajaron, 2014).

For urban populations, Kovats and Akhtar (2008) compile a review of the health effects of climate and extreme weather on low-income urban residents in major Asian cities, finding that the greatest threats to coastal megacities, including Metro Manilla, are related to changes in freshwater resources, food supplies, and flooding. Contamination caused by poor sanitation in the aftermath of heavy rainfall and flooding can cause water-borne diseases to proliferate, including those that are particularly concerning from a nutrition standpoint as they affect the body’s ability to absorb nutrients (Kovats and Akhtar, 2008). For poor urban households living in flood-prone riverine communities in Manila, flooding renders them more vulnerable to health, livelihood, and asset loss (Porio, 2011; Morin et al., 2016). In a 2011 study, climate-related disasters including typhoons, floods, and tidal surges were found to have resulted in losses (including income, infrastructure, health, and assets) for approximately two-thirds of the survey population, and this further compounded the livelihood deprivations (such as access to potable water, sewage and sanitation, and electricity) of the most vulnerable among them (Porio, 2011). Similarly, drought conditions can affect water availability and condition in urban environments, increasing the chemical and microbiological load due to extreme low flows and resulting in bacterial outbreaks that compromise nutrition and health (Kovats and Akhtar, 2008). In terms of food security, community members, particularly mothers, report struggling to cover family expenses post-disaster, particularly in the light of the higher costs of food and water (Porio, 2011).

Considering the impacts of climate change on vulnerable or marginalized populations, such as the young, elderly, pregnant, and nursing; displaced and migrant communities; the disabled; and the poor, among others, research suggests that they are more likely to be affected and affected more profoundly than other sub-populations. In addition to the poor conditions following acute climate-related disasters, the typical living conditions of vulnerable populations can contribute to health conditions that complicate food security. For example, populations that do not receive a sufficiently nutritious diet prior to a climate-related disaster, including babies, young children, adolescent girls, and pregnant and lactating women, are at risk of having even less access to nutritious food (WFP, 2018). A recent study found that the costs of providing a nutritious diet for adolescent girls and lactating women in the Philippines are beyond the purchasing power means of families in the lower-income quintiles during normal times (WFP, 2018). It can be inferred that ensuring an affordable diet would be even less feasible with the financial pressures created by climate-related hazards. Similarly, in a study on food insecurity among vulnerable populations in the Philippines, Roa (2007) found that the most significant factors that influence children’s nutrition are total food budget, the nutrient knowledge of the caregiver, and own-food production, meaning that climate hazards that impede food production or lessen income pose a threat to nutrition.

MODELING

The impacts of climate change are experienced most acutely by vulnerable populations in both rural and urban areas, whose preexisting conditions such as poverty, lack of income diversification, and poor health and nutrition predispose them to greater climate risks. Based on this understanding, we set out to identify the populations that are most vulnerable to climate change, based on these preexisting attributes. We began by classifying populations using a human settlement classification map based on population density, ranging from “very low density rural” to “dense urban” to cluster populations (Figure 29). With those categories, we further disaggregated the data to identify patterns in the types of livelihoods and income across urban and rural sectors, with the goal of understanding their vulnerabilities to climate change.

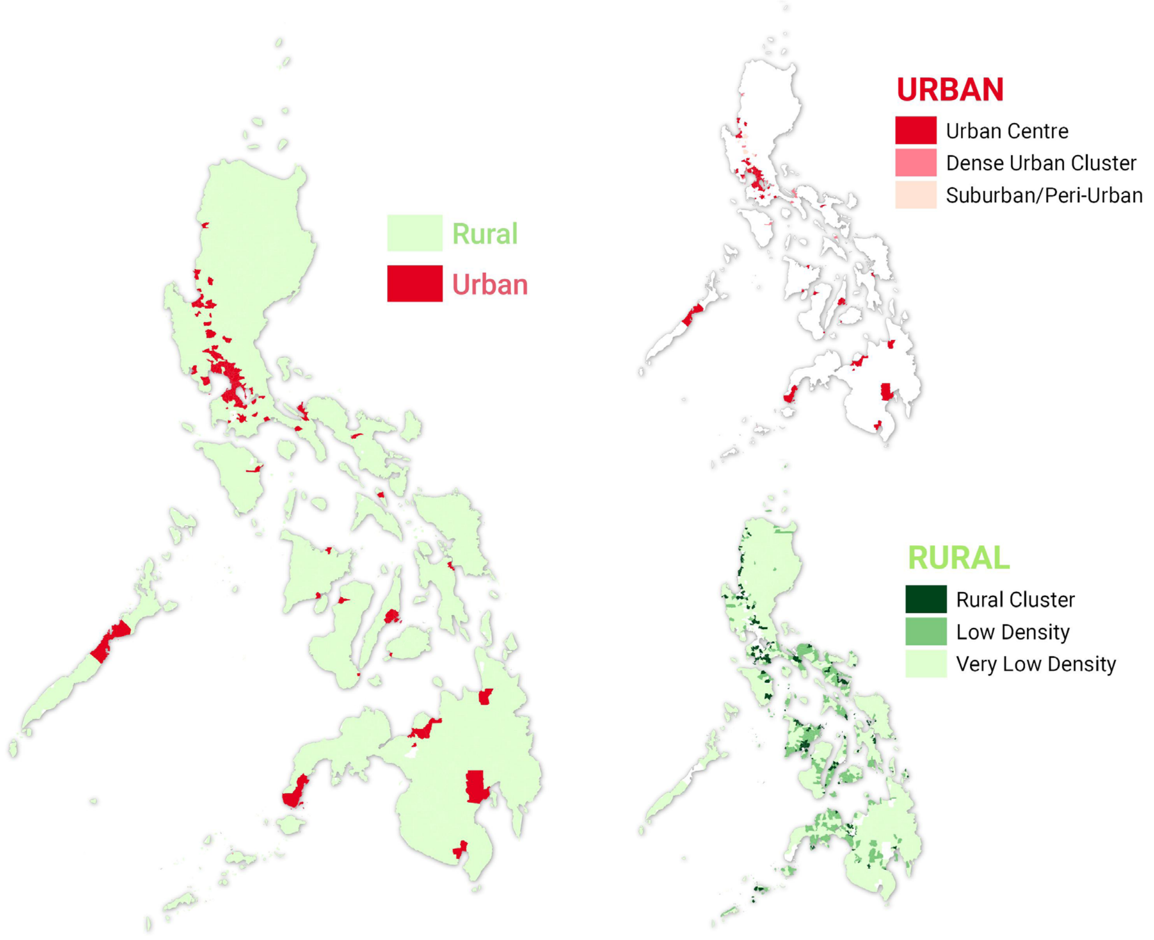


FIGURE 29. Mapping of urban and rural zones in the Philippines, based on population density.

The Philippines is predominantly rural, with urban settlement concentrated in specific geographic areas with relatively limited urban sprawl. Moreover, rural areas are overwhelmingly dedicated to agricultural and fishing endeavors, with comparably little manufacturing, industrial, and mining activity, meaning that rural livelihoods are inextricably linked to the production of food (Figure 30). Because agriculture is particularly vulnerable to many of the impacts of climate change, rural livelihoods face a disproportionately high level of risk exposure to climate-induced shocks. In the low-density and very-low-density rural clusters, more than one-quarter of the population relies heavily on agriculture, with the agricultural workforce employing a proportional share of the male wage-earning class. In comparison, very few women in rural areas are engaged in agricultural wage work.

FIGURE 30. Classification of gainful workers in the Philippines disaggregated by gender, sector, and urban-rural demographic.

In contrast, the manufacturing sector plays an important role in urban and suburban zones, employing approximately one-quarter and one-third of the total male wage-earning class, but negligible shares of females in either urban or rural sectors. The service sector is more equitably distributed between male and female wage-earners, constituting just over and just under one-quarter of the total population of each respective group in both urban and rural settings. This information is particularly relevant when we consider that poverty is negatively correlated with population with more people involved in manufacturing and services-oriented jobs (Figure 31). This would suggest that diversified employment opportunities help to counter some of the effects that predispose an individual to poverty, while the same might not be true for women, particularly in the manufacturing and agricultural sectors. As an aside, the recent disruption of manufacturing- and services-oriented jobs by the COVID-19 pandemic underscores the sensitivity of the service and manufacturing sectors to non-climate-related stressors.

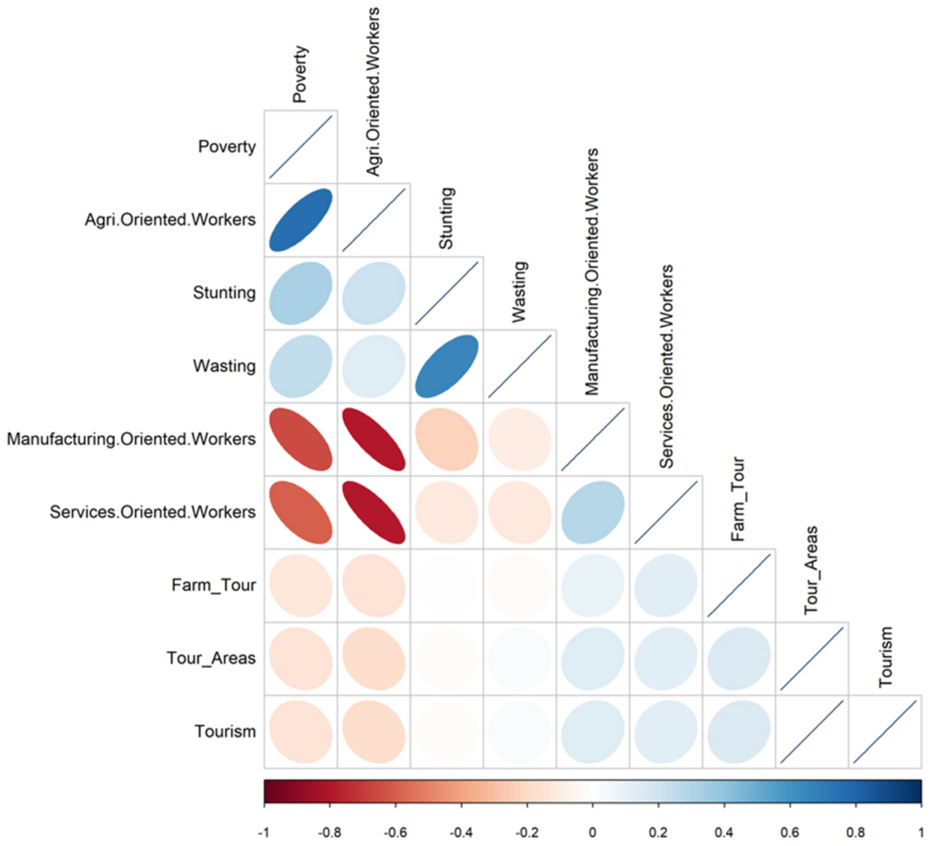


FIGURE 31. Graph depicting the relationships between different indicators of poverty and types of wage employment.

Moreover, across the Philippines, the "very low density rural" cluster is characterized by very high poverty, which is correlated with different health and nutrition indicators, such as stunting and wasting. The incidence of extreme poverty in these highly rural areas is compounded by the lack of diversity in sources of income, predisposing the sector to shocks that affect nutrition. However, the "dense urban" population cluster exhibits the second highest incidence of health and nutrition-related indicators, including high poverty, stunting, and wasting. As described in the literature review, particularly the poor urban populations living in informal settlements face food and nutrition challenges that are quickly and profoundly complicated by climate-related disasters and hazards.

ADDRESSING THE IMPLICATIONS

The question of access to food is underscored by the potential for climate change to create food price shocks that exacerbate food insecurity in both urban and rural sectors. This is problematic in regions characterized by large urban populations that purchase food in the market, relying very little on their own food production, and especially so where a disproportionately large percentage of the household income is dedicated to food purchases (Figure 32). For example, Region III in Luzon, Region VIII in the Visayas, and Regions X and XIII in Mindanao all exhibit large portions of the population that purchase food exclusively (or, in the case of Regions X and XIII predominantly (75% or more)) from the market and spend more than half of their household income buying food. At the same time, many rural areas that offer few alternative income sources to agriculture, and particularly where substantial portions of income are spent on food, are similarly at risk. These findings are based on the results of the survey conducted that was spatially linked to the Livelihood Zones Map.

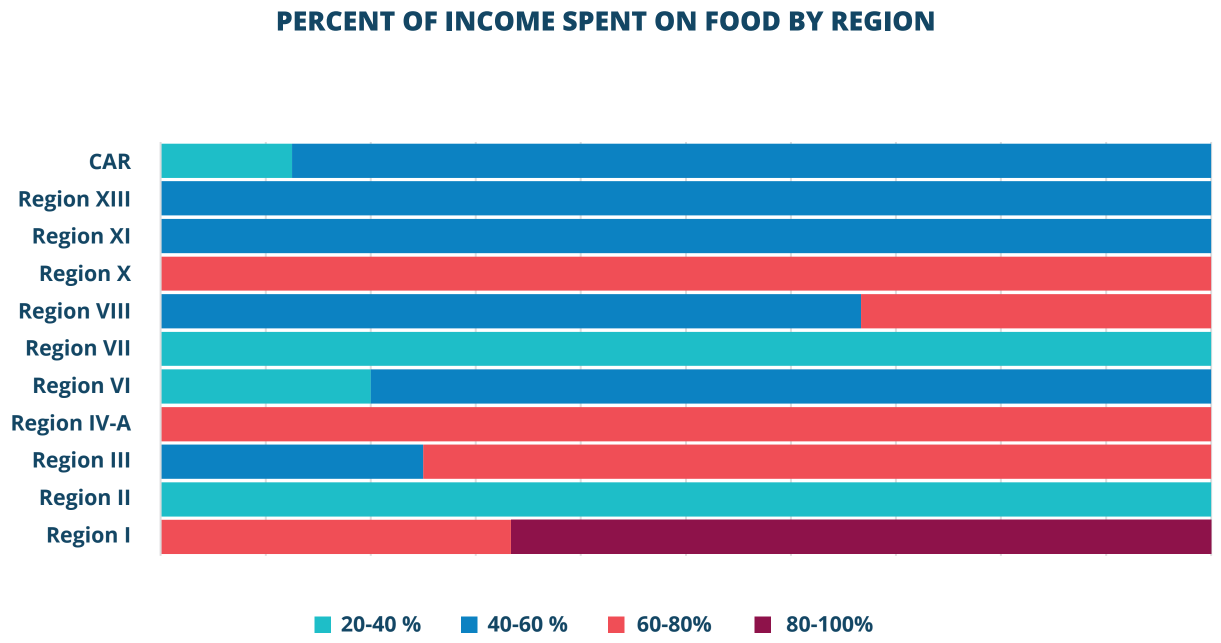


FIGURE 32. Percentage of income spent on food across regions in the Philippines.

Because the effects of climate change on food and nutrition security will vary so significantly across demographics in the Philippines, it is important to consider the existing coping and adaptation strategies that are employed by different sub-sectors of the population. Some adaptive behaviors that are considered positive coping strategies are income diversification; informal loans, whether financial, food, in-kind, or otherwise; and migration inspired by opportunities (pull factors). Negative coping strategies might involve decreasing food intake, eating less diverse foods, preferential feeding of the children or specific family members, heavy borrowing, and overreliance on foreign remittances or domestic money transfers (Pajaron, 2014). This is crucially important for understanding how communities that farm heterogeneous crops, livestock, and/or fish will be able to cope with the impact of climate-related hazards that affect entire areas or food systems. Likewise, it is critical to consider how urban populations can ensure access to affordable food and water sources in an urgent event and in a day-to-day context.

3.2. Climate-sensitive zones in the Philippines

3.2.1. CLIMATE-SENSITIVE FOOD SECURITY ZONES

Spatial distribution, incidence, and risk of climate-related hazards in the Philippines vary across geographic areas. To capture this spatial variability, we used official government and open-source databases to map hazard risks. To match the data with the livelihood zones and socioeconomic dataset, we represent hazard risk at the municipality level. Figure 33 shows the risk level (from very low to very high) for each of six major hazards (typhoon, flood, drought, storm surge, sea-level rise, and saltwater intrusion) for each municipality. The assessment of risk level is based on historical analyses. The typhoon risk map broadly agrees with the map generated by Cinco et al. (2016). While typhoon, drought, and flood are the major threats to food security, sea-based hazards were also considered to capture the scope of risks in the Philippines. The spatial distribution and differences in risk level were used as bases to identify risk patterns using cluster analysis.

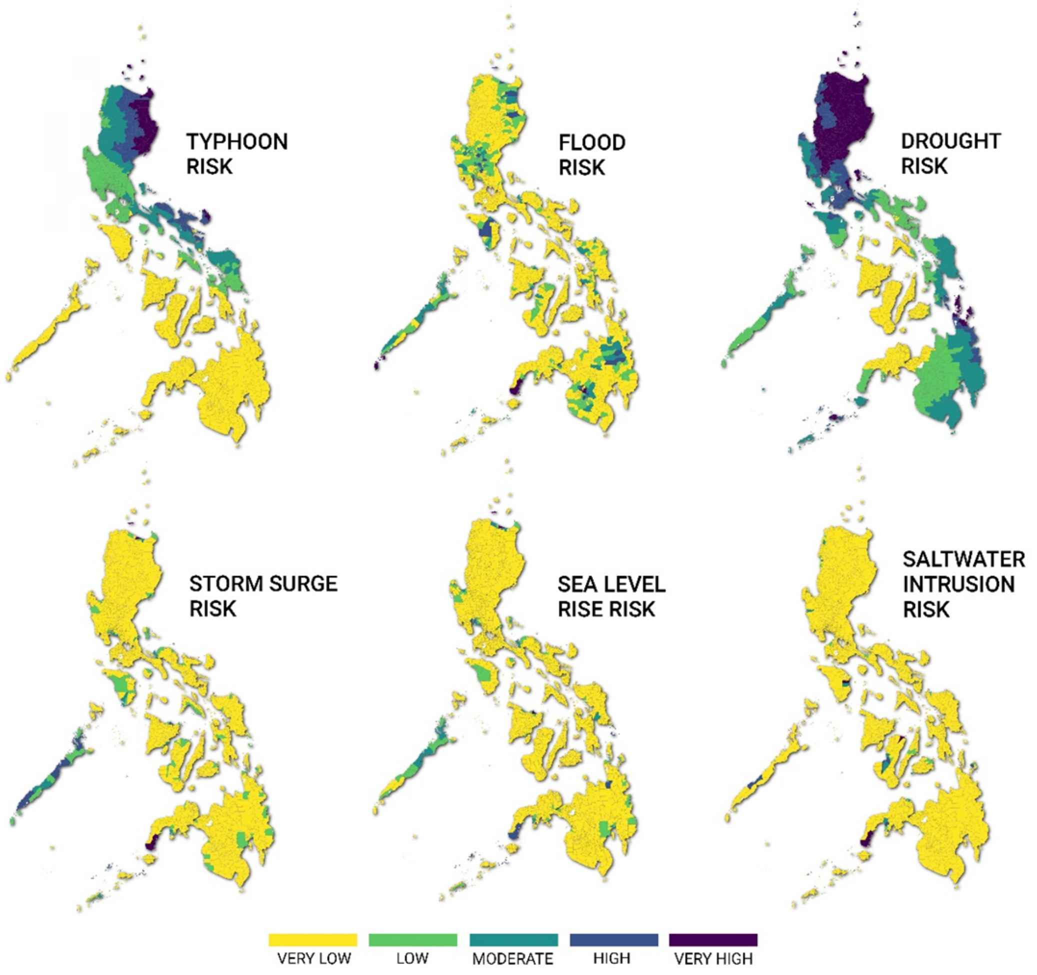


FIGURE 33. Risk level mapping for six major climate-related hazards in the Philippines.

In order to cluster the information on hazards, we used hierarchical clustering based on Ward's method with K-means for data partitioning. The optimal number of clusters was determined based on the inertia gain in the hierarchical tree. The clustering analyses were designed to produce groups of hazard risks that experienced similar patterns. Four clusters were ultimately generated from the analysis and each cluster was characterized to analyze the key threat to food security and nutrition (Figure 34).

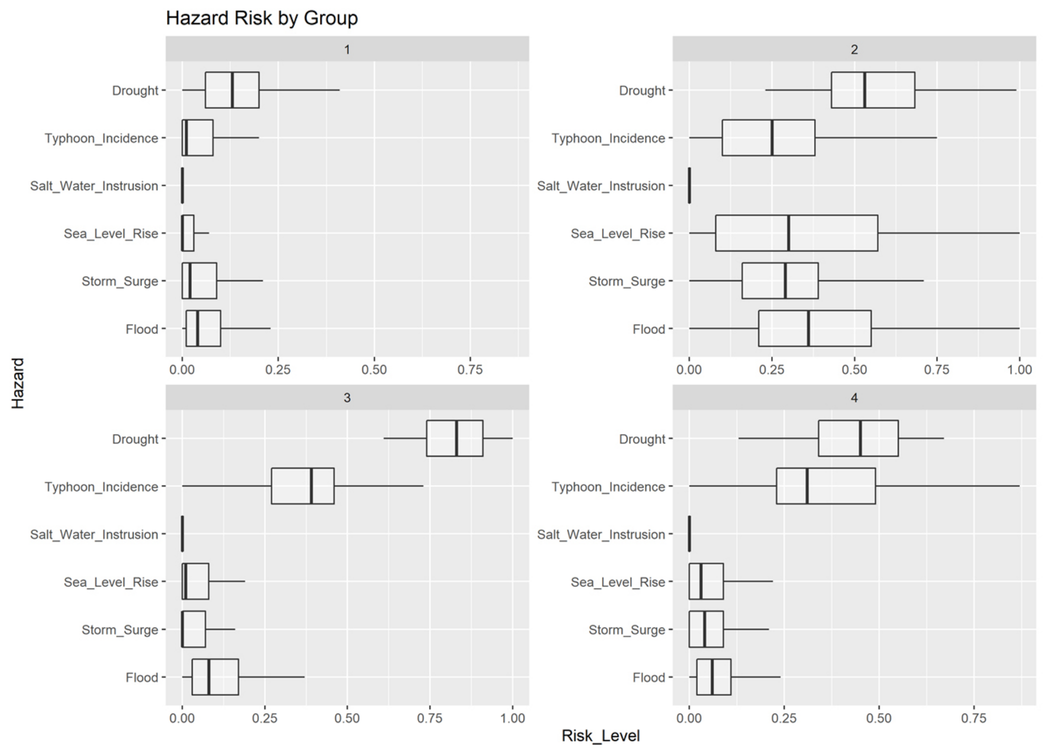


FIGURE 34. Four main hazard clusters in the Philippines, with details regarding the risk level of each component hazard.

Each of the four identified hazard risk clusters features livelihood zones, and hence subpopulations, that are particularly vulnerable to different unique and combined climate hazards that are considered to have serious implications for food security. In Cluster 1, the potential climate risks are less severe than in other cluster areas; however, the livelihood indicators regarding the prevalence of poverty and the dependency on agriculture are the highest of any group, indicating that this cluster is among the most vulnerable to climate risk due to the preexisting demographic context. The high incidence of multidimensional poverty implies that populations in this cluster would have an especially difficult time coping with, and are unlikely able to adapt to, the impacts of climate risks.

In Cluster 3, drought poses the most significant risk, although typhoon risks are present, and some low-lying areas are exposed to flooding. Despite these risks, Cluster 3 is slightly less vulnerable because the incidence of poverty is much lower than in the rest of the country. This can be explained by the generally strong economic activity throughout this cluster, which creates diverse income sources and less dependence on agriculture as the sole source of livelihood. The Philippine Statistics Authority in 2015 profiled Cluster 4 as having a high incidence of poverty. These areas are dominated by typhoon and drought, with some coastal areas and low-lying areas also suffering from flooding and storm surges. Because of the variable climatic conditions, food prices can be volatile, which can affect poor communities' access to food during and after the occurrence of extreme climate events. Moreover, communities in this area largely depend on agriculture as the main source of income. In a cyclical manner, agriculture is highly sensitive and exposed to climate-related risks, which can exacerbate poverty driven by income losses, which can affect the capacity to access food. Based on future historical data from 1951 to 2013, we observe a consistently increasing trend in economic losses and damage due to more occurrences of extreme typhoons, which is expected to continue and worsen by 2050 (Cinco, 2016).

In the past, one of the major risks associated with climate-related disasters like those profiled in the hazard risk clusters above was food price volatility. In the wake of significant climatic events such as major typhoons and floods that caused widespread destruction to the agricultural sector, there has been a corresponding increase in the prices of basic goods, particularly food items (NEDA, 2015). In the past decade, typhoons Yolanda, Rolly and Ulysses have all led to major food inflation that has had a direct influence on the incidence of poverty in the most impacted areas and across the food supply chain. The threats to the food systems featured in these prioritized climate risk clusters, coupled with an already vulnerable population that is ill-equipped to cope with disaster, make these clusters high-priority zones for adaptation preparedness (Figure 35).

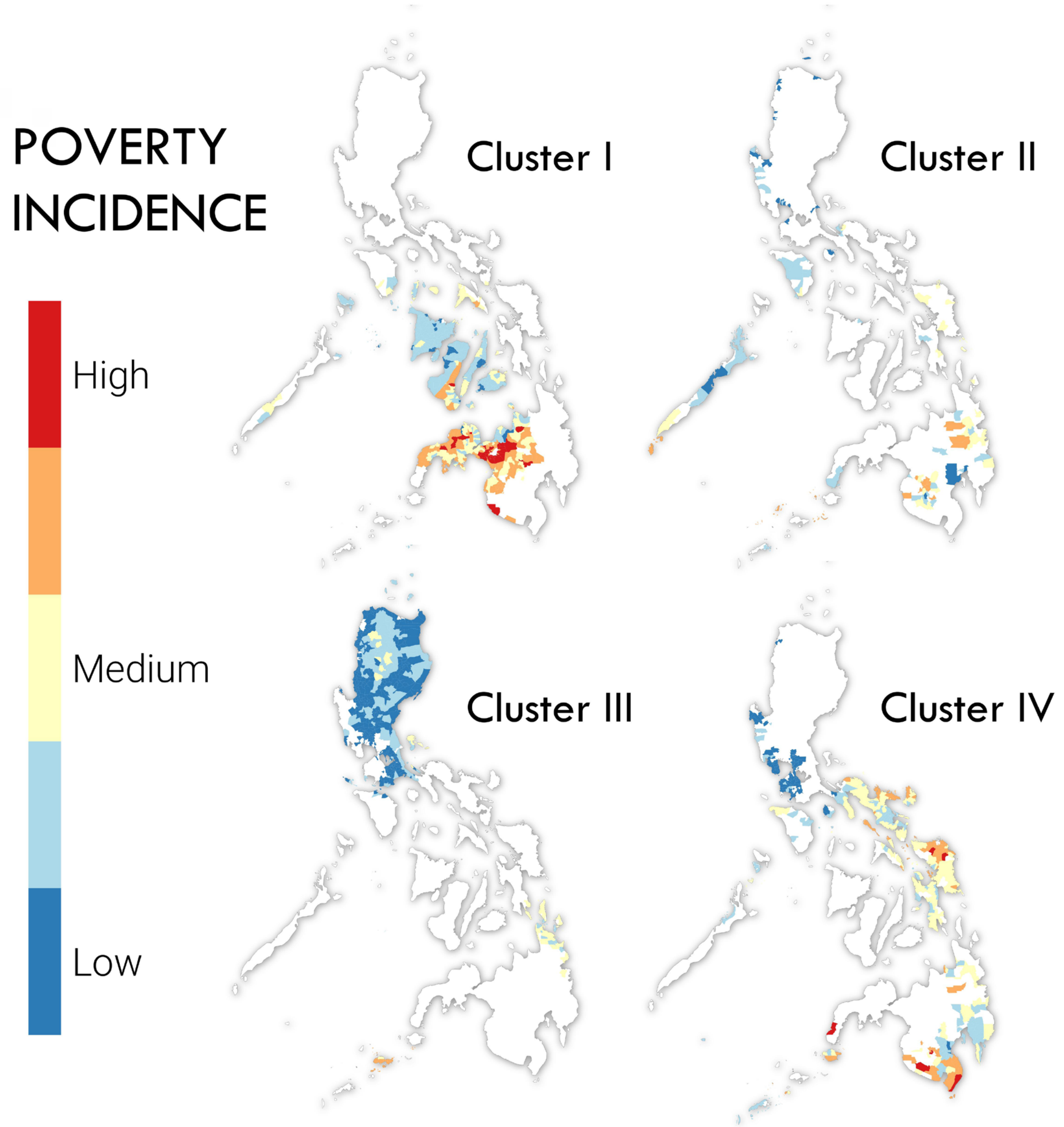


FIGURE 35. Map of the four main hazard clusters in the Philippines, with details regarding poverty incidence.

3.2.2. CLIMATE-SENSITIVE NUTRITION ZONES

In order to identify the areas where climate change poses the greatest risks to nutrition, we characterized groups of landscapes based on demographic information relating to food security and nutrition, such as poverty, wasting, and accessibility. Prior to overlaying climate hazards and crop mapping, it was important to develop an accurate mapping of groups that are socially vulnerable based on factors that contribute to malnutrition such as childhood stunting and wasting, including high levels of poverty and inaccessibility (Figure 36). These populations are considered particularly vulnerable to potential shocks, which are likely to further aggravate their conditions in both the short and long term. The study used human settlement classification to group populations based on population density, ranging from very low density rural to dense urban clusters.

The classification analysis found that, across the Philippines, the very low density rural cluster is characterized by very high poverty and the greatest prevalence of stunting and wasting. The incidence of more extreme poverty in these highly rural areas is compounded by the lack of diversity in sources of income, predisposing the sector to shocks that affect nutrition. Because the predominant settlement pattern in the Philippines is rural and agriculture-based, this underscores the fact that the majority of livelihoods are exposed to climate-induced risks and shocks. At the same time, populations in the dense urban cluster are the second most vulnerable to high poverty, stunting, and wasting. As described in the literature review, particularly the poor urban populations living in informal settlements face food and nutrition challenges.

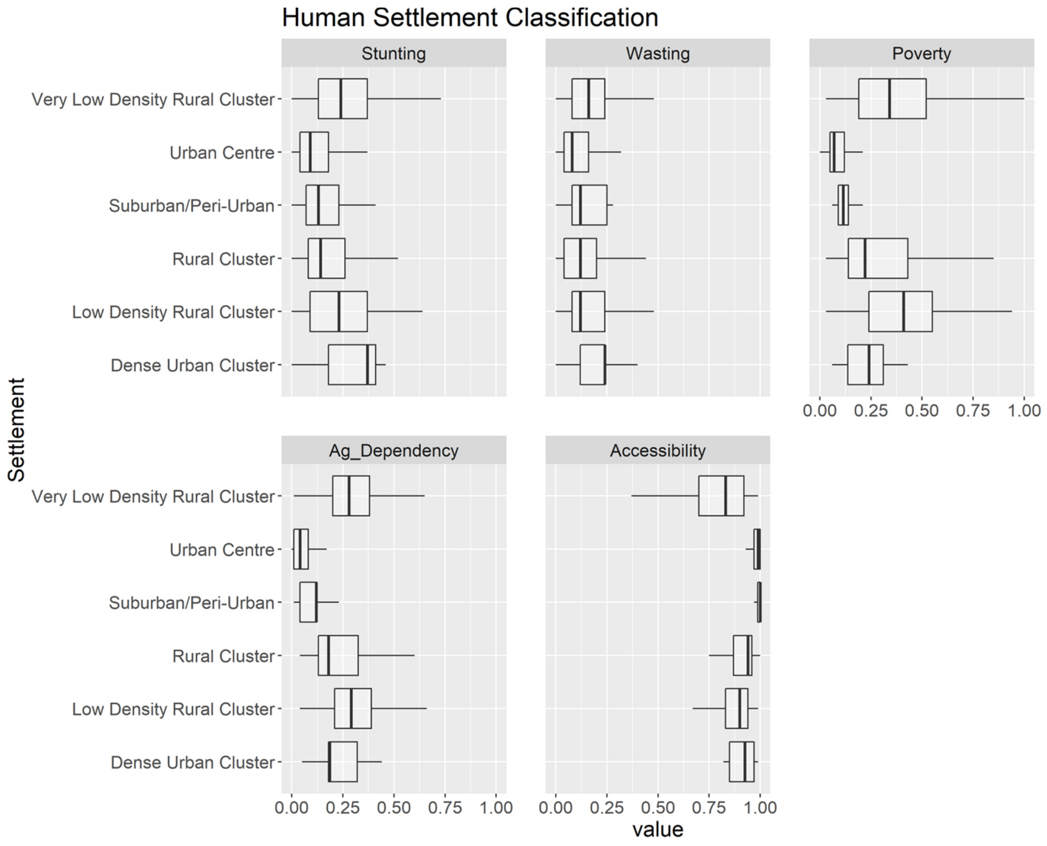


FIGURE 36. Nutrition-sensitive impact on human settlement classification.

By analyzing the human settlement clusters in terms of the spatial distribution of different climate-related hazards, we identified areas where climate change poses the greatest risk to nutrition in the Philippines. Figure 37 identifies four clusters of nutrition-sensitive climate risks. Cluster 1 definitely has very low hazard risks, Cluster 2 is high in drought and flood, and Clusters 3 and 4 are high in drought and typhoon. The map indicates the areas where high prevalence of malnutrition among children under five years (identified using indicators for stunting and wasting) coincides with the greatest exposure to climate-related hazards, such as typhoon, drought, and flood events (Cluster 3) or flooding and drought but not typhoon (Cluster 2).

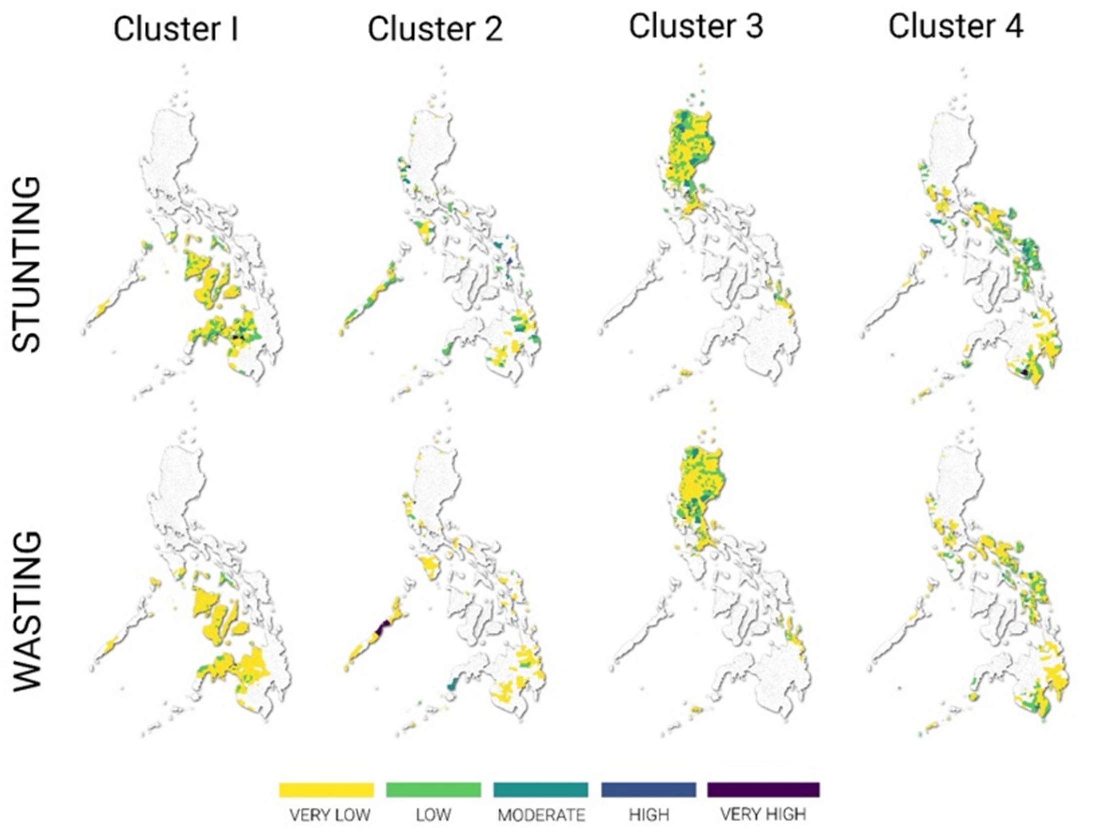


FIGURE 37. Nutrition-sensitive impact areas based on climate-hazard cluster. The wasting and stunting data were normalized before overlaying on each cluster.

Based on this analysis, we can identify some of the populations that are the most vulnerable to the impacts of climate change on nutrition. For example, Puerto Princesa City in Region IV-B in Luzon is a municipality dominated by a highly urbanized livelihood zone, where the population, characterized by a high incidence of wasting and moderate stunting, will be exposed to several climate-related hazards, including storm surges, flood, drought, and sea-level rise (Cluster 2). When exposed to these climate shocks, the population of Puerto Princesa City will likely face challenges accessing basic needs, including an adequate food supply which will, in turn, contribute to a higher incidence and degree of poverty.

Similarly, in the Mindanao group of islands, particularly in South Cotabato, we find that vulnerable populations will be especially at risk to drought and flooding (Cluster 4). The municipalities of Banga and Tampakan, characterized by perennial crops such as coconut, banana, and mango, and the municipality of T'Boli, characterized by vegetable production, are projected to be among the hardest hit by climate-related hazards. Meanwhile, in the Visayas group of islands, particularly in Samar, stunting and wasting commonly fall under the high to very high category in many municipalities, including Laoang, Mapanas, San Roque, and Silvino Lobos (Northern Samar) and Calbayog City, Gandara, San Jorge, San Jose de Buan, Motiong, and Basey (Samar). These areas are all characterized by annual vegetable production livelihood zones that are heavily at risk to both drought and flooding (Cluster 4).

4. Conclusion

The CCFSA study aims to enhance the understanding of the potential risks and impacts of climate change on food security and nutrition in the Philippines. Climate variability and hazards are projected to continue having a substantial impact on agricultural, livestock, and fishery supply chains that will affect all aspects from production to distribution to consumption across both urban and rural sectors. This in turn affects the availability, affordability and accessibility to nutritious food, particularly for the most vulnerable, poor and marginalized populations.

By analyzing climate change through both geospatial and livelihood lenses, this study highlights that the effects of climate change and climate hazards can significantly vary at the local and regional level, and also nationwide for particular types of livelihoods. Both the urban and rural poor that are already afflicted by indicators of food and nutrition insecurity are the most vulnerable, particularly rural families whose livelihoods are almost exclusively dependent on agricultural income. They are generally also the most vulnerable to hazards and shocks due to the compounding loss of productive and non-productive assets as well as the lack of alternative sources of income.

Understanding the key risks and vulnerabilities such as through this highly localized analysis of climate-related impacts on critical value chains and livelihood groups is a first, yet very important, step in order to identify the most appropriate policies and programmes that WFP, the Philippine government, and partners should consider in their effort towards building resilient food systems and achieving Zero Hunger. As part of the CCFSA study, WFP and CIAT have built a database containing 71 indicators including crop suitability data based on medium- and long-term climate projections for key types of crops, climate risk susceptibility index for selected natural hazards, socio-economic indicators and rural-urban dynamics. The overlay of livelihood zones, crop suitability, hazard index and socio-economic data at the city and municipal level, as shown in this report, can provide national agencies and provincial governments with important data-driven insights to inform the design of tailored climate change adaptation and mitigation measures.

Both informal and formal coping strategies have supported and will continue to support households against the impact of climate change and extreme climate hazards. However, tailored measures aimed at mitigating the effects of shocks and preparing households to adapt can go a long way in decreasing the incidence and severity of food and nutrition insecurity across the country. These can include inclusive programmes and policies aimed at strengthening food production and distribution systems as well as enhancing producers' and consumers' access to efficient value chains for prioritized nutritious foods in order to improve the communities' resilience to severe climate shocks.

In addition, context-sensitive programmes and policies that facilitate the provision of technical support and inputs to smallholder farmers for crop and livelihood diversification, the enhanced access of farmers to agricultural macro- or micro-insurance and credit schemes, as well as the construction and rehabilitation of disaster- and climate-resilient rural infrastructure and assets, can help tackle the key risks identified in this report.

Finally, adapting, strengthening, and scaling up shock-responsive social safety net programs that are proven to be effective in supporting vulnerable communities before and right after extreme climate hazards will be an important component of an effective national strategy towards food security, especially in the new reality of compound disasters that the COVID-19 pandemic has highlighted at a global scale.

It is now more apparent than ever that we need to shift from recurrent crisis response to forward-looking climate risk management. Moreover, we need to develop proactive plans and programmes that take into account the systemic nature of current and future disaster risks and how impacts from different hazards interact with and reinforce each other. Solutions that address medium- to long-term climate risks are necessary to complement the groundbreaking disaster risk management initiatives being implemented in the Philippines at the moment, with key innovations being scaled-up including forecast-based anticipatory actions to mitigate losses and damages from predictable climate hazards, and the development of last-mile climate information services that enable smallholder farmers to make informed decisions against climate variability and change.

Going forward, WFP will work with the Philippine government and partners to identify and co-develop the most appropriate policies and programmes to implement in order to prepare for climate risks, respond to climate-related disasters and adapt to longer-term climate change. This next step will also include working with provincial and local government actors to enhance their awareness and capacity to integrate these climate risk data and analytical insights into their planning processes to help address future climate-related impacts on communities' food security and livelihoods.

Overall, there is a need to develop a comprehensive and strategic approach at country level to better understand, prepare for and manage these risks across different timeframes – from the current season to the coming decades. Accordingly, as a next step to fully utilizing this rich foundation of data, WFP will continue to support governments at all levels to conduct additional analyses, including at regional level, on specific crops or other priority topics of concern. These will be published in the form of complementary thematic reports.

It is the hope of WFP that the CCFSA study can provide academic institutions in the Philippines with the basic information and momentum to further pursue local-level analytical studies on the intersections of climate change and food security across the country, especially focusing on the geographically isolated and disadvantaged areas. Strengthening this type of multisectoral collaboration at the local and national levels will be invaluable in our joint effort to protect the most vulnerable against climate change and improve the resilience of Filipinos in the years to come.

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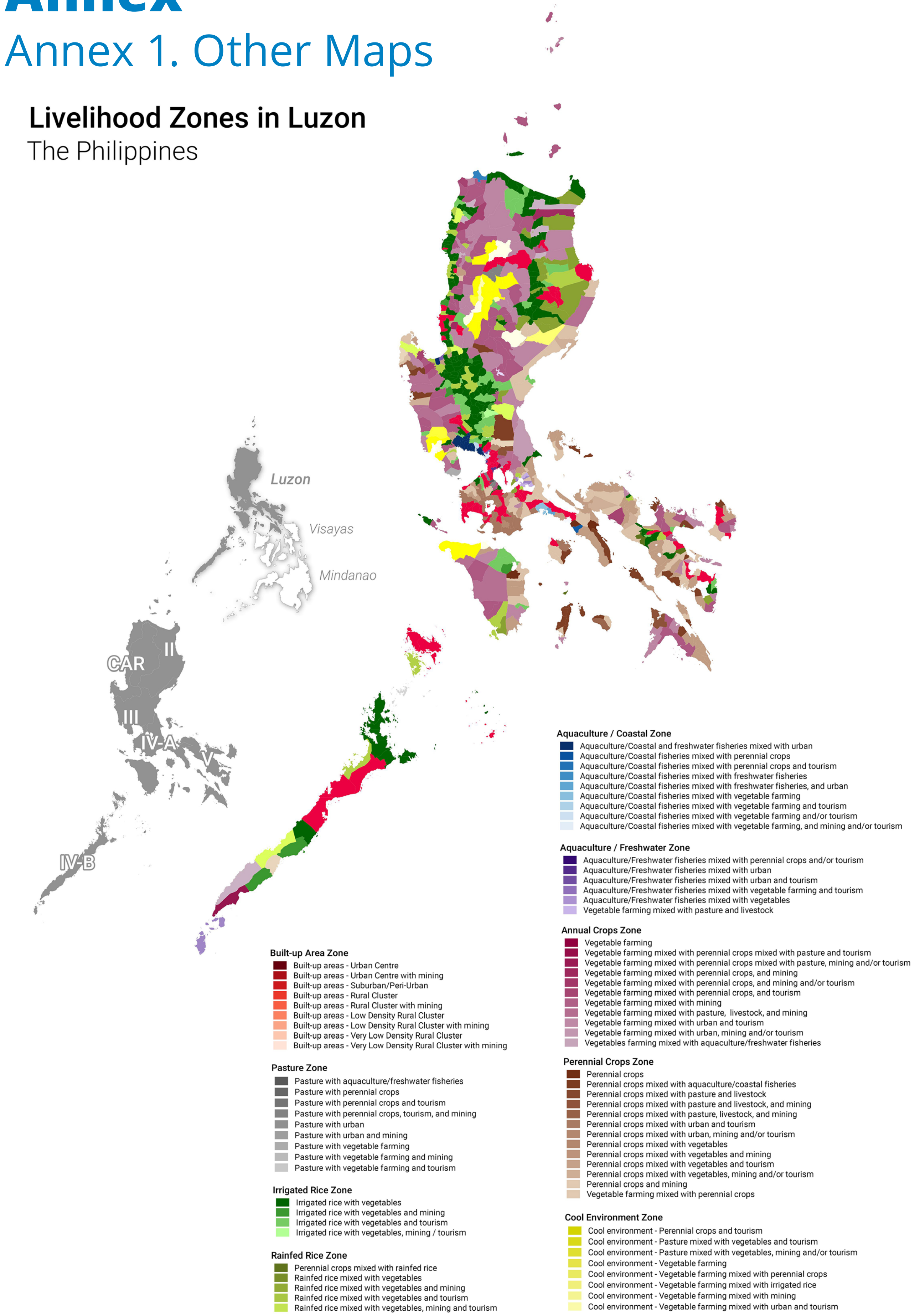
Annex

Annex 1. Other Maps

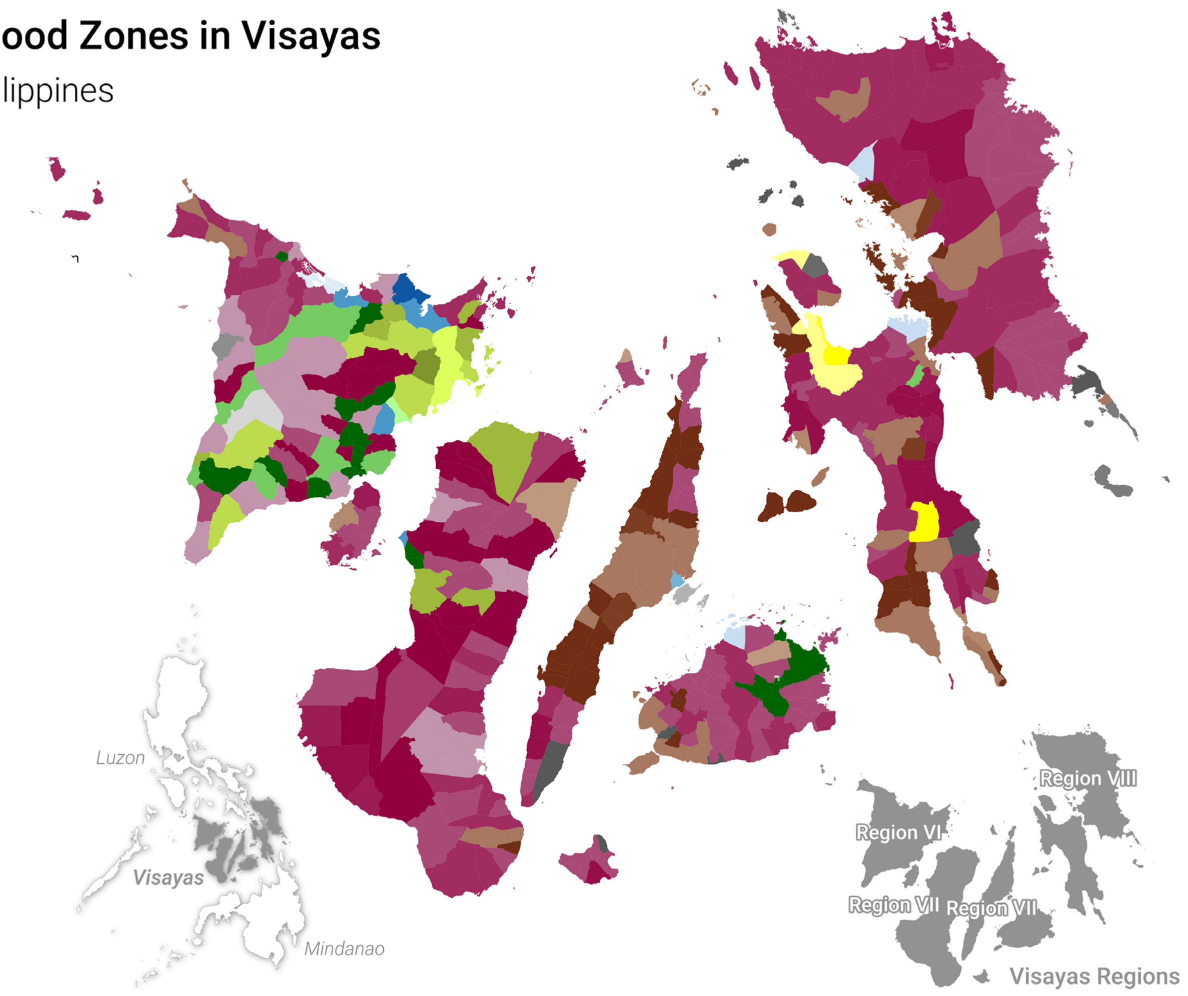
Livelihood Zones in Luzon

The Philippines



Livelihood Zones in Visayas

The Philippines



Aquaculture / Coastal Zone

- 🟦 Aquaculture/Coastal and freshwater fisheries mixed with urban
- 🟦 Aquaculture/Coastal fisheries with perennial crops
- 🟦 Aquaculture/Coastal fisheries with perennial crops and tourism
- 🟦 Aquaculture/Coastal fisheries mixed with freshwater fisheries
- 🟦 Aquaculture/Coastal fisheries mixed with freshwater fisheries, and urban
- 🟦 Aquaculture/Coastal fisheries mixed with vegetable farming
- 🟦 Aquaculture/Coastal fisheries mixed with vegetable farming and tourism
- 🟦 Aquaculture/Coastal fisheries mixed with vegetable farming and/or tourism
- 🟦 Aquaculture/Coastal fisheries mixed with vegetable farming, and mining and/or touri

Aquaculture / Freshwater Zone

- 🟪 Aquaculture/Freshwater fisheries with perennials and/or tourism
- 🟪 Aquaculture/Freshwater fisheries mixed with urban
- 🟪 Aquaculture/Freshwater fisheries mixed with urban and tourism
- 🟪 Aquaculture/Freshwater fisheries with vegetables and tourism
- 🟪 Aquaculture/Freshwater fisheries mixed with vegetables
- 🟪 Vegetable farming mixed with pasture and livestock

Annual Crops Zone

- 🟥 Vegetable farming
- 🟥 Vegetable farming mixed with perennial crops, pasture, and tourism
- 🟥 Vegetable farming mixed with perennials, pasture, mining and/or tourism
- 🟥 Vegetable farming mixed with perennial crops, and mining
- 🟥 Vegetable farming mixed with perennial crops, and mining and/or tourism
- 🟥 Vegetable farming mixed with perennial crops, and tourism
- 🟥 Vegetable farming mixed with mining
- 🟥 Vegetable farming mixed with pasture, livestock, and mining
- 🟥 Vegetable farming mixed with urban and tourism
- 🟥 Vegetable farming mixed with urban, mining and/or tourism
- 🟥 Vegetables farming mixed with aquaculture/freshwater fisheries

Perennial Crops Zone

- 🟫 Perennial crops
- 🟫 Perennial crops mixed with aquaculture/coastal fisheries
- 🟫 Perennial crops mixed with pasture and livestock
- 🟫 Perennial crops mixed with pasture and livestock, and mining
- 🟫 Perennial crops mixed with pasture, livestock, and mining
- 🟫 Perennial crops mixed with urban and tourism
- 🟫 Perennial crops mixed with urban, mining and/or tourism
- 🟫 Perennial crops mixed with vegetables
- 🟫 Perennial crops mixed with vegetables and mining
- 🟫 Perennial crops mixed with vegetables and tourism
- 🟫 Perennial crops mixed with vegetables, mining and/or tourism
- 🟫 Perennial crops and mining
- 🟫 Vegetable farming mixed with perennial crops

Cool Environment Zone

- 🟨 Cool environment - Perennial crops and tourism
- 🟨 Cool environment - Pasture with vegetables and tourism
- 🟨 Cool environment - Pasture with vegetables, mining and/or tourism
- 🟨 Cool environment - Vegetable farming
- 🟨 Cool environment - Vegetable farming mixed with perennial crops
- 🟨 Cool environment - Vegetable farming mixed with irrigated rice
- 🟨 Cool environment - Vegetable farming mixed with mining
- 🟨 Cool environment - Vegetable farming mixed with urban and tourism

Pasture Zone

- ⬛ Pasture with aquaculture/freshwater fisheries
- ⬛ Pasture with perennial crops
- ⬛ Pasture with perennial crops and tourism
- ⬛ Pasture with perennial crops, tourism and mining
- ⬛ Pasture with urban
- ⬛ Pasture with urban and mining
- ⬛ Pasture with vegetable farming
- ⬛ Pasture with vegetable farming and mining
- ⬛ Pasture with vegetable farming, and tourism

Rainfed Rice Zone

- 🟩 Perennial crops mixed with rainfed rice
- 🟩 Rainfed rice mixed with vegetables
- 🟩 Rainfed rice mixed with vegetables and mining
- 🟩 Rainfed rice mixed with vegetables and tourism
- 🟩 Rainfed rice mixed with vegetables, mining and tourism

Built-up Area Zone

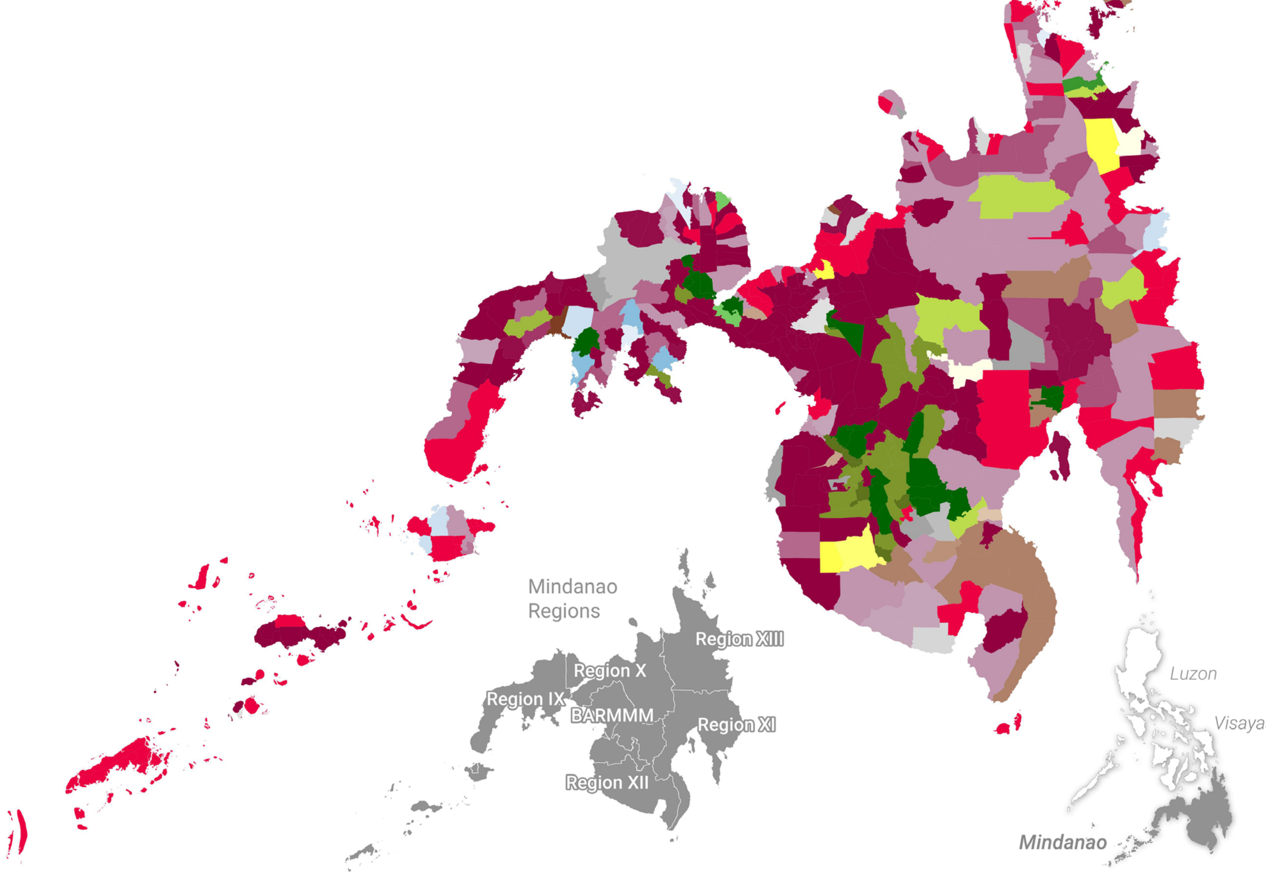
- 🟥 Built-up areas - Urban Centre
- 🟥 Built-up areas - Urban Centre with mining
- 🟥 Built-up areas - Suburban/Peri-Urban
- 🟥 Built-up areas - Rural Cluster
- 🟥 Built-up areas - Rural Cluster with mining
- 🟥 Built-up areas - Low Density Rural Cluster
- 🟥 Built-up areas - Low Density Rural Cluster with mining
- 🟥 Built-up areas - Very Low Density Rural Cluster
- 🟥 Built-up areas - Very Low Density Rural Cluster with mining

Irrigated Rice Zone

- 🟩 Irrigated rice with vegetables
- 🟩 Irrigated rice with vegetables and mining
- 🟩 Irrigated rice with vegetables and tourism
- 🟩 Irrigated rice with vegetables, mining, and tourism

Livelihood Zones in Mindanao

The Philippines



Aquaculture / Coastal Zone

- 🟦 Aquaculture/Coastal and freshwater fisheries mixed with urban
- 🟦 Aquaculture/Coastal fisheries with perennial crops
- 🟦 Aquaculture/Coastal fisheries with perennial crops and tourism
- 🟦 Aquaculture/Coastal fisheries mixed with freshwater fisheries
- 🟦 Aquaculture/Coastal fisheries mixed with freshwater fisheries, and urban
- 🟦 Aquaculture/Coastal fisheries mixed with vegetable farming
- 🟦 Aquaculture/Coastal fisheries mixed with vegetable farming and tourism
- 🟦 Aquaculture/Coastal fisheries mixed with vegetable farming and/or tourism
- 🟦 Aquaculture/Coastal fisheries mixed with vegetable farming, and mining and/or tourism

Aquaculture / Freshwater Zone

- 🟪 Aquaculture/Freshwater fisheries with perennials and/or tourism
- 🟪 Aquaculture/Freshwater fisheries mixed with urban
- 🟪 Aquaculture/Freshwater fisheries mixed with urban and tourism
- 🟪 Aquaculture/Freshwater fisheries with vegetables and tourism
- 🟪 Aquaculture/Freshwater fisheries mixed with vegetables
- 🟪 Vegetable farming mixed with pasture and livestock

Irrigated Rice Zone

- 🟩 Irrigated rice with vegetables
- 🟩 Irrigated rice with vegetables and mining
- 🟩 Irrigated rice with vegetables and tourism
- 🟩 Irrigated rice with vegetables, mining / tourism

Rainfed Rice Zone

- 🟩 Perennial crops mixed with rainfed rice
- 🟩 Rainfed rice mixed with vegetables
- 🟩 Rainfed rice mixed with vegetables and mining
- 🟩 Rainfed rice mixed with vegetables and tourism
- 🟩 Rainfed rice mixed with vegetables, mining and tourism

Built-up Area Zone

- 🟥 Built-up areas - Urban Centre
- 🟥 Built-up areas - Urban Centre with mining
- 🟥 Built-up areas - Suburban/Peri-Urban
- 🟥 Built-up areas - Rural Cluster
- 🟥 Built-up areas - Rural Cluster with mining
- 🟥 Built-up areas - Low Density Rural Cluster
- 🟥 Built-up areas - Low Density Rural Cluster with mining
- 🟥 Built-up areas - Very Low Density Rural Cluster
- 🟥 Built-up areas - Very Low Density Rural Cluster with mining

Annual Crops Zone

- 🟥 Vegetable farming
- 🟥 Vegetable farming mixed with perennial crops mixed with pasture and tourism
- 🟥 Vegetable farming mixed with perennials, pasture, mining and/or tourism
- 🟥 Vegetable farming mixed with perennial crops, and mining
- 🟥 Vegetable farming mixed with perennial crops, and mining and/or tourism
- 🟥 Vegetable farming mixed with perennial crops, and tourism
- 🟥 Vegetable farming mixed with mining
- 🟥 Vegetable farming mixed with pasture, livestock, and mining
- 🟥 Vegetable farming mixed with urban and tourism
- 🟥 Vegetable farming mixed with urban, mining and/or tourism
- 🟥 Vegetables farming mixed with aquaculture/freshwater fisheries

Perennial Crops Zone

- 🟫 Perennial crops
- 🟫 Perennial crops mixed with aquaculture/coastal fisheries
- 🟫 Perennial crops mixed with pasture and livestock
- 🟫 Perennial crops mixed with pasture and livestock, and mining
- 🟫 Perennial crops mixed with pasture, livestock, and mining
- 🟫 Perennial crops mixed with urban and tourism
- 🟫 Perennial crops mixed with urban, mining and/or tourism
- 🟫 Perennial crops mixed with vegetables
- 🟫 Perennial crops mixed with vegetables and mining
- 🟫 Perennial crops mixed with vegetables and tourism
- 🟫 Perennial crops mixed with vegetables, mining and/or tourism
- 🟫 Perennial crops and mining
- 🟫 Vegetable farming mixed with perennial crops

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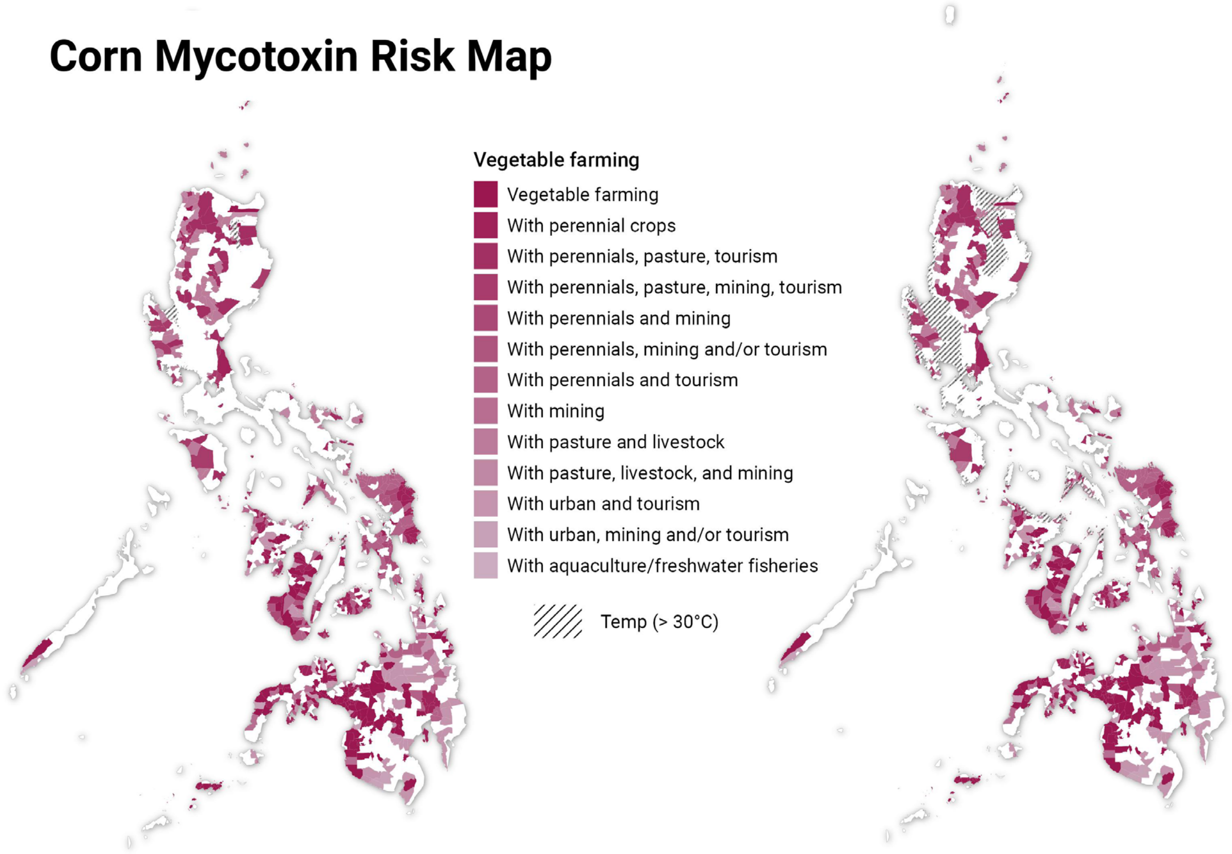
- 🟨 Cool environment - Vegetable farming mixed with mining
- 🟨 Cool environment - Vegetable farming mixed with urban and tourism

Pasture Zone

- ⬛ Pasture with aquaculture/freshwater fisheries
- ⬛ Pasture with perennial crops
- ⬛ Pasture with perennial crops and tourism
- ⬛ Pasture with perennial crops, tourism, and mining
- ⬛ Pasture with urban
- ⬛ Pasture with urban and mining
- ⬛ Pasture with vegetable farming
- ⬛ Pasture with vegetable farming and mining
- ⬛ Pasture with vegetable farming, and tourism

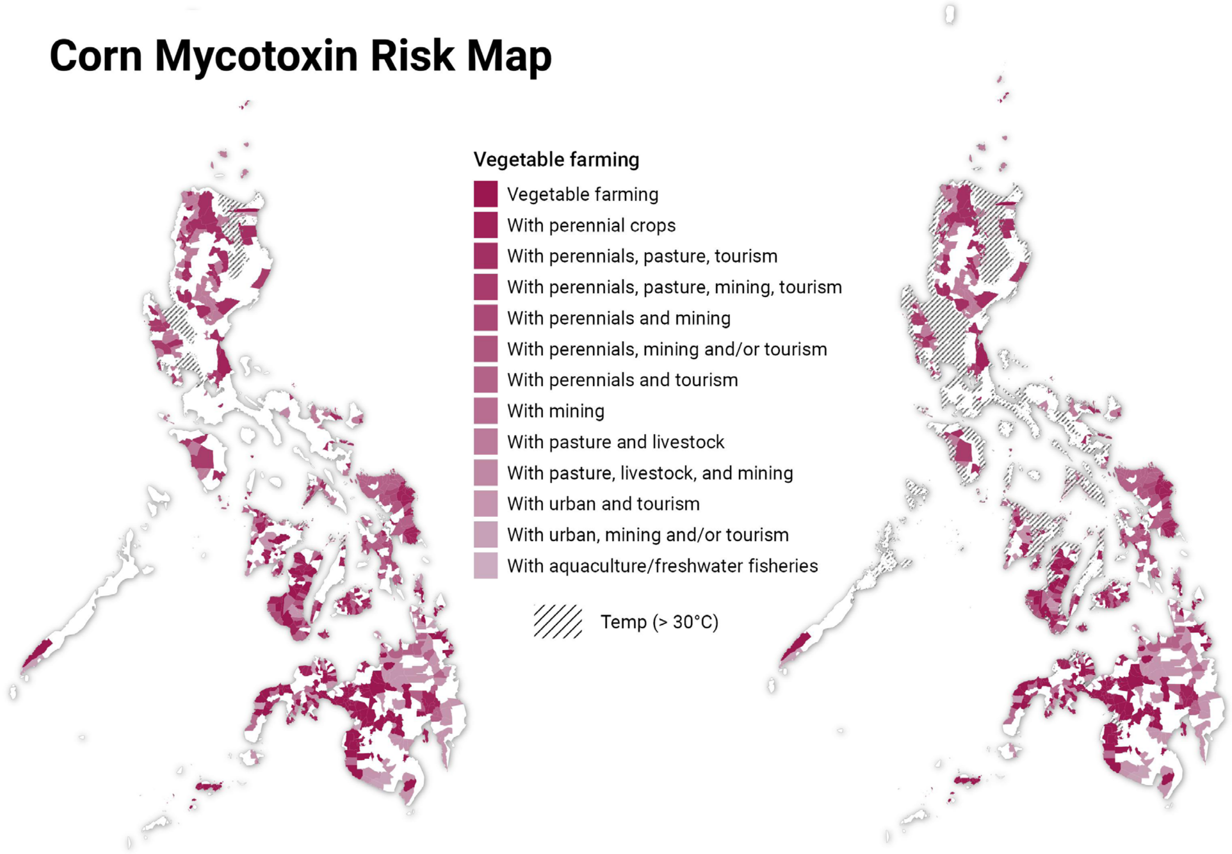
Corn Mycotoxin Risk Map



Year 2030 – RCP 4.5

Year 2050 – RCP 4.5

Corn Mycotoxin Risk Map



Year 2030 – RCP 8.5

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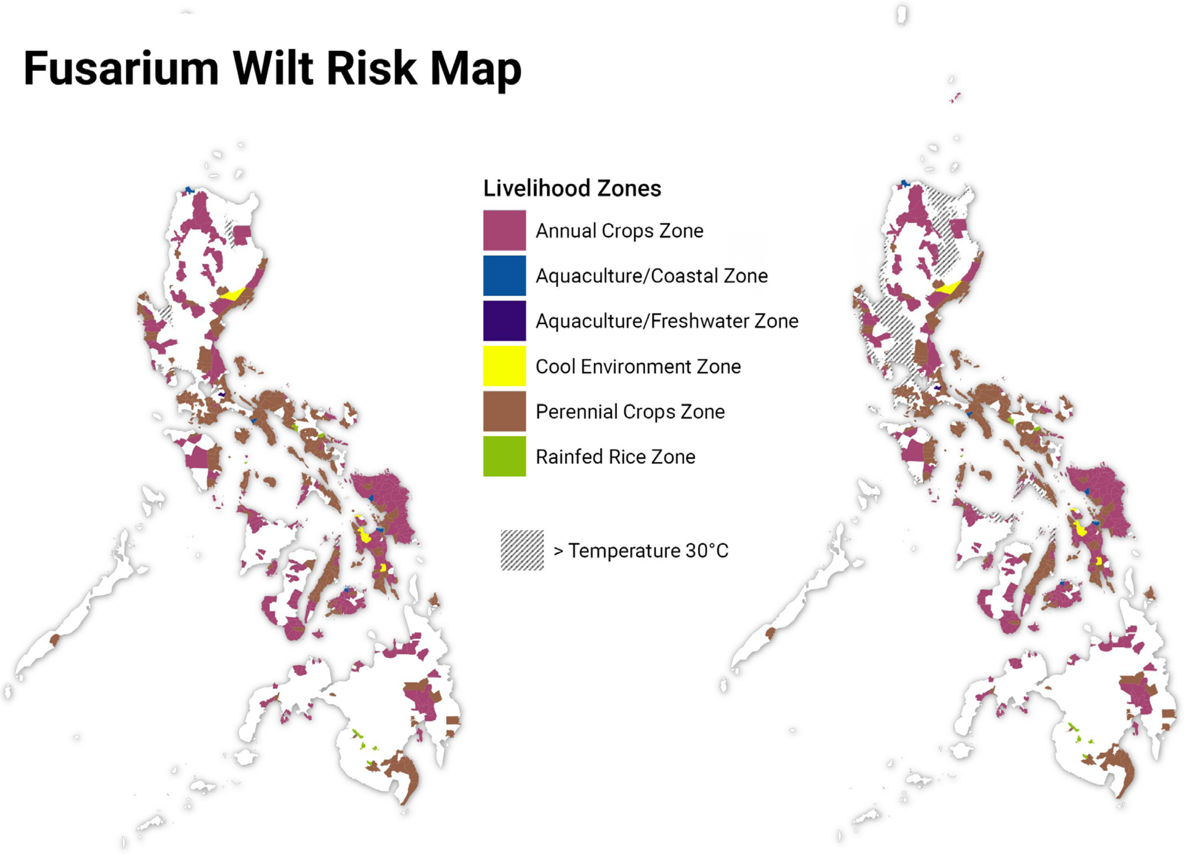
Fusarium Wilt Risk Map



Year 2030 – RCP 4.5

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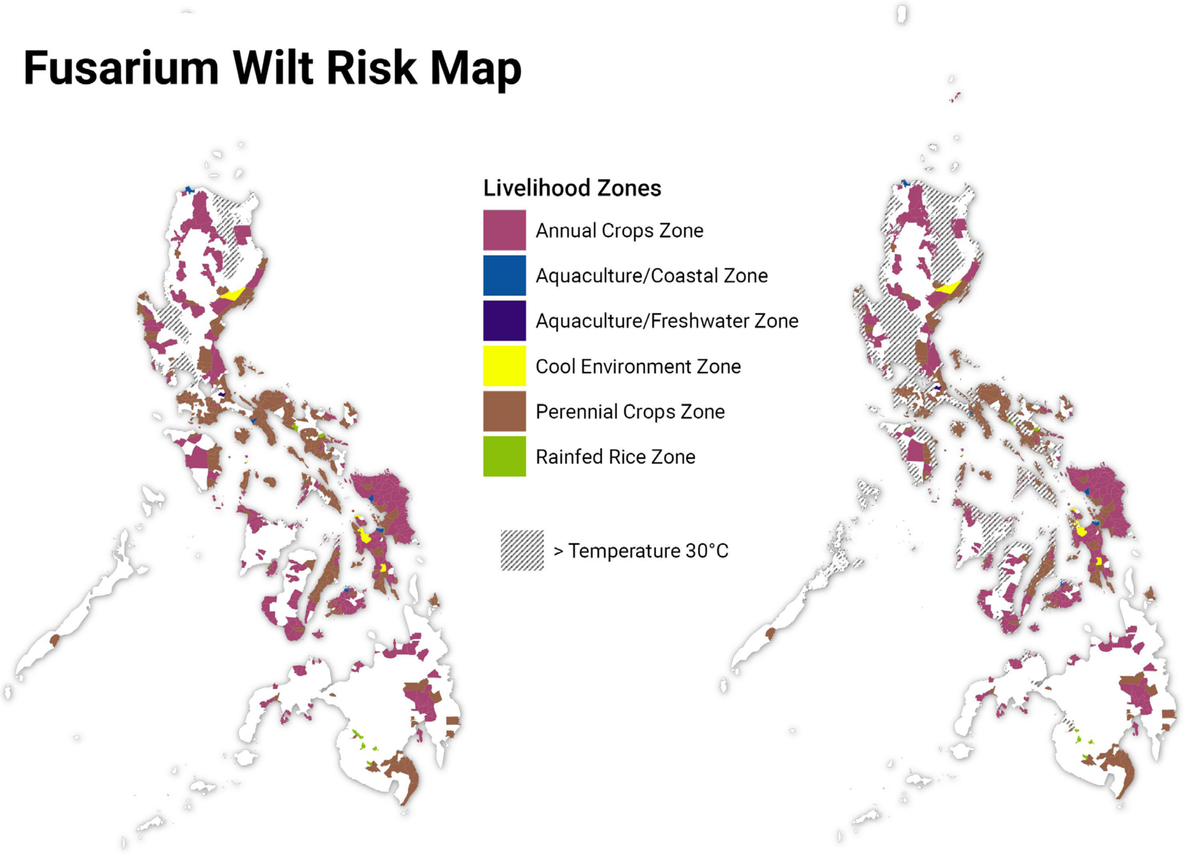
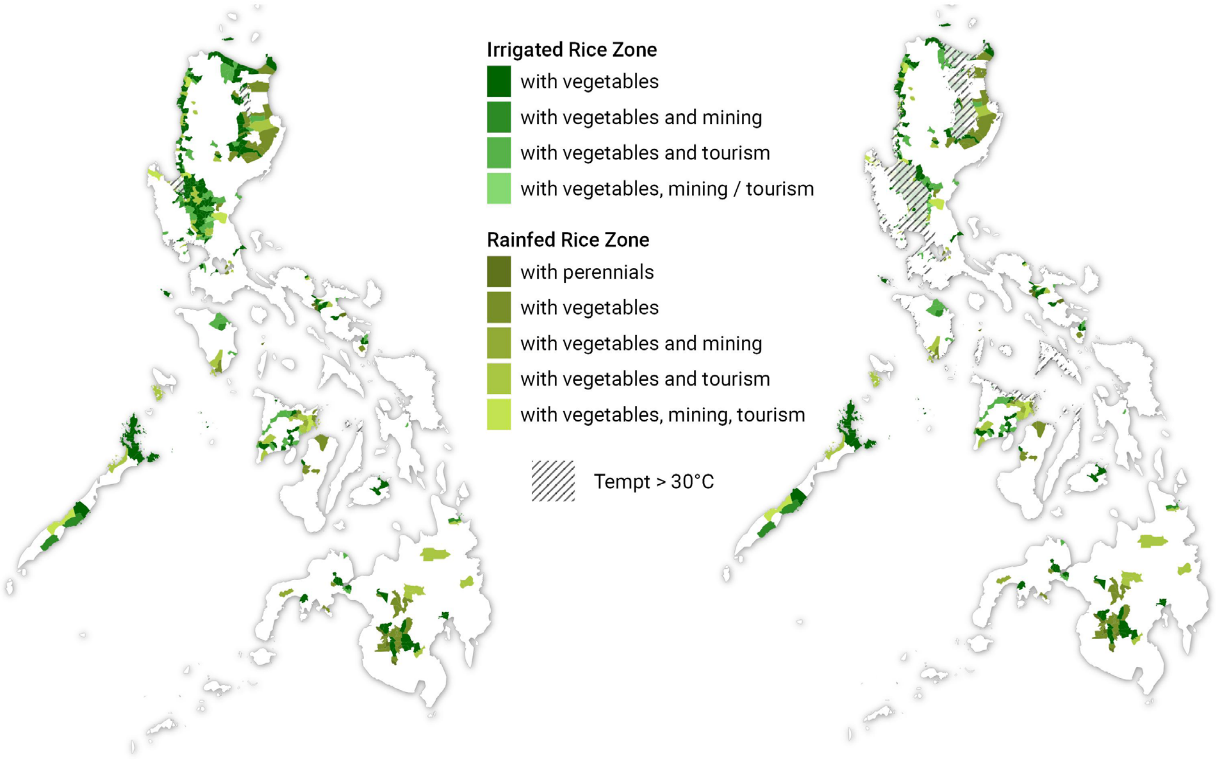
Fusarium Wilt Risk Map



Year 2030 – RCP 8.5

Year 2050 – RCP 8.5

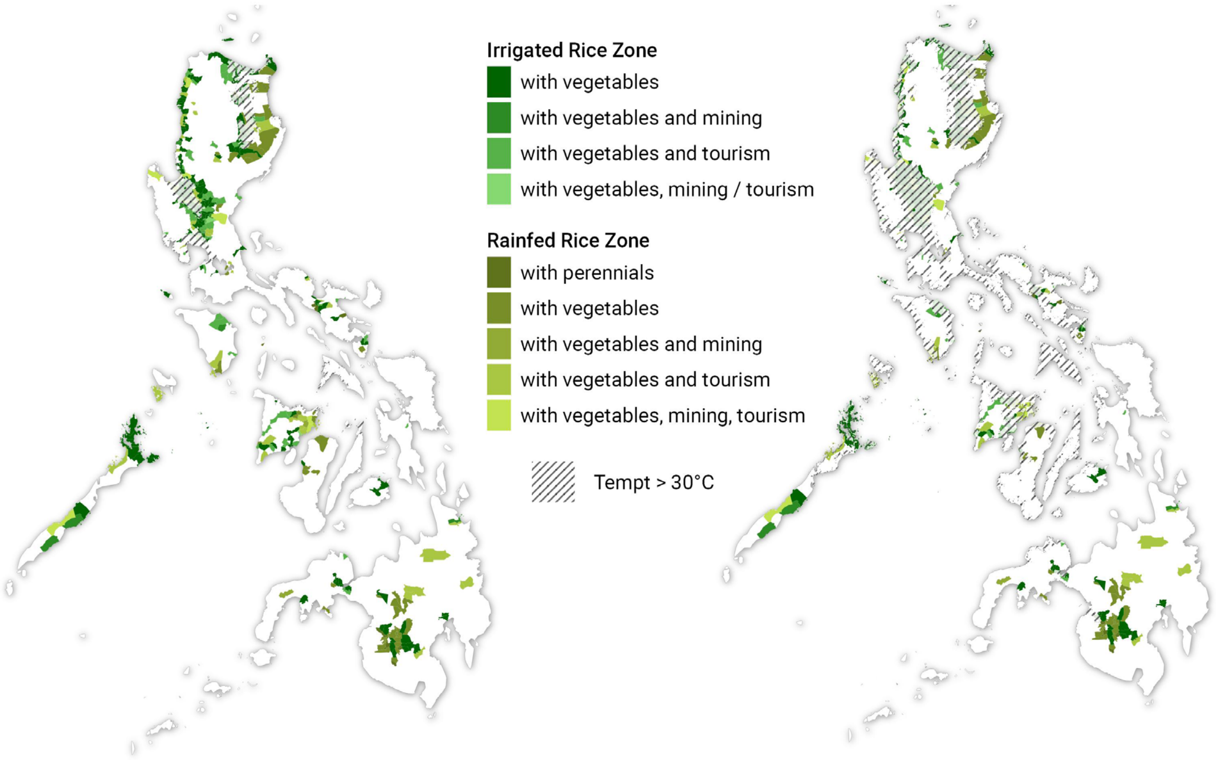
Northern Corn Leaf Blight Risk Map



Year 2030 – RCP 4.5

Year 2050 – RCP 4.5

Northern Corn Leaf Blight Risk Map



Year 2030 – RCP 8.5

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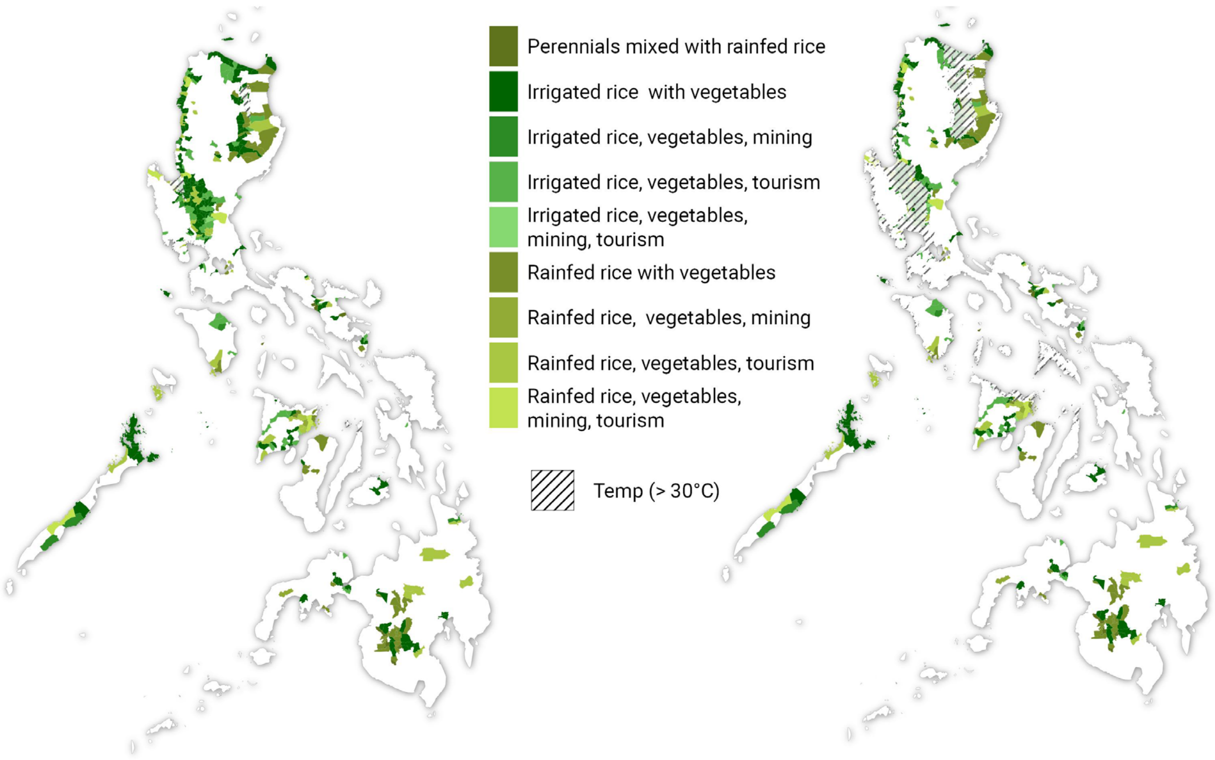
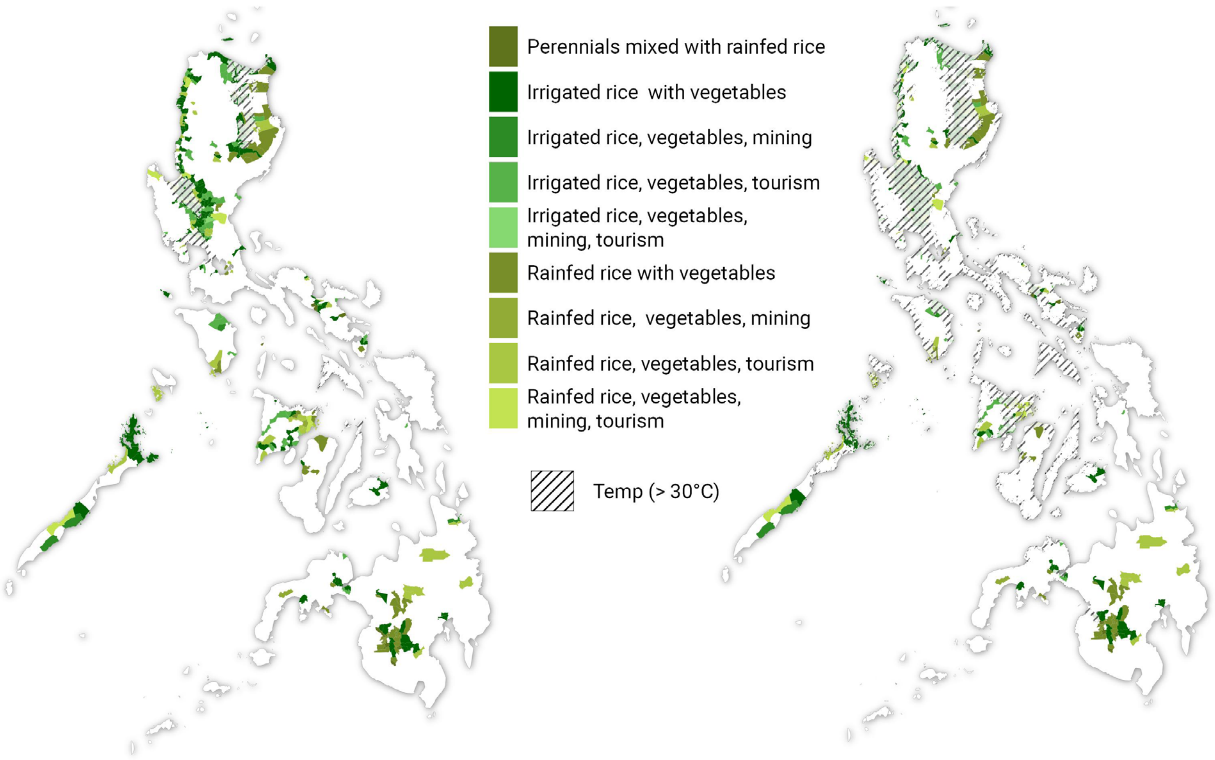
Rice Shealth Blight and Bacterial Leaf Blight Risk Map



Year 2030 – RCP 4.5

Year 2050 – RCP 4.5

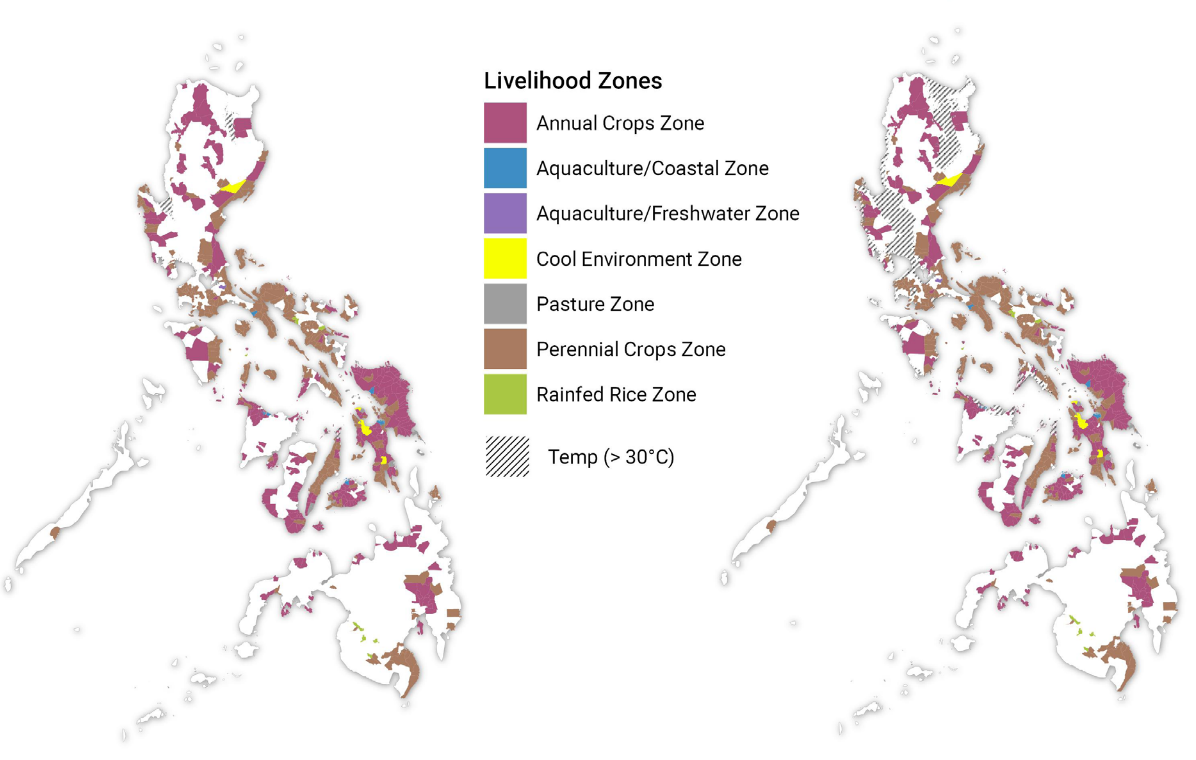
Rice Shealth Blight and Bacterial Leaf Blight Risk Map



Year 2030 – RCP 8.5

Year 2050 – RCP 8.5

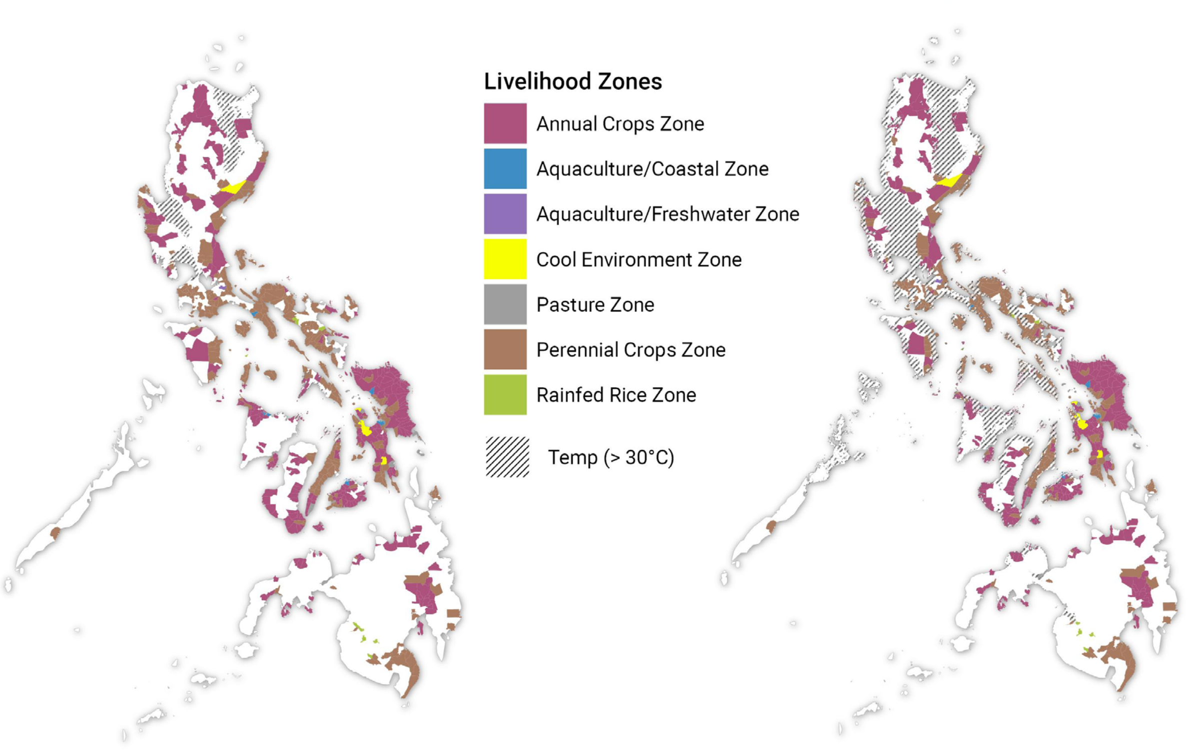
Black Sigatoka Risk Map



Year 2030 – RCP 4.5

Year 2050 – RCP 4.5

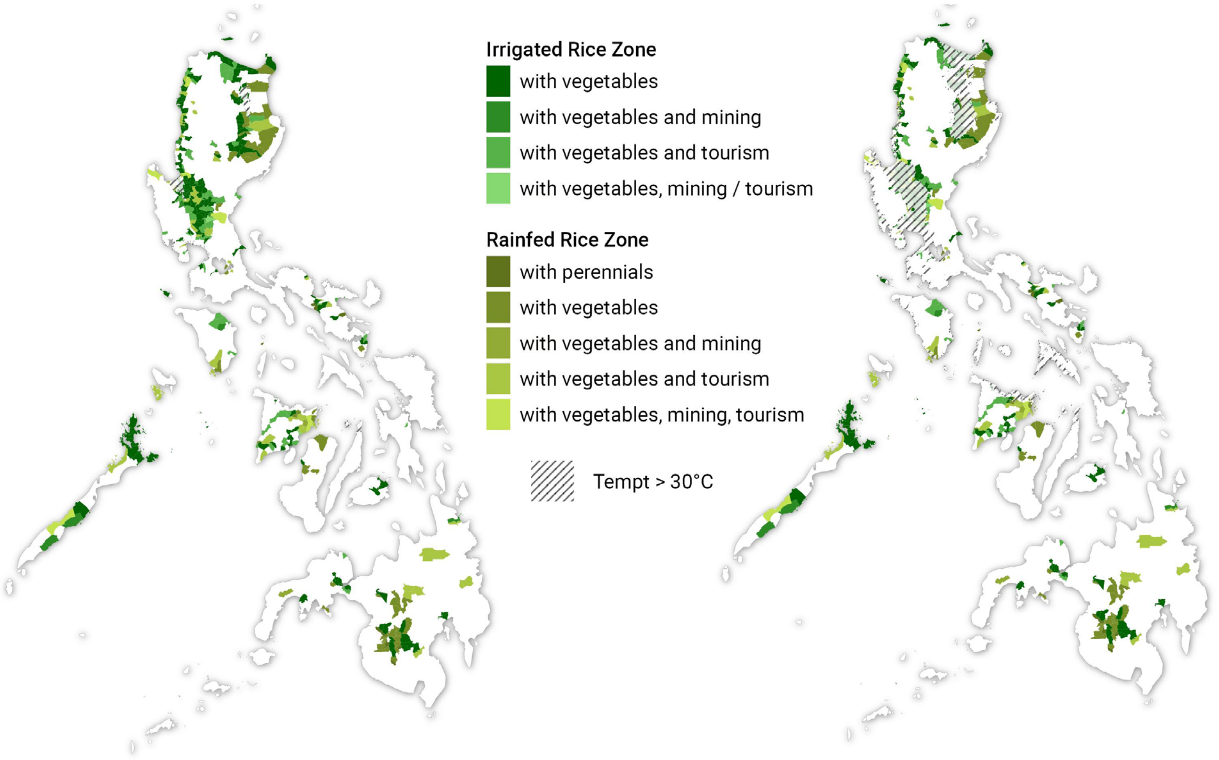
Black Sigatoka Risk Map



Year 2030 – RCP 8.5

Year 2050 – RCP 8.5

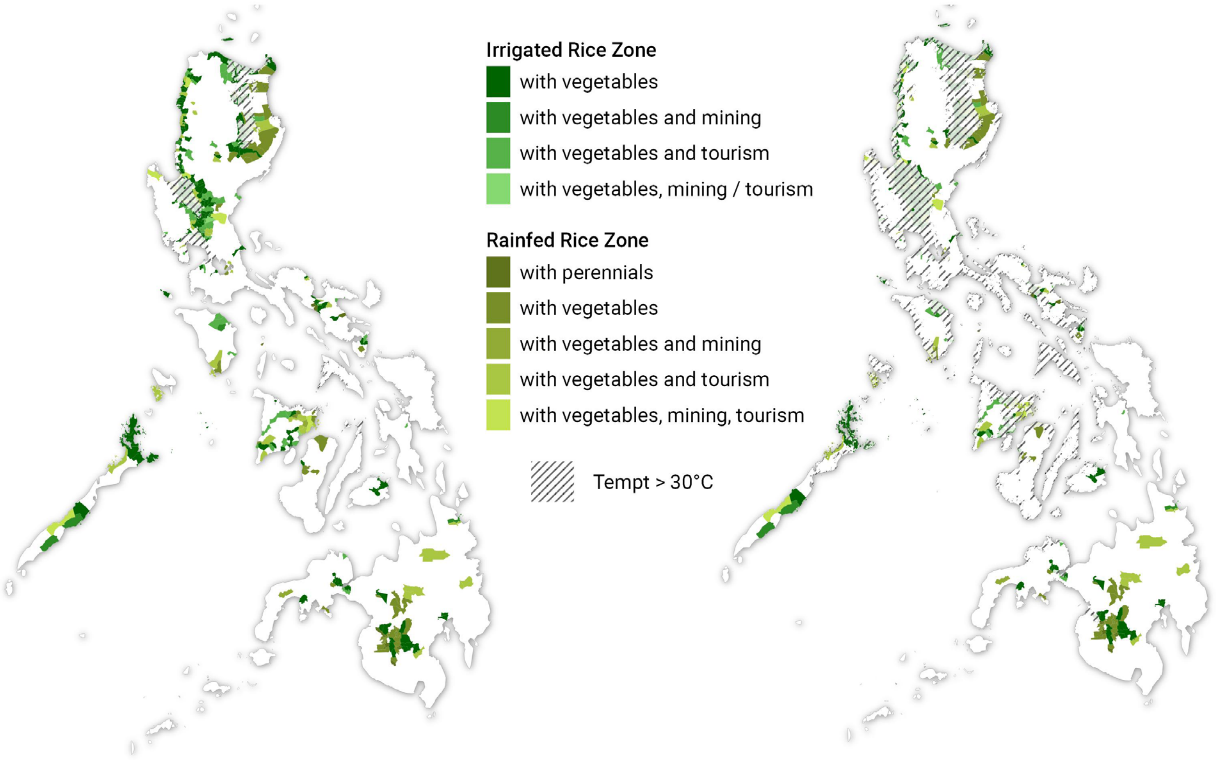
Southern Corn Leaf Blight Risk Map



Year 2030 – RCP 4.5

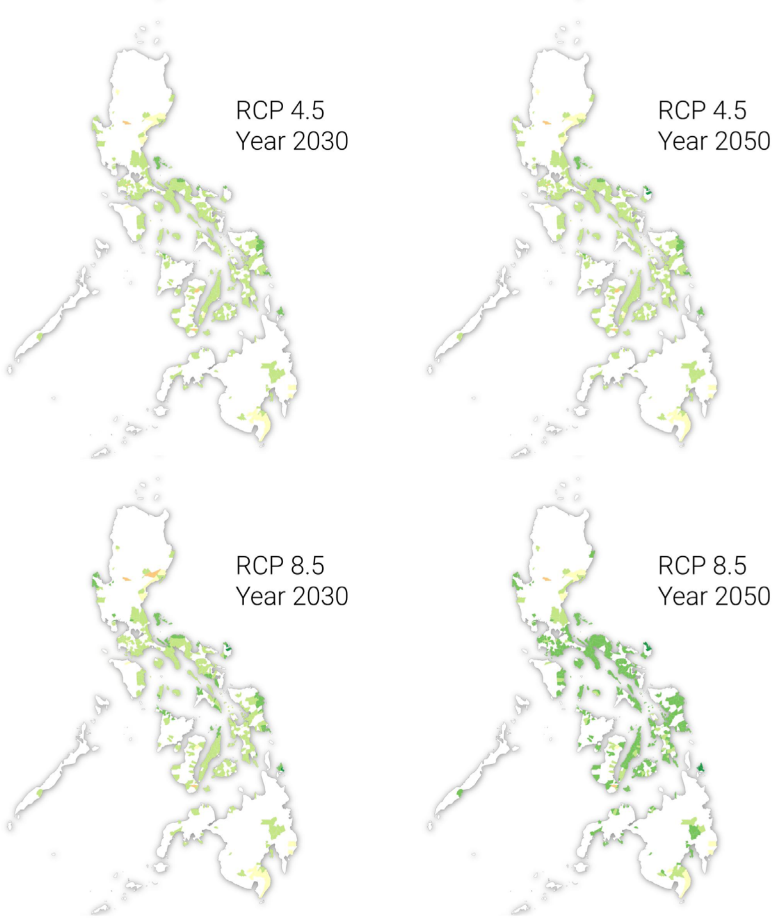
Year 2050 – RCP 4.5

Southern Corn Leaf Blight Risk Map



Year 2030 – RCP 8.5

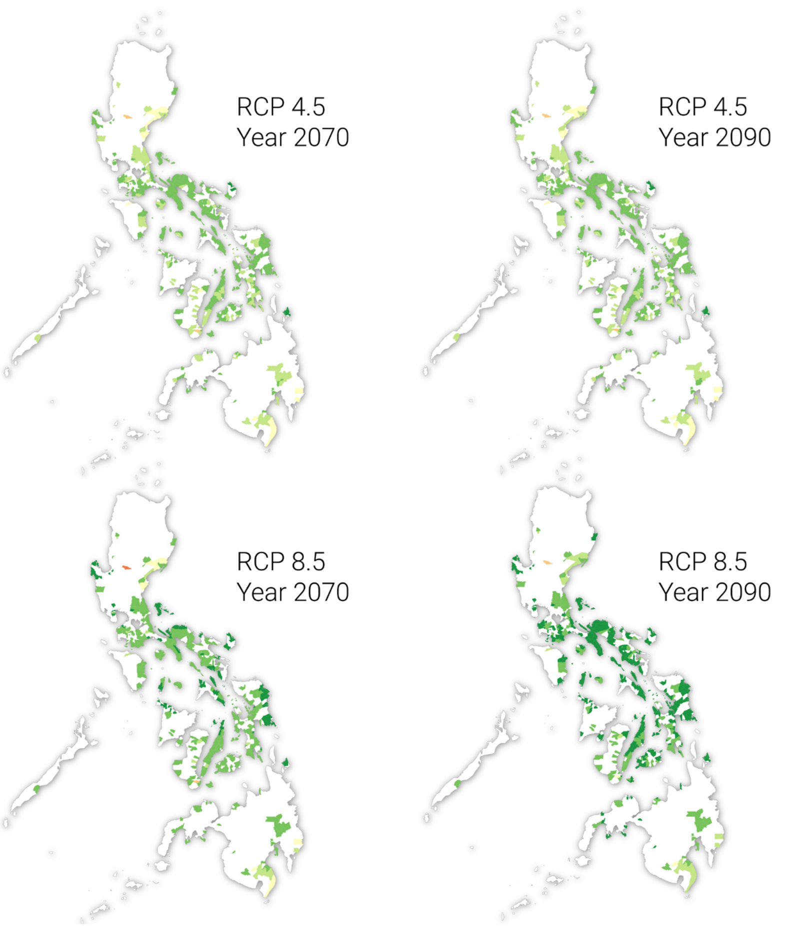
Year 2050 – RCP 8.5



Banana Sensitivity

Sensitivity Index

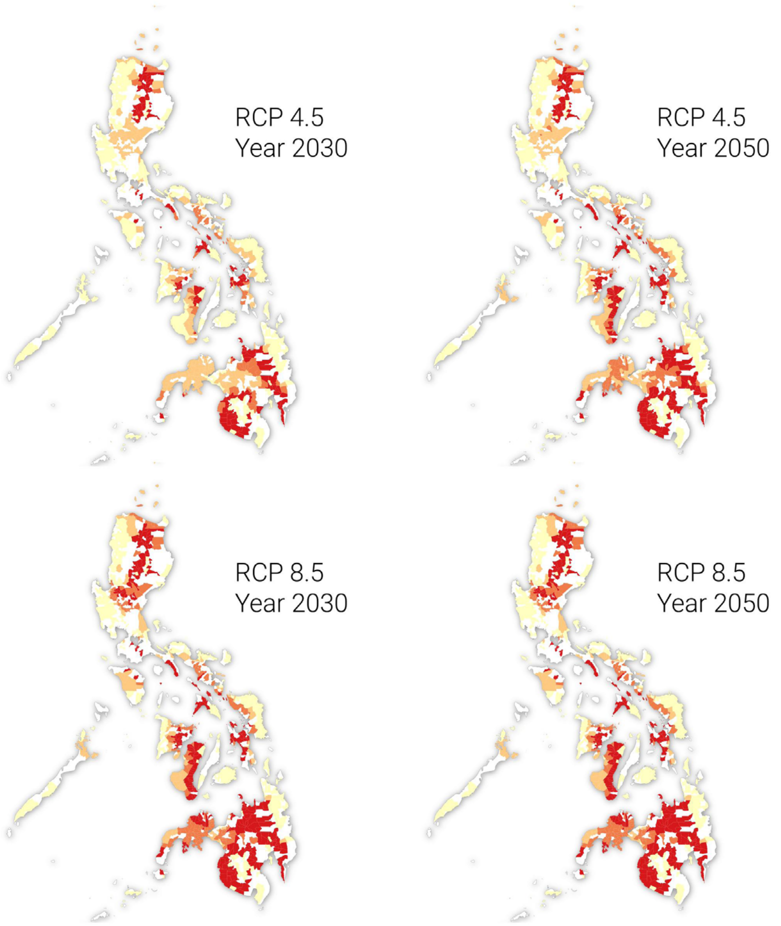
🟩 Gain
🟩
🟩
🟨 No change
🟧
🟧
🟥 Loss



Banana Sensitivity

Sensitivity Index

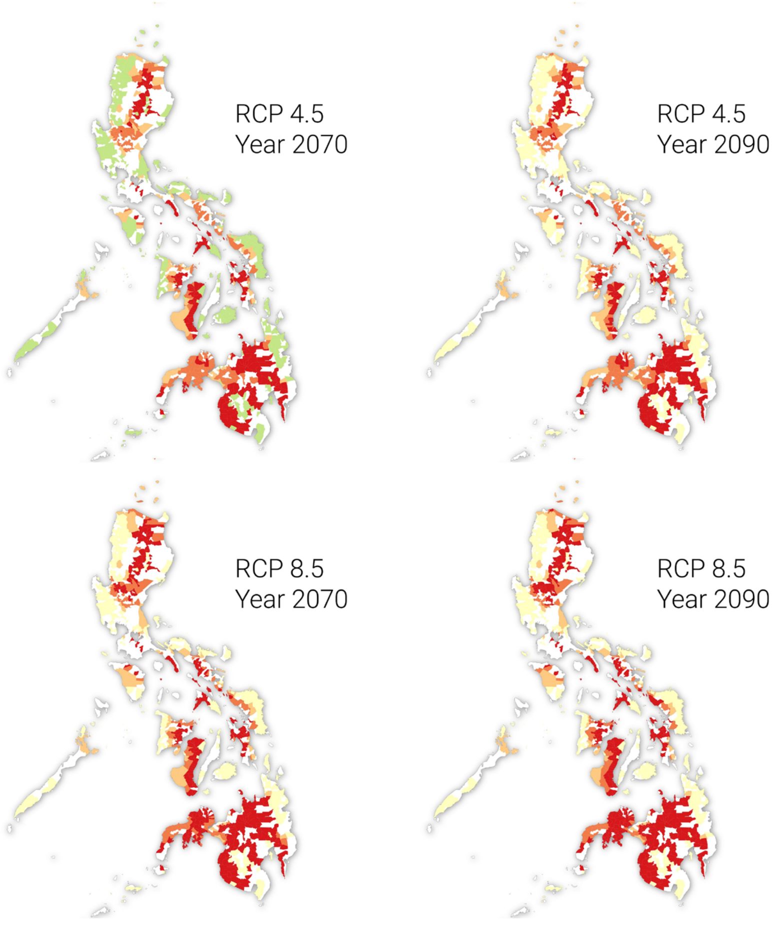
🟩 Gain
🟩
🟩
🟨 No change
🟧
🟧
🟥 Loss



Eggplant Sensitivity

Sensitivity Index

🟩 Gain
🟩
🟩
🟨 No change
🟧
🟧
🟥 Loss



Eggplant Sensitivity

Sensitivity Index

🟩 Gain
🟩
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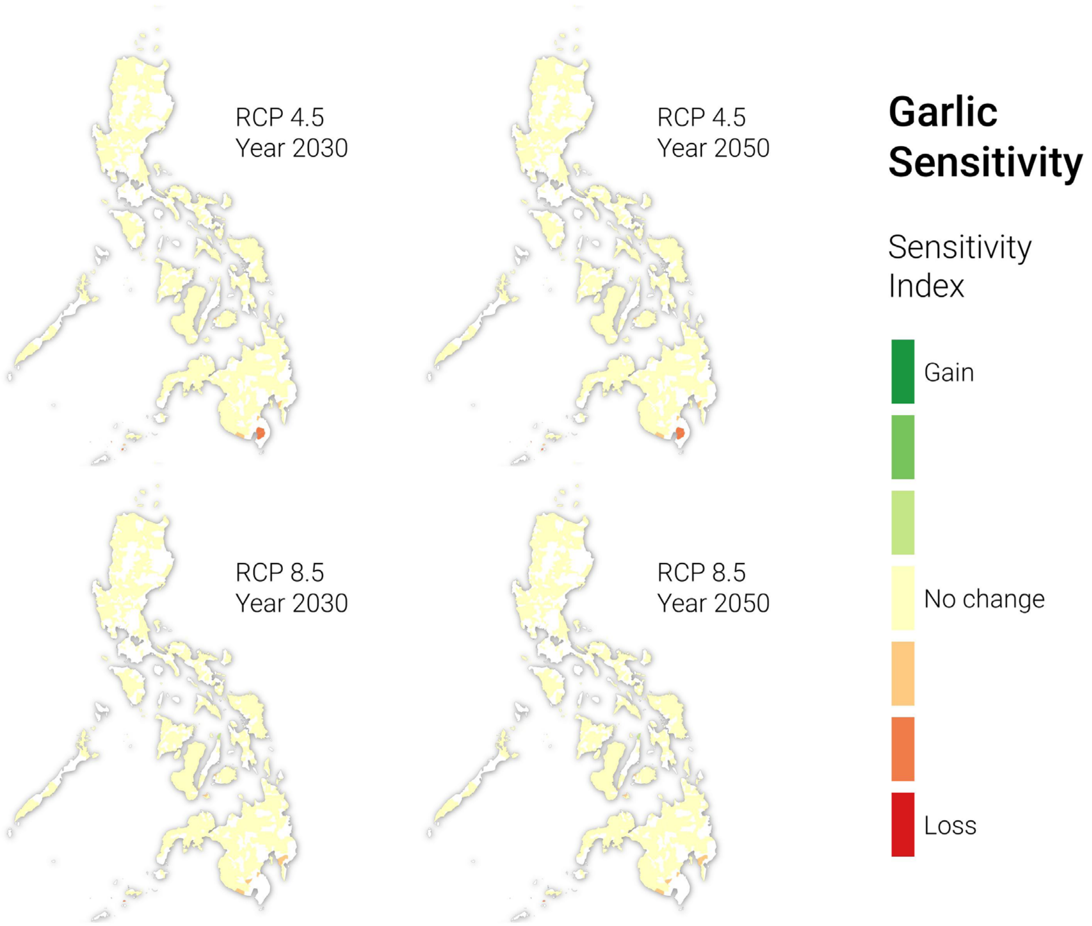
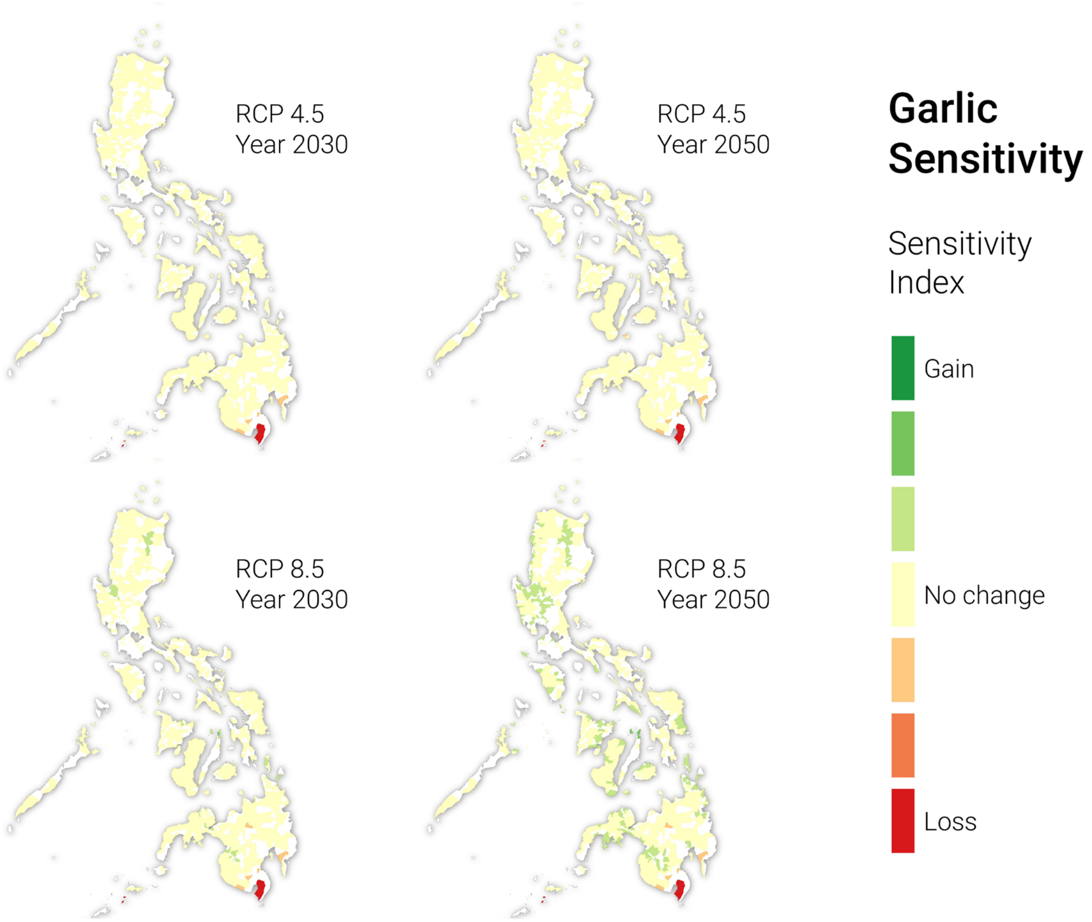
🟨 No change
🟧
🟧
🟥 Loss

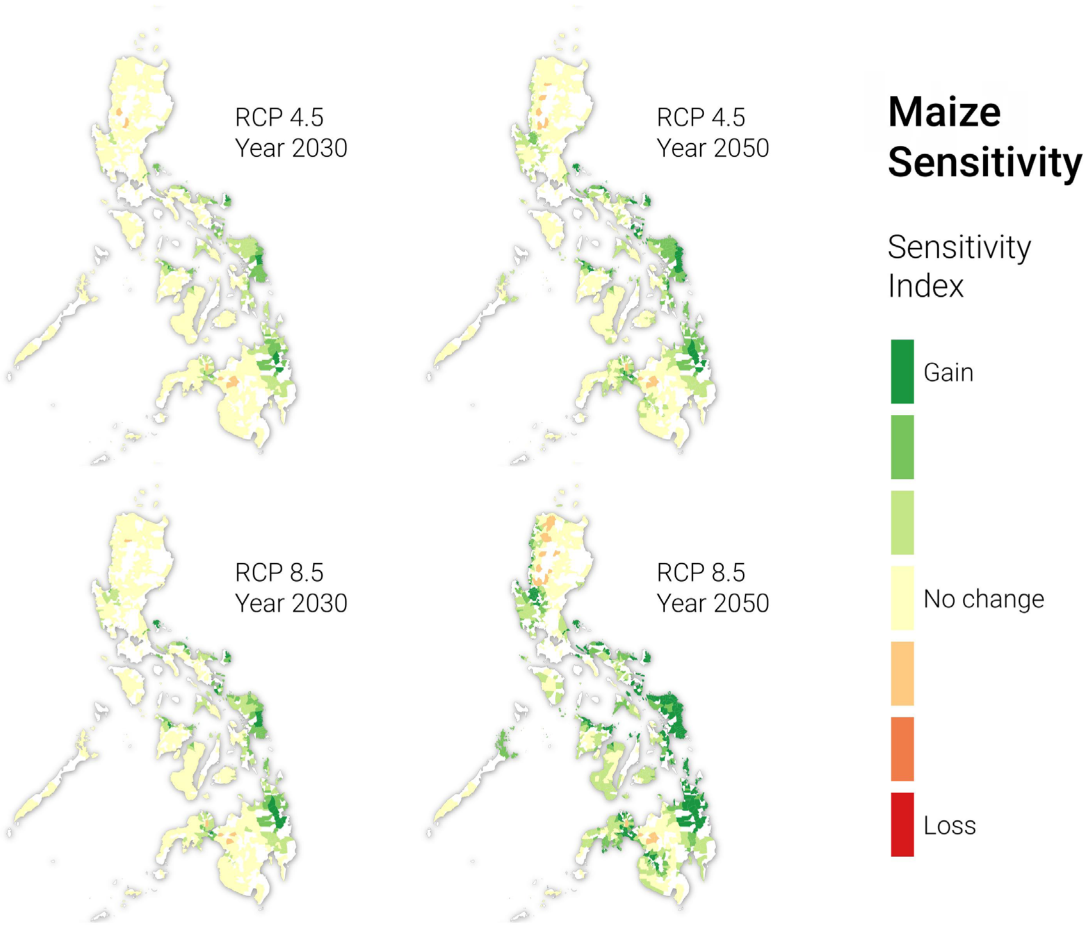
Garlic Sensitivity



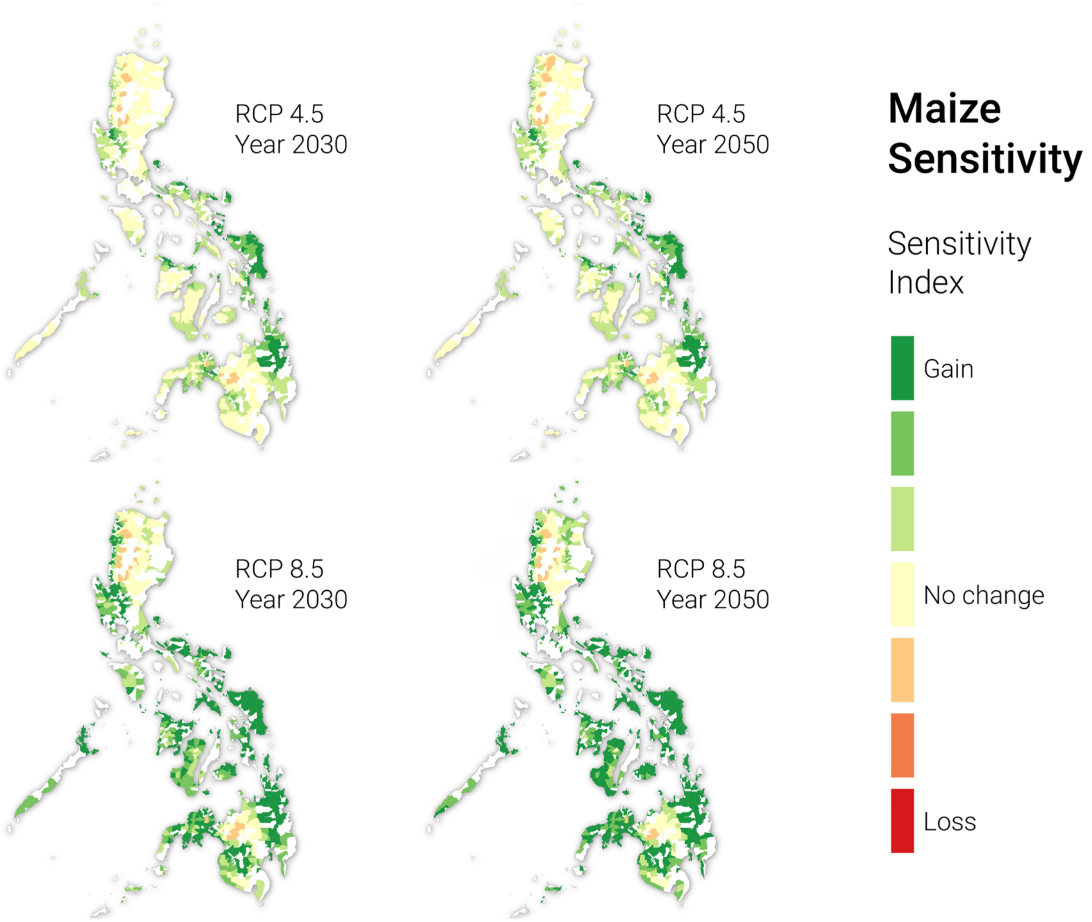
Garlic Sensitivity



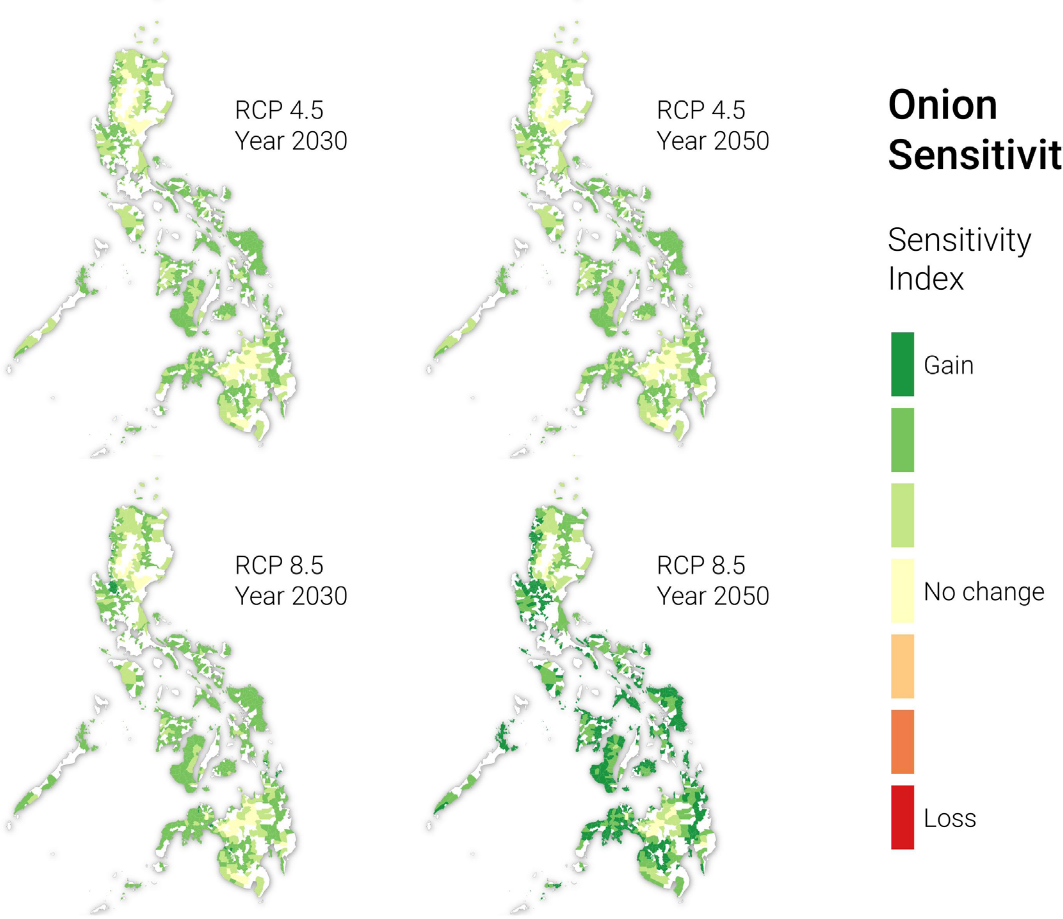
Maize Sensitivity



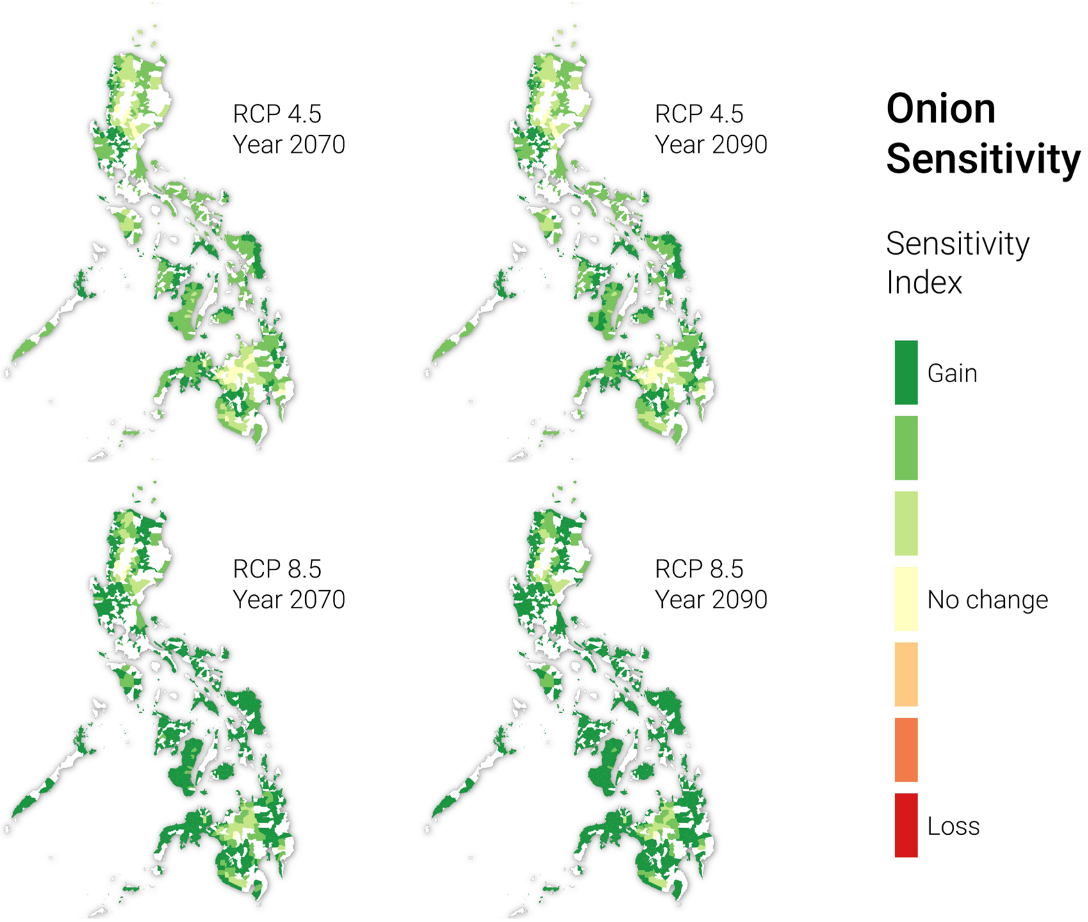
Maize Sensitivity



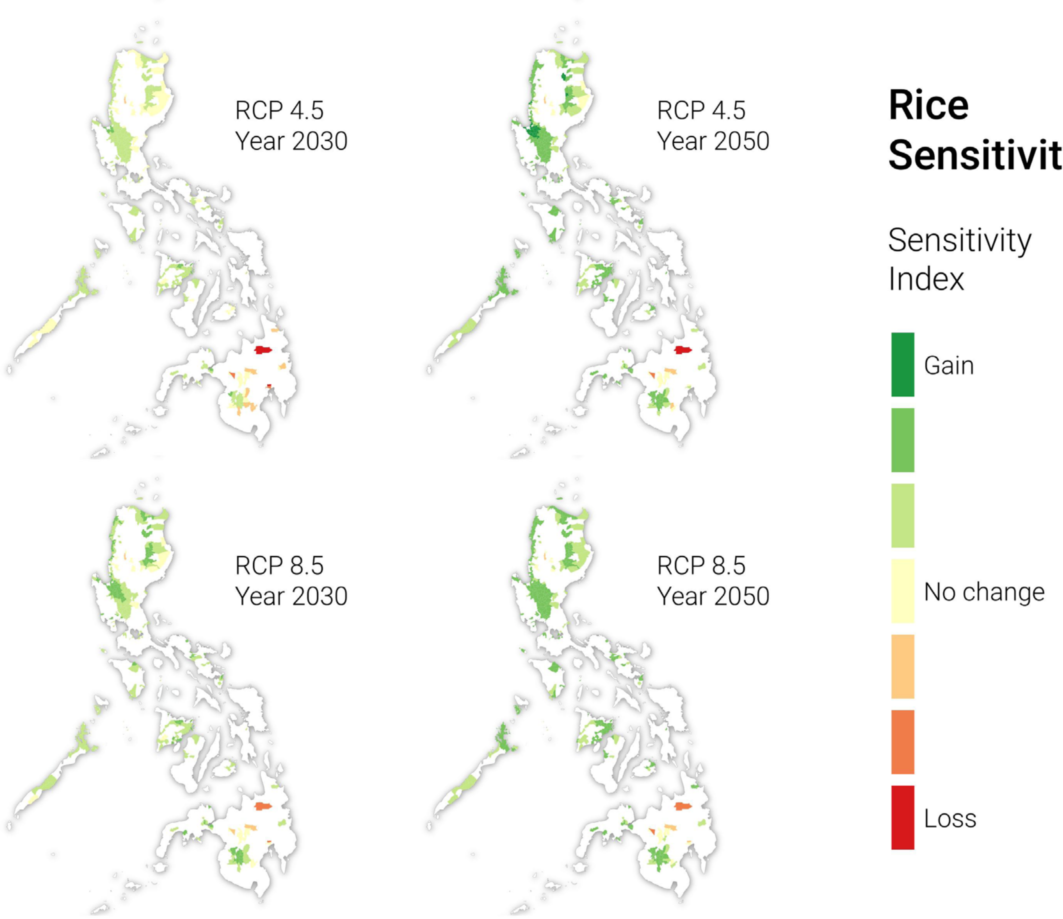
Onion Sensitivity



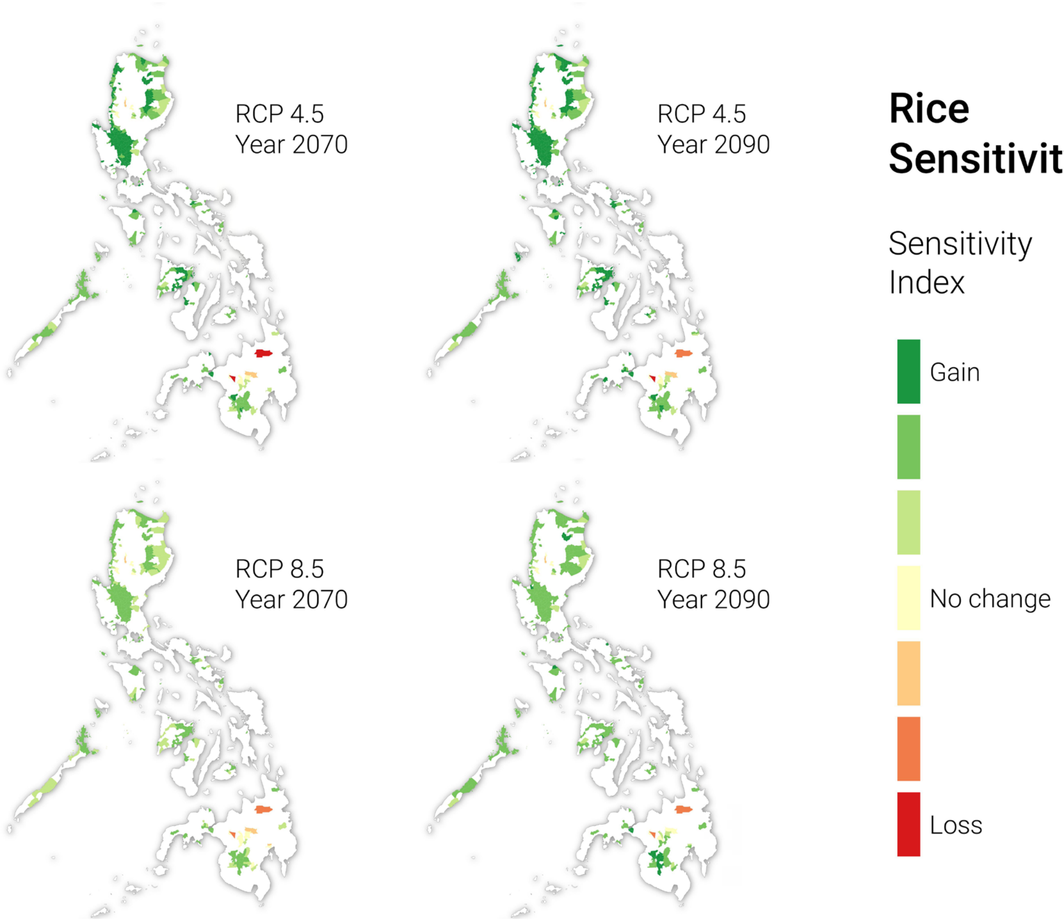
Onion Sensitivity



Rice Sensitivity



Rice Sensitivity



Acronyms

AMIA	Adaptation and Mitigation Initiative in Agriculture
CC	climate change
CCA-DRR	Climate Change Adaptation and Disaster Risk Reduction
CCC	Climate Change Commission
CCET	Climate Change Expenditure Tagging
CIAT	Centro Internacional de Agricultura Tropical
CMIP5	Coupled Model Intercomparison Project Phase 5
CRVA	Climate Risk Vulnerability Assessment
CSA	climate-smart agriculture
DA	Department of Agriculture
DA-BAR	Department of Agriculture, Bureau of Agricultural Research
DOLE	Department of Labor and Employment
DSWD	Department of Social Welfare and Development
FS	food security
GCM	Global Climate Model
GHG	greenhouse gas
INDC	Intended Nationally Determined Contributions
LCCAP	Local Climate Change Action Plan
M&A	mitigation and adaptation
NCCAP-FS	National Climate Change Action Plan-Food Security Pillar
NCCAP	National Climate Change Action Plan
NDC	Nationally Determined Contribution
NDRRMP	National Disaster Risk Reduction and Management Plan
NEDA	National Economic and Development Authority
NFSCC	National Framework Strategy on Climate Change
NGO	nongovernment organization
PDP	Philippine Development Plan
RCP	Representative Concentration Pathways
RFO	Regional Field Office
SEA	Southeast Asia
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
WFP	World Food Programme

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https://alliancebioversityciat.org