Technical Assistance to Strengthen R&D for Climate Change Resilience of Agriculture in the Philippines

Reference: CPH1064

CIRAD-UPLB synthetic report, June 2024

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Executive summary

The Government of the Philippines, the Asian Development Bank (ADB) and AFD launched the Climate Change Action Program (CCAP) which is a program loan to address the climate-related challenges and to mainstream and implement national climate policies including the Nationally Determined Contribution and the Climate Adaptation Plan. In this framework AFD provides technical assistance for research and development to agriculture and fisheries sector (AF R&D).

The technical assistance support for AF R&D policy reform agenda of the Policy Based Loan for CCAP was carried out through a partnership between CIRAD and UPLB. The Philippine government's R&D support for agriculture in general and R&D for climate-resilient agriculture crops, fisheries, and livestock and poultry have been minimal. AFD technical support on R&D policy reforms and for climate-smart technologies and practices on high-value crops and fisheries is designed to assist the Department of Agriculture of the Philippines in fulfilling its policy action and outcome commitments under Reform Area 2 (resilience to climate impacts enhanced) of the Subprogram 2 of the Philippine Climate Change Action Program (CCAP), co-financed by AFD and ADB.

This report summarizing the collaborative efforts between the University of the Philippines Los Baños (UPLB) and the French Agricultural Research Centre for International Development (CIRAD) to deliver this technical support. This Technical Assistance had two components:

- Component 1: comprehensive policy review and appraisal of the agriculture R&D landscape in the Philippines
- Component 2: Capacity building for Philippine agricultural research on specific themes. This Component should achieve the delivery of the PBL Subprogram 2's outcomes by 2024 of at least 5 R&D projects on developing new climate-resilient crop varieties and fish strains.

Component 1 of the report focuses on research and development (R&D) policy for agriculture food and fisheries (AFF) in the context of climate change:

- **Objectives**: The component aims to evaluate and enhance the AF R&D policy framework to improve agricultural resilience to climate change in the Philippines.
- **Main Findings**: It highlights the current priorities of the government in agriculture, forestry, and fisheries AF R&D, identifying regional disparities and bottlenecks in extension services. He notes the fragmentation of AF R&D across numerous AF research institutions, which reduces Philippines AF R&D effectiveness. This report notes that the Philippines' AF R&D budget is below international standards and emphasizes the importance of AF R&D as a government investment to support resilience.
- **Recommendations**: It suggests guidelines for calibrating the AF R&D budget and recommends improvements to increase resilience to climate change in the sector. AF R&D efforts must prioritize technologies that enhance productivity while also strengthening resilience to climate change, optimizing the utilization of natural resources through strategies like agroecology, and improving the livelihoods of small farmers and fishermen. This report reminds that investment in AF R&D represents the best long-term investment strategy for supporting the AF sector in the Philippines. To guarantee that the level of investment in AF R&D is adequate, two criteria are recommended: 1) the ratio of R&D expenditure to government's General Support Service (GSS) for the AFF, and 2) the more traditional ratio of R&D expenditure to GDP in the agriculture and fisheries sector (AgrGDP). While sufficient investment in the AF R&D budget is essential, it is not a standalone solution. Other necessary measures are outlined in this report.

In component 2, five UPLB-CIRAD teams followed the same procedure. CIRAD experts traveled to the Philippines to gain a comprehensive understanding of the context and needs, with the support of colleagues from UPLB. In a number of instances, a study of the value chains in question was conducted. Conversely, to enhance their comprehension of CIRAD's technological capabilities, researchers from the Philippines undertook training in genetics in Montpellier, while another UPLB researcher traveled to Réunion Island for sugarcane. As a result, the various teams were able to propose R&D projects tailored to the context and demand in the Philippines. The outcomes did not always align with the initial expectations. For instance, enhancing sugarcane varieties through the transfer of varieties from Reunion Island has become a more pressing priority than the transfer of AI technologies, which are also available on Reunion Island. Nevertheless, in all cases, innovative and aspirational projects have been proposed:

1. **Genetics and Genome Editing:** The report discusses training and research initiatives in genome editing, particularly using CRISPR/Cas9 technology, to improve crop resilience. The mission to the Philippines by the CIRAD team and the training courses given in Montpellier to 3 Philippine's researchers have enabled the UPLB-CIRAD genetic team to identify 3 promising gene editing projects tailored to the Philippines' needs. Projects on banana, citrus, and coconut are good examples of R&D that can meet the challenges of climate change while minimizing the use of chemical inputs and ensuring greater profitability for farmers. Notably, the banana project was developed with the specific objective of integrating it into the R&D program of Department of Agriculture's (DA).
2. **Mango Production:** Research focuses on improving mango production and strengthening the mango value chain to adapt to climate change would have been highly beneficial for the Philippine economy. It would have helped to meet strong local market demand, improve the trade balance of AF sector, and, most importantly, enhance the livelihoods of small-scale farmers. However, R&D efforts on mango have been overlooked. The team determined that mango R&D on digital tools for climate change adaptation and mitigation in the Philippines should not be the primary focus, contrary to initial expectations. It is becoming increasingly clear that climate change will have a significant impact on mango production. The primary focus of mango research should be on ecophysiology, orchard management, and agro-ecology for controlling Cecil flies. The development of digital tools for climate change adaptation and mitigation is a secondary priority. To develop digital tools, the UPLB-CIRAD team recommends: 1) Quantifying the needs of smallholders and other stakeholders, 2) Scaling up existing digital tools from the SARAI project (Smarter Approaches to Reinvigorate Agriculture as an Industry in the Philippines), 3) adapt PixFruit based digital decision support tool of CIRAD for evaluating mango size, color grade and pest & damage levels at harvest.
3. **Aquaculture: The report highlights the impact** of climate change on Philippine aquaculture and proposes strategies for mitigation and adaptation, including technological innovations for aquaculture waste reduction and community-based approaches. The aquaculture UPLB-CIRAD team proposes 3 R&D projects: 1) One is on the circular economy in the context of aquaculture, 2) Another is on integrating several types of small-scale aquaculture. This integration would be adapted to small-scale producers and it's also link to circular economy and support young people and women, 3) The third project is on a genetics program. This program would enhance the value of local species. The first two projects based on circular approaches in aquaculture provide opportunities for adaptation/mitigation of aquaculture to climate change. The concept includes new ways to increase resource use efficiency, lower production cost as well as carbon emission and thus the footprint of aquaculture to ecosystems and climate.
4. **Biomass and Circular Economy**: Research on biomass and lignocellulosic waste aims to enhance energy production and promote a circular economy. The UPLB-CIRAD team proposes 4 actions: 1) Updating and improving the Biomass Energy Resources Atlas of the Philippines, 2) R&D for establishment of new decentralized rice husk biochar production units, 3) R&D for decentralized heat production from rice straw: pellets and briquettes production, 4) R&D for establishment of one or more hydrochar production pilots and mechanization units, using wet waste from vegetable production.
5. **Sugarcane**: The document reviews sugarcane production challenges due to climate change and suggests R&D initiatives for technology transfer and value chain improvements. The main R&D project identified is to provide access to the best-performing cane varieties developed by eRcane, a CIRAD breeder partner in Réunion Island. These varieties are appreciated and in demand in the Philippines, for their good resistance to ratooning after harvesting: 8 to 10 ratoons compared with 2 to 3 at present in the Philippines fields. The latest varieties available on Reunion Island would provide better resistance to disease and high temperatures, as well as an opportunity to broaden the genetic base available to Filipino breeders from public and private research centers. The introduction of new varieties is an opportunity to steer agricultural practices towards more agroecology, i.e. reduced pesticide use, and greater consideration for soil health and biodiversity. This project could include French and Filipino private stakeholders, ensuring the sustainability of this R&D initiative beyond the CCAP program.

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List of acronyms

AED - agro-enterprise development

AF - agriculture and fisheries

AFC - agricultural and fishery council

AFMA - Agriculture and Fisheries Modernization Act

AFMP - Agriculture and Fisheries Modernization Plan

AO - administrative order

ASEAN - Association of Southeast Asian Nations

ASF - African swine fever

BAFE - Bureau of Agricultural and Fisheries Engineering

BAFPS - Bureau of Agriculture and Fisheries Product Standards

BAR - Bureau of Agricultural Research

BAS - Bureau of Agricultural Statistics

BFAR - Bureau of Fisheries and Aquatic Resources

BFT - Barangay food terminal

BSWM - Bureau of Soils and Water Management

CARP - Comprehensive Agrarian Reform Program

CERDAF- Council for Extension, Research, and Development in Agriculture and Fisheries

CHED - Commission on Higher Education

CIRAD – French Center for International Research on Agriculture and Development

CSO - civil society organization

DA - Department of Agriculture

DA-AMIA - Department of Agriculture-Adaptation and Mitigation Initiatives in Agriculture

DAP - Development Academy of the Philippines

DAR - Department of Agrarian Reform

DA-RFO 2- DA-regional field office 2

DBM - Department of Budget and Management

DOST - Department of Science and Technology

EO - Executive order

FAO - Food and Agriculture Organization

FDI - foreign direct investment

FIES - Family Income and Expenditure Survey

FMR - farm-to-market road

FNRI - Food and Nutrition Research Institute

GDP - gross domestic product

GHG - greenhouse gas

GM - genetically modified

GSSE - General Services Support Estimate

GVA - gross value added

ha - hectare

HEI - Higher education institution

HNRDA - harmonized national R&D agenda

I-O - Input-output

ICT - Information and communications technology

IFPRI - International Food Policy Research Institute

IRR - Implementing Rules and Regulations

IRRI - International Rice Research Institute

ISI - Import substitution industrialization

IUU - Illegal, unreported, and unregulated

JICA - Japan International Cooperation Agency

LDC - Local development council

LGU - Local government unit

M&E - Monitoring and evaluation

MT - Metric ton

NACF - National Agricultural Cooperative Federation

NAFC - National Agriculture and Fishery Council

NAFIAT - Nationwide Agri-Fisheries Investment Audit Team

NAFMIP- National Agriculture and Fisheries Modernization and Industrialization Plan

NEDA - National Economic and Development Authority

NFA - National Food Authority

NFD - net food disposable

NFRDI - DA-National Fisheries Research and Development Institute

NGO - nongovernment organization

NIA - National Irrigation Administration

NIS - national irrigation systems

NPAAAD -Network of Protected Areas for Agricultural and

Agro-Industrial Development

OECD - Organisation for Economic Co-operation and Development

PAFEA - Philippine Agriculture and Fisheries Extension Agency

PAFES - Province-led Agriculture and Fisheries Extension System

PCAF - Philippine Council for Agriculture and Fisheries

PCAARRD - Philippine Council for Agriculture, Aquatic and Natural Resources Research & Development

PhD - Doctor of Philosophy

PhilFIDA - Philippine Fiber Industry Development Authority

PhilFSIS - Philippine Food Security Information System

PhilRice - Philippine Rice Research Institute

PHP - Philippine peso

PIAF - Provincial Institute of Agriculture and Fisheries

PIDS - Philippine Institute for Development Studies

PRDP - Philippine Rural Development Project

PRIR - Philippine Rice Industry Roadmap

PRRI - Philippine Rubber Research Institute

PSA - Philippine Statistics Authority

R&D - Research and development

R4DE - Research for development and extension

RDEAP - Research, Development, and Extension Agenda Program

RDI - Research and development institute

RRDEN - Regional Research and Development Extension Network

SBF - Sugarcane block farming

SCT - Single commodity transfer

SDG - Sustainable Development Goal

SEARCA - Southeast Asian Regional Center for

Graduate Study and Research in Agriculture

SFF - Small farmers and fisherfolk

SOE - State-owned enterprise

SRA - Sugar Regulatory Administration

SUCs - State universities and colleges

TESDA - Technical Education and Skills Development Authority

TFP - Total factor productivity

tmt - thousand metric tons

TSE - Total Support Estimate

UP - University of the Philippines

UPLB - University of Philippines Los Baños

USAID - United States Agency for International Development

USD - United States dollar

VCD - value chain development

WTO - World Trade Organization

Overview of AFD support to Philippines's agriculture and fisheries sector

Project summary and scope of this report

Project duration	**June 2023 to June 2024 – 1 year.**
Reporting period	March to June 2024
Global objective	Support to Philippines's agriculture and fisheries sector for Climate Change resilience.
Context	The Philippine government's R&D support for agriculture in general and for climate-resilient agriculture in particular, has been minimal. In a context of a policy loan to the Government of Philippines for Climate Change, AFD is providing technical assistance to create a dialogue for facilitating policy reforms which will enhance government's support for climate-resilient agriculture and fisheries sectors.
Specific objective	This Technical Assistance (TA) will provide support for R&D policy reforms and the implementation of climate-smart technologies and practices for high-value crops, fisheries, a livestock, and poultry. CIRAD is engaged to provide R&D support to the Department of Agriculture (DA). This technical support will assist the Department of Agriculture of the Philippines in fulfilling its policy action and outcome commitments under Reform Area 2 (resilience to climate impacts enhanced) of the Subprogram 2 of the Philippine Climate Change Action Program (CCAP), co-financed by AFD and ADB.
Donor	Agence Française de développement
Beneficiary	Government of the Philippines, Department of Agriculture
Geographic scope	Philippines
Two main components	Component 1: Comprehensive policy review and appraisal of the agriculture R&D landscape in the Philippines. Two main deliverables: a main report and a policy brief. Component 2: Capacity building for Philippine agricultural research on specific themes: 2.1 Genetic expert CRISPR/Cas9 -Training in France 2.2 Mango data acquisition, analysis - (Pixfruit & Soyield). 2.3 Research project on aquaculture 2.4 Research on lignocellulosic wastes and by products 2.5 Sugarcane technologies transfer and R&D
Scope of this report	Synthetic report

Background

Impacts of climate change in the Philippines

The Philippines is most vulnerable to climate change. Climate change is already affecting the Philippines' climatic variables and events. The mean temperature increase for the country was 0.68°C over the period 1951–2015 (World Bank, 2022). Rainfall has also changed, with some parts of the country experiencing a decrease of rainfall during the dry months (March to May) and the northeastern parts of the country experiencing an increase of rainfall (OML & PAGASA, 2023). Tropical cyclones have changed their paths towards more southern entry points in the last few decades. The country is particularly vulnerable to these extreme weather events (regionally called typhoons), which hit the Philippine coast every year, causing major damage, especially to agriculture. The average number of tropical cyclones is around 20, which generate a cost estimated to 1.2% of the Gross Domestic Product (GDP) every year (World Bank, 2022). Projections made by the Intergovernmental Panel on Climate Change (IPCC) indicate that: (i) temperatures in the Philippines will continue to increase by about 1–2°C by the end of the 21st century; (ii) average rainfall may not change much, but may be more variable and intense; (iii) extreme events, like cyclone, will become stronger and more frequent (World Bank Group & Asian Development Bank, 2021). The magnitude and direction of change will be highly variable due to the Philippine geography, with the northern and central parts of the country projected to become wetter and the southern parts drier throughout the year.

Climate change has already had an impact on agriculture, and will continue to do so in the future. Changing climate has resulted in increasing damages and losses in the agriculture sector. Noticeable changes that have significant adverse bearing on the country’s agriculture (crops, livestock, fisheries) are: (i) annual mean temperature increasing from 1.4-14% resulting more frequent drier days and during rainy season, more rainfall (ii) increased annual precipitation (4-5%), (iii) stronger and more frequent tropical cyclones, (iii) rise in sea level and heightened acidification. Increasing temperatures affect crop and livestock yields, foster greater pest incidence, and reduce labor productivity. By 2050, agricultural productivity in the Philippines is estimated to decline by 9–21% due to climate change (Pulhin & Tapia, 2016). Already about 99.9% of total production losses during the last decade were climate-related hazards. Climate changes like increased temperature impacts negatively on yields. For instance, it is estimated that a 1°C degree rise in temperature reduces rice yield by 10%. Fruits and vegetables are also sensitive to changes in temperature. Such yield reductions especially in crops and livestock attenuate the already low yield performance of the agriculture sector when compared to its ASEAN country neighbors.

Reduced agricultural production will lead to higher food commodity prices making food commodities less accessible especially for poor people. By 2050, large price increases are projected for cereals (+24%), fruits and vegetables (+13%), and pulse (+12%) (IFPRI, 2016). A decline in average per capita consumption is projected: Filipinos will reduce their consumption of fruit and vegetables by 2.3% by 2050. Climate change will also impact the income and food security of rural populations: poverty already affects a third of the rural population, who are heavily dependent on agriculture (CIAT & DA-AMIA, 2017). On a national scale, climate change will cost the Philippines’ economy approximately 520 million$ per year by 2050. This will also make the country more dependent on agricultural imports, which are set to increase for rice and vegetables (CIAT & DA-AMIA, 2017). The upward as well as the midstream and downstream segments of the agri-based value chains are adversely affected too. For example, increased temperature hastens ripening and hence spoilage; these also induce microbial organisms like salmonella. Tropical cyclones and floods destroy agri-based infrastructure and facilities.

CCAP and AFD Technical Assistance for CCAP

The Government of the Philippines, the Asian Development Bank (ADB) and AFD launched the Climate Change Action Program (CCAP) which is a program loan to address the climate-related challenges and to mainstream and implement national climate policies including the Nationally Determined Contribution and the Climate Adaptation Plan. The responsibility for the execution of the CCAP lies with the Department of Finance (DoF), with a consortium of implementing agencies, including Climate Change Commission (CCC), Department of Agriculture (DA), Department of Budget and Department of Environment and Natural Resources (DENR). In this framework AFD provides technical assistance for research and development for agriculture and fisheries sector (AF R&D).

The technical assistance support for AF R&D policy reform agenda of the Policy Based Loan for CCAP was carried out through a partnership between CIRAD and UPLB. The Philippine government's R&D support for agriculture in general and R&D for climate-resilient agriculture crops, fisheries, and livestock and poultry have been minimal. AFD provided technical support on R&D policy reforms and for climate-smart technologies and practices on high-value crops and fisheries. Because of the long-applied research experience and deep understanding of climate-resilient agriculture, CIRAD was engaged to provide R&D support to the Department of Agriculture (DA). The technical support assisted the Department of Agriculture of the Philippines in fulfilling its policy action and outcome commitments under Reform Area 2 (resilience to climate impacts enhanced) of the Subprogram 2 of the Philippine Climate Change Action Program (CCAP) co-financed by AFD and ADB.

The Technical Assistance has two components:

- Component 1: comprehensive policy review and appraisal of the agriculture R&D landscape in the Philippines,
- Component 2: Capacity building for Philippine agricultural research on specific themes. This Component 2 will achieve the delivery of the PBL Subprogram 2's outcomes by 2024 of at least 5 research projects on developing new climate-resilient crop varieties and fish strains.

Activities and deliverables:

The list of activities and deliverables is on annex 2. AFD funding was provided in two phases. This explains the organization of the activities and deliveries described in appendix 3. CIRAD received the funding for the second phase in February 2024, which imposed a very tight schedule, to which the various CIRAD and UPLB teams had to adapt. Most of the component 2 work has been done between February 24 and end of June 24.

Component 1

Objectives of Component 1

This component is a policy analysis for recommending reform agenda for climate-resilient/climate smart AF R&D. This will include:

1.1. Overview and contributions of the Philippine R&D policy to its agriculture commodities (crops, livestock, poultry, fisheries).

1.2. Review and Analysis of the AF R&D demand: who are the clients (regions, type of workforce, gender disaggregation, value chain segment players), and what relevance of the AF R&D on their production, incomes, and capacity to adapt and mitigate climate change, what are the feedback mechanism to suppliers of AF R&D.

1.3. Review and Analysis of the R&D extension and agriculture services: bridge of supply and demand.

The products have been produced, as expected, i.e. a policy brief and a main report. However, the process of publication of the policy brief by the Philippines SEARCA institution is taking longer than contractual deadlines allow.

Main finding on R&D Policy for agriculture in context of Climate change

Government AF R&DE Priorities and Policy

Government Priority for Agriculture and Fisheries

The agriculture and fishery sectors are a priority for the Philippines, as emphasized in President Ferdinand Romualdez Marcos Jr.'s inaugural message on June 30, 2021, where he stated that the country's agricultural sector "cries for urgent attention." In 2022, agriculture accounted for 8.9% of the gross domestic product (GDP) as reflected in Table 1 (PSA, 2023), a significant decrease from its 23% share in 1982, as well as in the recent years.

Industry	**2018**	**2019**	**2020**	**2021**	**2022**
Agriculture, forestry, and fishing	*9.7*	*9.2*	*10.2*	*9.6*	*8.9*
Industry	30.6	30.4	29.2	29.9	29.7
Services	59.8	60.4	60.7	60.5	61.4
Gross Domestic Product	100.0	100.0	100.0	100.0	100.0

Table 1: Percent Share to GDP, by Industry, Philippines, 2018-2022 (at Constant 2018 Prices) - Source: Philippine Statistics Authority (PSA, 2023)

The trade deficit widened to -$11.8 billion in 2022 from -$7.0 billion in 2018 (Table 2) (PSA,2023). This expanding deficit makes the country increasingly vulnerable to the international food market given fragile global food security system, series of health and geopolitical crises, and the long-term risk posed by climate change - which is not just a crisis but the foremost risk to life on our planet.

Industry	2018	2019	2020	2021	2022
Agriculture and Fishery Exports	6,117.84	6,677.06	6,199.96	6,820.91	7,499.59
Agriculture and Fishery Imports	13,141.24	13,531.78	12,575.59	15,706.75	19,303.00
Trade Balance	-7,023.39	-6,854.72	-6,375.63	-8,885.84	-11,803.41

Table 2: Agriculture and Fisheries Trade Balances of the Philippines, 2018-2022 (Export and Import in FOB million USD) Source: Philippine Statistics Authority (2023)

The Department of Agriculture (DA) and its many offices, the Department of Environment and Natural Resources (DENR), the Department of Agriculture and Agrarian Reform (DAR), and the Bureau of Fisheries and Aquaculture (BFAR) are the agencies in charge of the agriculture and fisheries sector. The National Economic and Social Development Council (NEDA) is responsible for coordinating the activities of these different agencies. It produces a national plan, The Philippine Development Plan, which brings together the government's priorities. This national plan draws upon existing plans produced by the various agencies responsible for the AF sector, including the National Agriculture and Fisheries Modernization and Industrial Plan 2021-2030 or NAFMIP (DA, 2022).

The government's priorities for the agriculture and fisheries sector are set out in the NAFMIP and The Philippine Development Plan 2023-2028 (NEDA, 2023). To respond to the perennial agriculture and fishery sector challenges, the NAFMIP defined National priorities highlighting the need to further transform the agriculture and fishery (A&F) sector in the Philippines, building upon the previous plans grounded in the National A&F Modernization Act (AFMA). The NAFMIP highlights that the sector has not undergone sufficient reform, citing examples such as the disproportionate allocation of government support: nearly 50% for rice, 13% for sugar, 30% for pigs and poultry, leaving only 7% for other priorities, including essential investment in bananas, coconuts, vegetables, fruits, and climate change.

The NAFMIP is not solely focused on production growth-oriented; it also aims to double smallholder farmers' and fishers' incomes to meet their family needs, considering also their environmental impacts and climate risks, among others. A key strategy to reach this goal involves diversify farming, creating more value adding ventures, and connecting farmers to value chain actors by attracting large private investments. At the local level, one of the strategies is to establish Agri-Fishery Industrial Business Corridors, supported by five pillars: (1) farm and fisheries clustering and consolidation, (2) linking farmers to market, (3) infrastructure development, (4) investment promotion and agribusiness development, and (5) climate change resiliency and natural resource management. Overall, the NAFMIP calls for mobilizing PhP 8.0 trillion across the 10 years planning duration to achieve the sector's transformation.

The National Development Plan devotes a chapter to the Agriculture, Fishery, and Food (AFF) sector, incorporating the main ideas of the NAFMIP. Three challenges were identified:

1. The sector does not generate decent incomes for its actors along the value chains, particularly at the beginning of the chain for farmers and fishermen, most of whom are unable to escape poverty.
2. The sector does not ensure the sustainable use of natural resources. Farming and fishing practices contribute to the depletion of natural land (particularly deforestation that causes flooding, landslides and soil erosion), coastal and marine resources. Paradoxically, while the sector depends on natural capital as inputs particularly soil and water resources, it contributes to their degradation, which is compounded by the effects of climate change.
3. The final challenge lies at the other end of the value chains, with consumers, who are not guaranteed good nutrition and health by this system.

Based on its findings, this National Development Plan, (NEDA, 2023), proposes a strategy organized around four outcomes: 1) Enhanced efficiency of AF production, 2) Expended access to market and AFF-based enterprises, 3) Improved resilience of AF value chains, and 4) Strengthened agricultural institutions.

Improving the efficiency of the sector requires far-reaching changes in agricultural systems. This includes diversification of farm incomes to make better use of land, water and human capital, in order to increase farm incomes and create more jobs with higher wages. Such changes entail adopting alternative farming models such as agroforestry, agroecology, and precision farming, as well as diversifying production. Additionally, improved technologies are needed to reduce disease threats, enhance sustainability and yields, build resilience to climate change, and reduce input costs to increase farm and non-farm incomes. Measures like systematic composting, utilizing agricultural waste and biological materials for energy and fertilizers, are also crucial components. The plan underscores the importance of increased investment in AF R&D. Furthermore, it outlines strategies for grouping farms and fisheries to take advantage of economies of scale.

Market access and business development based on AF means, for example, opening up new income opportunities for smallholders, such as for upland communities, agroforestry and the establishment of commercial forest plantations, or for fishing communities, whose activities are often seasonal, opening up and promoting viable livelihood options such as adaptive aquaculture, agrotourism, salt production or agricultural activities.

Government Priority for Adaptation in the Agriculture and Fisheries Sector

Improving the resilience of value chains includes both the development and adoption of climate and disaster-resilient technologies. The plan (CCC, 2023) emphasizes the necessity to increased investment in research, development and extension (R&DE) to minimize the impacts of climate change and disasters. This includes the promotion of climate-resilient technologies and nature-based solutions. Proposed strategies encompass the advancement of improved crop and livestock varieties, adoption of water-saving irrigation systems, implementation of soil erosion control technologies and utilization of environmentally-controlled crop production systems. Additionally, enhancing resilience requires the establishment of systems to anticipate and analyze the risks associated with climate change.

Strengthening the institutions that serve this AF sector is obviously the keystone of this strategy. The National Development Plan points to the need to streamline public R&DE to eliminate duplication between the various agencies involved.

Two recent documents outline the government's priorities on climate change. The first and most important is the **National Adaptation Plan of the Philippines** 2023-2050 or **NAP** (CCC,2023), while the second is the **Nationally Determined Contribution** (NDC) of the Philippines (CCC,2011), which primarily focus on mitigation policies. This report will mainly discuss NAP, although recent documents for both policies have been prepared and will serve as references.

The NAP defines the country's priorities for adaptation to climate change. These priorities are divided into eight sectors, starting with Agriculture, fisheries and food security.

Alongside Agriculture, fisheries and food security, the seven other sectors for climate change adaptation and resilience are: 1) Water Resources, 2) Health, 3) Ecosystems and Biodiversity, 4) Cultural Heritage, Population Displacement and Migration, 5) Lands Use and Human Settlements, 6) Livelihoods and Industries, 7) Energy, Transport, and Communications. It is evident that these sectors exhibit a certain degree of interconnection. The NAP recognizes the vital role that ecosystems and biodiversity play in sustaining life and the AF sector. By protecting and restoring these ecosystems, the Philippines can conserve biodiversity, clean air and water, and help mitigate climate change. This, in turn, **improving the resilience of the AF sector to the effects of climate change requires ensuring the sustainability of ecosystem services necessary for the activities of smallholders and fishermen**. Ultimately, the conservation of ecosystems is a prerequisite for the country's food security. The NAP also notes that four of the eight sectors—agriculture and fisheries, land use and human settlements, energy, transport and communications, livelihoods and industry—face significant economic costs associated with inaction, necessitating urgent action. The cost of inaction in the AF sector alone is estimated at hundreds of PHP billion.

Agriculture, fisheries and food security are key sectors in the Philippines. Agricultural land covers more than 40% of the country. Agriculture sector is producing 75% of the food consumed in the country but food resources are still a concern as 10% of Filipinos still suffer from food insecurity.

The sector accounts for 8.9% of the country's Gross Domestic Product (GDP) and employs a quarter of the country's labor force, with 30% of these farmers and fisherfolk living in poverty. The average size of a Philippine farm in 2012 was only 1.29 hectares, which significantly limits the potential for productivity gains from economies of scale (Briones 2021, see NAP page 226). This poverty is one of the causes of the vulnerability of these populations to climate change (see Adaptation plan).

The NAP proposes five strategies, all of which apply to the agriculture and fisheries sector:

1. The first strategy focuses on strengthening the resilience of infrastructure. It is necessary to strengthen the resilience of water infrastructure, irrigated areas, roads and seaports to withstand the disruptions caused by climate change in AF sector.
2. To face climate change, it is necessary to safeguard the livelihoods of smallholder farmers and fisherfolk through social protection and regulation, as they are vulnerable populations because they are poor and highly exposed to the effects of climate change.
3. Decentralize decision-making by empowering local governments and communities will help taking adaptation measures at the local and community level.
4. The fourth strategy is to establish integrated governance for adaptation. Adopting adaptation solutions requires a multi-stakeholder and multi-disciplinary approach. This strategy emphasizes the importance of fostering coordinated cooperation between stakeholders along value chains, policy makers and institutions across horizontal and vertical chains of command.
5. **Finally, the last strategy proposes the development of nature-based solutions. Given the Philippines' wealth of natural resources, this strategy emphasizes the importance of prioritizing the use of nature-based solutions, where possible, to build climate resilience and protect vulnerable populations. The current trend of choosing adaptation measures based on gray infrastructure such as seawalls, which often have negative impacts, needs to be corrected. In agriculture and fisheries, nature-based solutions include agroforestry, agroecology, the protection or restoration of mangroves, and the development of technologies that minimize the use of pesticides and other inputs, which are also sometimes costly. This requires adaptation measures based on the best available science.**
6. The last point is particularly important as the Philippines' ecosystems and biodiversity are exceptional. Ecosystem services enhance the resilience of the aquaculture, agriculture and fisheries sectors, while protecting communities from climate risks. However, these ecosystems have been severely degraded in recent decades, both as a result of anthropogenic development activities and already as a result of climate impacts. It is of paramount importance to protect and restore these ecosystems in order to enhance the resilience of the agricultural and fisheries sectors in the face of climate change.

The NAP has also analyzed the risks of impact from various climate change factors, including temperature rise, drought, sea-level rise, extreme precipitation, winds and tropical cyclones. The aforementioned objectives can be grouped into the following categories:

1. Achieving productive and resilient agriculture and fisheries. This necessitates the utilization of optimal practices and technologies tailored to climate change, with the objective of maintaining food self-sufficiency, diversifying or replacing crops, livestock and aquaculture, and enhancing agricultural infrastructure, with due consideration for the gender dimension. This outcome also requires investment in R&DE to obtain adapted and resilient species.

2. The second anticipated outcome pertains to the prudent management of natural resources to support the ecosystem services that sustain agriculture, aquaculture and fisheries. This includes integrated pest management to combat emerging climate change pests, reduced pesticide-use through biological control, precision agriculture and aquaculture that minimizes agricultural and aquaculture waste, and R&DE activities on soil conservation, water-efficient irrigation, climate-resilient crop varieties, circular agriculture and aquaculture, and integrated mangrove aquaculture systems.

3. The third outcome is to ensure that the livelihoods of farmers and fishermen are guaranteed in the context of climate change.

Government Priority for Mitigation in Agriculture and Fisheries

The Republic of the Philippines Nationally Determined Contribution (NDC) outlines the country's GHG reduction commitments. The NDC is focused on climate change mitigation, but the Philippine government has not committed to unconditional emission reduction targets for the AF sector. The government estimates that the agricultural sector's emissions of 211 million tons of CO2-e can be offset by ongoing plantation activities, such as the planting of 3.6 million hectares of coconuts, which has considerable sequestration potential.

However, the NDC allows to identify some government priorities for changing agricultural practices, with the aim of contributing to climate change mitigation in the AF sector.

One of the main sources of carbon emissions from the agricultural sector in the Philippines is irrigated rice. The alternate rice cropping system has the potential to significantly reduce greenhouse gas (GHG) emissions, particularly methane (CH_4) and nitrous oxide (N_2O), two of the main GHGs produced by agriculture. In flooded rice fields, methane is produced by anaerobic decomposition processes of organic matter. However, when rice fields are occupied by dry crops, methane production is reduced. The government plans to adopt this technique on all rice fields, which represents 3.21 million hectares (NDC).

The use of natural solutions and selection interventions in livestock enteric fermentation is the second most effective measure for reducing GHG emissions from the AF sector. Other measures that can help reduce emissions are also contributing to adapting and improving the efficiency of agricultural production systems. Cropland management and precision farming with biotech crops can reduce NO2 emissions from cultivated soils. For instance, practices such as planting deep-rooted plants, nitrogen-fixing trees, cover crops, and using biochar all contribute to soil health, carbon sequestration, and better nutrient management. These techniques are commonly found in agroforestry and agroecology. Finally, plantations, such as coconut plantations or forest plantations, contribute also to carbon sequestration. Their association with crops can contribute to adaptation by creating cropping systems that are more resistant to wind or excessive temperatures.

AF R&D priorities for CC adaptation

- *Government Research Priorities for Agriculture and Fisheries*

Two key entities, The Department of Agriculture (DA) and The Department of Science and Technology (DOST), are responsible for coordinating research for agriculture and fisheries, the first with a core mandate for agriculture and the second for science. Research priorities for the agriculture and fisheries sector are defined through a consultative process involving national agencies under DA as the Bureau of Agriculture Research (BAR) or the Bureau of Fisheries and Aquatic Resources (BFAR), Academic and Research Institutions as universities, colleges and stakeholder groups and industry associations, as well as International Organizations as ASTI (Stads, 2020) or FAO.

The R&D priorities for the agricultural sector in the Philippines were set out in two important documents: the "*National Agriculture and Fisheries Research for Development* and Extension Agenda (NAREA) *2023-2028"* (DA 2023) and the "*National Harmonized Research and Development Agenda (2022-2028*)" (DOST, 2022). The general objectives of these documents align with the national plans, with priorities established through a coordinated effort and consultation between the different agencies. Considering their respective mandates, DOST prioritized basic and applied research, while the DA-BAR focuses on applied research and extension. Priorities are defined by commodities, but DOST also incorporates some transversal priorities. In the crop sector, for example, there has been a shift in research priorities towards the principles of Climate Smart Agriculture (CSA), encompassing smart farming approaches, optimization of nutrient and water management, development of climate-resilient technologies, intercropping, integrated farming systems, and decision support systems (DOST, 2018).

In the context of climate change, research and development priorities must align with several government priorities. These include 1) resilience to the impacts of climate change, 2) increasing production efficiency to ensure the country's food self-sufficiency, and 3) improving living conditions and incomes for smallholders and fishermen. Priorities must be set in a sort of triangle, with the three previous poles at the apexes. While climate change mitigation may not be a main priority, but can be a welcome additional outcome for the Philippines.

With the above, the following research priorities have been identified:

1. Those based on nature, so as to preserve the resilience it offers. Research on agroecology, agroforestry, integrated landscape and natural resource management, mangrove restoration, biological control, precision agriculture and aquaculture that creates synergy between agriculture, forestry and the environment and minimizes agricultural and aquaculture wastes, among others.
2. The research that will enable the production of efficient crops, without relying much on pesticides, genetically improved organisms (non-GMOs) as those produced by CRISPR technology (see component 2.1).
3. The research which will enhance value chain efficiencies while improving livelihood of smallholders and fishermen, with a particular focus on gender.

According to the ASTI's projections for the Philippines, prioritizing research investments focused on fruits, vegetables, livestock and aquaculture could yield faster and more sustainable growth over the next 30 years compared to a singular focus on rice (Stads, 2021). This kind of research can simultaneously improve farmers' incomes and be integrated into agroforestry production systems.

Organization of the Philippines AF R&DE systems

Agricultural and Fisheries research in the Philippines is highly fragmented as noted by Stads & al (2007 a) who count 24 government agencies and 55 HEIs engaged in such mandate. In addition to the divisions that exists in many countries between government research agencies, research conducted in Higher Education Institutions (HEIs[1]), and research conducted by associations or private companies, there is also a division of research within the government itself at the central level and through their many decentralized agencies. The result is a lack of coordination between these different research institutions, regional disparities, and great difficulty in assessing the real research effort in the Agriculture and Fisheries sectors. Furthermore, this fragmentation has the potential to spread already limited financial resources too thinly.

The AF R&DE system in the Philippines encompasses most of the services of the Department of Agriculture (DA) and some in the Department of Science and Technology (DOST), as well as the various research centers, universities and colleges, the private sector, Local Government Units (LGUs) and the extension services responsible for agricultural research and extension.

[1] HEI’s include both public and private institutions. Public HEIs are composed of: 1) State Universities and Colleges (SUCs); and 2) Local Colleges and Universities (LCUs) while Private HEIs are composed of 1) Sectarian: Owned and operated by religious organizations; and 2) Non-sectarian: Independent institutions not affiliated with a particular religion. SUCs in the diagram is therefore a subset of HEIs.

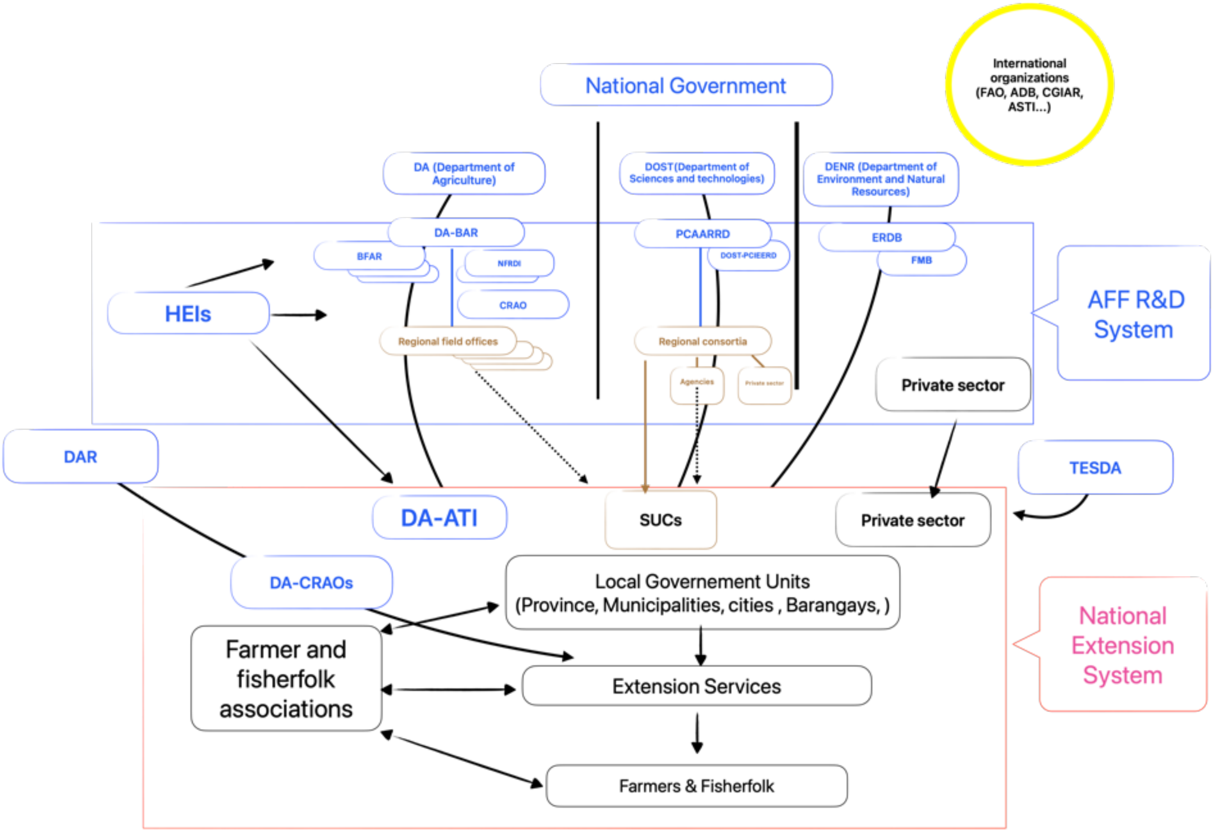

Figure 1: Fragmentation of National R&DE System in the Philippines (Sources: Author from discussions and Baconguis, 2023; Stads 2007 a, b)

- *National level*

At the central level, two entities, The Department of Agriculture (DA) and The Department of Science and Technology (DOST), are responsible for coordinating research for agriculture and fisheries, the first with a core mandate for agriculture and the second for science.

The Department of Agriculture (DA) is responsible for policy framework, regulation, public investment and research and extension in agriculture, while the DA has a specialized research bureau, the DA-BAR, it has also various R&DE activities, which are spread across the DA's 9 bureaus, 8 attached agencies, 8 attached companies and 15 regional field offices. Under DA, The Climate Resilient Agriculture Office (CRAO) is the office tasked to provide strategic direction and oversight in mobilizing the DA's resources and capacities towards achieving its climate resilient agriculture agenda. This agenda encompasses creating climate-resilient food systems and achieving sustainable increases in productivity, food self-sufficiency and incomes of farmers and fisherfolk, all in the face of a constantly-changing climate. The DA CRAO implements the flagship program of the DA for climate adaptation and mitigation, known as the Adaptation and Mitigation Initiative in Agriculture or AMIA Program. The overarching vision of the AMIA Program is a climate-resilient Philippine agriculture with empowered and prosperous farmers and fisherfolk.

The National Fisheries Research and Development Institute (NFRDI), under the DA, is responsible for research and development for fisheries and aquaculture to improve the practices of stakeholders in the sector. It assesses fish stocks and aquatic resources and collects environmental and economic data to ensure the sustainability of fisheries and aquaculture activities. It provides technology transfer programs and extension services. It is the main agency for advising the government and guiding policy in the sector.

Within the Department of Science and Technology (DOST), the Philippine Council for Agricultural, Aquatic, and Natural Resources Research and Development (PCAARRD) formulates policies, plans, and programs for scientific and technological research on agricultural, aquatic, and natural resources. PCAARRD has eight technical research divisions.

Other entities are engaged in research and development activities related to the agriculture and fisheries sector including:

- Higher education institutions (HEIs) also engage in research and extension activities. The Philippines has four national multi-product agricultural and fisheries research universities including the University of the Philippines Los Baños (UPLB). UPLB is renowned for its research and education programs in agriculture, food science, forestry and the environment. HEIs funding comes from a variety of sources, including government departments (DOST, DA, DNER) via their various agencies, as well as from the private sector and international research organizations. Many research centers are located in HEIs.

- Some State Universities and Colleges (SUCS) have specialized institutes and research centers as well. The SUCS are either national, regional or provincial units, but they are autonomous and therefore independent of each other. The country's four national multi-product research universities have limited institutionalized links with regional research universities or regional R&D centers and institutes. SUCS funding comes mainly from government research budget (CPBRD, 2022).

- In addition to SUCs, some private universities also conduct research and development projects in agriculture and fisheries getting funding support from various sources.

- The DOST-PCIEERD, The Philippine Council for Industry, Energy, and Emerging Technology Research and Development, under DOST, aims to support the development of priority sectors, including agriculture, fisheries, and renewable or natural resource management.

- The Department of Environment and Natural Resources (DENR) is responsible for the conservation and management of the country's natural resources. The DENR's Ecosystems Research and Development Bureau (ERD) is the principal research and development unit of the DENR which focuses its R&DE activities on the five major ecosystems of the Philippines, such as the forests, upland farms, grassland and degraded areas, coastal zone and freshwater, and urban areas.

- Farmer and fisherfolk associations collaborate with research institutions to develop and disseminate new agricultural or fishing technologies that can enhance productivity and sustainability.

- Private companies as large agri-food companies have established research laboratories to meet their needs. These laboratories are sometimes in partnership with HEIs or SUCS. Some provide services to the public for a fee. They are, at the same time, part of the R&D system and the Extension System.

As discussed earlier, national agencies, through government objectives and the planning system, drive the priorities of the agricultural R&DE system. However, this system is also influenced by HEIs, private, and multinational companies. The private sector is often the origin of new technologies and also of research demands in the agricultural inputs sector, such as seeds, fertilizers, animal feed, livestock, or fish. Government agencies and SUCs are also partners with the private sector through special programs.

- *RDE of National Agencies at Local level*

National agencies conduct research at decentralized levels. The division between the DA and PCARAARD is also reflected at this level:

- DA Regional Field Offices (RFO) serve as the DA national level's relay for promoting agricultural development. Each RFO has an integrated regional agricultural research center focusing on farming systems research, crops, and livestock.
- At the regional level, the Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development (PCAARRD) relies on a network of SUCs, government agencies, and private companies.

In addition, the Agricultural Training Institute (ATI) functions as the extension branch of the Department of Agriculture (DA). Its main responsibilities include training agricultural extension workers and other stakeholders within the agriculture and fisheries sector. ATI ensures that the training programs meet the actual needs of the agricultural community and effectively communicate research findings to farmers through tailored training and extension activities.

- *Role of LGUs in AF extension*

The Local Government Units (LGUs) in the Philippines are the administrative divisions below the national government. These LGUs are organized at different levels: Provinces are the highest level, followed by Cities and Municipalities, and finally Barangays, which are the smallest administrative divisions. All LGUs are responsible for the delivery of basic public services within their jurisdictions. In particular, LGUs are responsible for providing agricultural and fishery extension services.

Normally, the provincial government is expected to take the lead in planning and organizing the delivery of extension services to all municipalities under its jurisdiction. In practice, however, municipalities often plan and implement agricultural and fisheries extension services independently. Municipal LGUs frequently operate independently in planning and implementing their agricultural and fisheries extension services. This situation can present challenges for the effective dissemination of agricultural policy directives from the central government and contributes to the AF R&DE fragmentation.

- *Farmer associations*

Farmers associations collaborate for AF R&DE despite having many other responsibilities, these include: advocacy and representation, access to resources (seeds, fertilizers, equipment, fishing gear, boats, safety equipment and financial services), capacity building and training, marketing and distribution, community development (by supporting infrastructure projects), risk management (insurance scheme, emergency fund to anticipate impacts of climate change, crop failure), networking and collaboration (sharing knowledge and best practices), regulation and standardization to improve product quality and safety. This stakeholder group is essential to the system, as it has a deep understanding of the challenges faced by farmers and fishermen, and therefore of AF R&D needs.

- *Private companies*

The AFMA has succeeded in strengthening the role of the private sector in research and development (Briones, 2022). Private companies invest in R&DE to develop new technologies and practices in agriculture and fisheries. These innovations include disease-resistant crop varieties, climate-resilient agricultural practices, efficient water management systems, and sustainable fishing methods. Biotechnology firms, for instance, work on genetically modified crops to enhance yields and reduce pesticide usage, while technology companies develop advanced fishing gear and aquaculture systems that improve productivity and reduce environmental impact.

They engage in Public-private partnerships (PPPs) with public research institutions such as the Bureau of Agricultural and Fisheries Industries (BAFI) and the Philippine Rice Research Institute (PhilRice). These partnerships facilitate the sharing of resources, expertise, and infrastructure, leading to faster and broader dissemination of technological innovations.

They are key players in the commercialization of R&DE outputs. They have the necessary networks and logistical capabilities to bring new seed varieties, improved fertilizers or modern fishing equipment to market. Their involvement ensures that innovations reach farmers and fishers, enabling them to enhance their productivity and incomes. For example, agribusinesses may market high-yield seeds and efficient irrigation systems, while fisheries companies distribute advanced aquaculture technologies.

To ensure effective adoption of new technologies, private companies invest in training and capacity building for farmers and fishers. They organize workshops, seminars, and on-field demonstrations to educate local communities about the use of new methods and equipment. For instance, swine owners rely mostly on technologies and extension services from the private sector (Baconquis, 2023).

This approach contributes to technology adoption and strengthens the capacity of producers to innovate and improve their practices. Increasingly, private companies incorporate sustainable and responsible practices into their R&DE efforts. They aim to develop solutions that not only boost productivity but also preserve natural resources and protect the environment. Projects may focus on reducing the carbon footprint of agriculture, conserving marine biodiversity, and promoting fishing techniques that minimize by-catch.

Companies play an important role in R&DE in the Philippines. But private companies obviously have private interests that may conflict with those of small farmers and fishermen. This is why public R&DE research is absolutely essential to safeguard weakest players interests. Non-governmental organizations NGOs also have an important role to play in ensuring that companies work for the common good.

R&DE and regional disparities

There are significant regional disparities in the Philippines in terms of research, development and extension in the fisheries and agriculture sectors. These disparities are influenced by geographical factors, climate, infrastructure, R&DE institutional presence and capacity, local policies, access to extension services, private sector involvement and social factors such as conflicts.

There is a regional specialization of agricultural activities that influences associated RDE. The diversity of the Philippines' topography and climate leads to variations in agricultural and fishing practices. For example, the fertile plains of Luzon are better suited to rice and crop production, while the Visayas and Mindanao have more diversified agricultural activities due to the variety of climates and soil types. Coastal regions, especially those with rich marine biodiversity, are more focused on fishing and aquaculture. Luzon, for example, is home to a great deal of R&DE on rice.

Some regions are more exposed to natural disasters such as typhoons, floods and volcanic eruptions, which can disrupt R&DE activities and affect the implementation of innovations in agriculture and fisheries.

Wealthier regions, such as Central Luzon and Calabarzon, have more resources to invest in R&DE activities. These regions benefit from better funding, advanced technologies and easier access to information. In contrast, poorer regions, such as parts of Mindanao and Eastern Visayas, lack the financial resources and infrastructure to support significant R&DE efforts.

The availability of infrastructure, such as roads, transport and communication networks, influences R&DE activities. Regions with better infrastructure can more easily disseminate research results, transport goods, and provide extension services. Remote and underdeveloped regions often struggle with these aspects, limiting their access to new technologies and innovations.

The presence of research institutes and universities varies from region to region. Areas with major agricultural and fisheries research institutions, such as in Los Baños, Laguna (home to UPLB and the International Rice Research Institute) and Iloilo (home to several fisheries research centers), have more robust R&DE activities. Regions without these institutions lag further behind in terms of research results and innovation dissemination.

AF R&DE Planning

The coordination of the R&DE system is essential for the effective governance of research; to achieve this, it is necessary to ensure that priorities are aligned and harmonized. AFMA has designated the DA as the leader of the R&DE system and DA must coordinate with the DOST-PCAARRD (Briones 2022). But in practice, both DA and DOST are coordinating R&D, which could be perceived as a challenge.

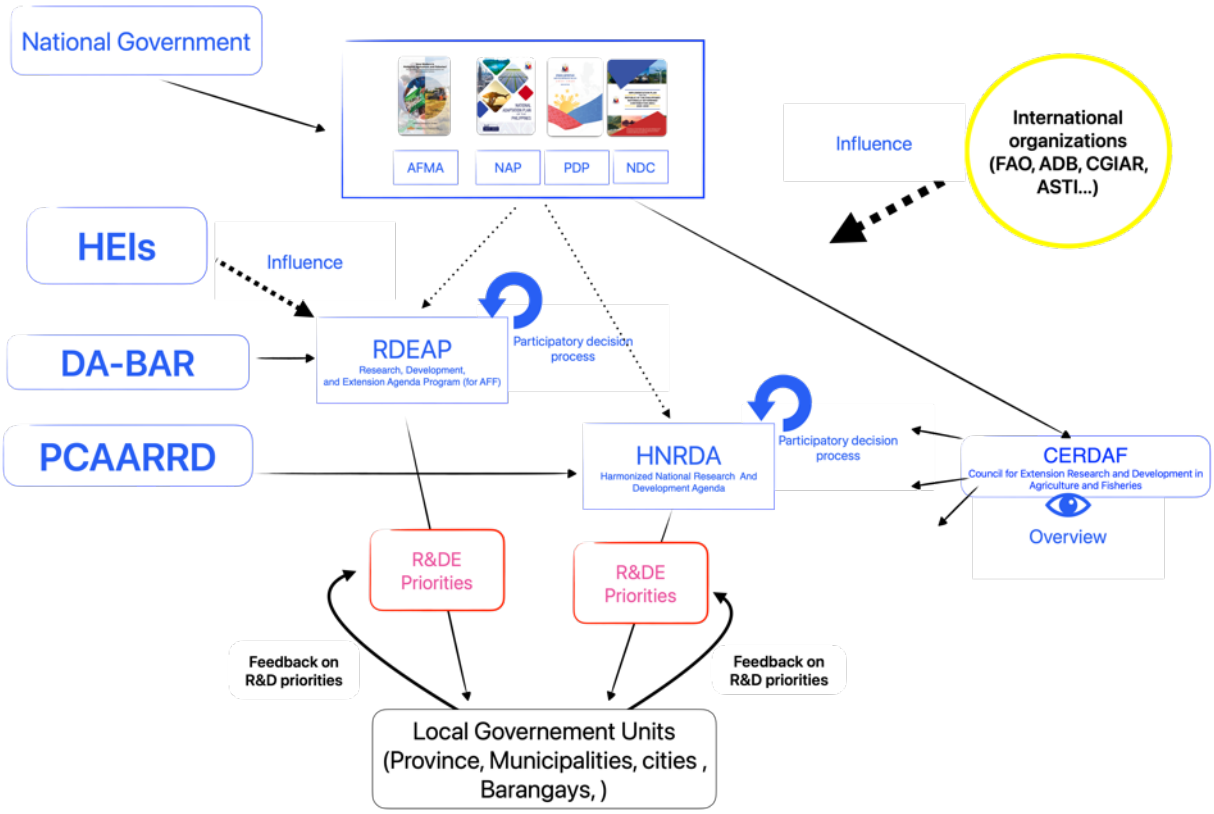

Figure 2: Planning AF R&D decision process

The DA's Bureau of Agricultural Research (BAR) and the DOST's PCAARRD sought to address the lack of a national agenda for agriculture, water and natural resources by developing R&DE plan through multi-stakeholder consultations, each with different frameworks. The DA used the value chain approach as a framework for defining priority programs, while PCAARRD focused the development of cutting-edge technologies. Both agencies defined their priorities by products. To transfer their priorities, each of these agencies relies on a regional presence - either through the DA's RFO for the BAR, or through consortia with HEIS, SUCS and private sector for the DOST (Baconguis, 2023).

Under the National Harmonized R&D Agenda[2], the DOST analyzed the R&D needs and calculated the

[2] NHRDA: National Harmonized Research and Development Agenda (2022-2028)" (DOST, 2022)

needed budgetary requirement over 7 years for the Agriculture, Aquatic and Natural Resources sector, which includes R&D in forestry, natural resources and the environment (DOST, 2022).

The players along the value-chains

It is important to differentiate between players in agricultural value chains and those linked to fisheries.

In Agriculture sector, the majority of farmers are smallholders who face numerous challenges, particularly limited access to technology, credit, and markets. In contrast, some large farms are managed quite differently, as they have resources, easy access to markets, and are often well integrated into modern value chains.

Input suppliers mainly supply farmers with seeds, fertilizers, and pesticides. There are two types of service providers in this sector: small local companies and multinationals. The latter have access to higher-quality products. For instance, in the corn sector, 82% of farmers are smallholders, due to the small size of farms, farmers in corn sector, are unable to achieve economies of scale, and yields are the lowest in the ASEAN region at 4.2 tons per hectare. The price of genetically modified seeds accounts for a significant 17% of production costs. The price of seeds has risen sharply by an average of 5.8% between 2002 and 2018. This indicates that the major players who control seeds have a quasi-monopoly position (Adriano, 2023).

Middlemen and traders play a crucial role in bringing farm produce to market. These middlemen enable small farmers to sell their produce, but are often in a position of power that allows them to exploit these small farmers. These traders occasionally extend credit to small farmers who encounter difficulties in obtaining loans from traditional financial institutions. This can result in a heightened level of reliance of these small farmers.

Processors are of different kinds, depending on the sector. In the case of corn value chain, corn is sold to millers who transform it into feed for livestock, poultry, or aquaculture. There are different categories of processors: some are industrial, such as San Miguel Foods, which specializes in the production of animal feed and supplies most of the country's demand for commercial animal feed, while others are small-scale, with processing carried out directly on the farm. In the case of chicken meat production, there is a high degree of concentration, with four to five companies holding over 50% of the market. These companies produce their own chicken feed, use contract growers to produce the chickens, and take care of sales, right up to supermarkets or retail outlets.

Retailers include local markets, supermarkets, and companies exporting agricultural products. Their demand for quantity and quality influences production and agricultural standards.

In the fisheries sector, a distinction is also made between small-scale fishermen, whose number dominates the sector and use traditional fishing methods, and commercial fishing companies. The latter use more advanced technologies and make a more significant contribution to catches, but sometimes pose problems for the sustainability of the resource and ecosystems.

Service providers in the fisheries sector supply fishermen with fishing gear, boats, nets, or feeds to aqua-culturists. For example, in milkfish production, which is mainly from aquaculture, feed accounts for about 60% of total operating costs. Other inputs include the purchase of alvin from hatcheries, of which there are not enough in the Philippines; some alvin for milkfish are imported from Indonesia or Taiwan.

Traders and intermediaries, who enable fishermen to sell their products on the market, affect the income levels of fishermen, depending on their practices.

Processors play a pivotal role in the aquaculture value chain, utilizing a range of processing technologies, including preservation by salting, fermentation, smoking, freezing and canning, as well as the production of minced fish as surimi. However, in the Philippines, the milkfish industry is not yet sufficiently developed and is still often processed by home-based businesses, with the exception of a few industries focused on processing and exporting milkfish.

The AFMA policy has led to some notable successes, particularly in terms of improving access to technology services for large companies. However, there is still a significant challenge for small-scale farmers and fishermen, who continue to face limited access to credit and the market.

Bottle-necks in Extension services

Agricultural extension services in the Philippines are under the authority of local government units (LGU)[3]. Within DA thirty entities have extension programs: five DA' bureaus - ATI, BFAR, BAI, BPI, Bureau of Soils and Water Management (BSWM); five attached agencies - PhilFIDA, PCC, Philippine Center for Postharvest Development and Mechanization (PhilMech), PRRI, and National Fisheries Research and Development and Mechanization; five corporations - NDA, NTA, PCA, PhilRice, and SRA; and all DA's 15 regional field offices (RFO). ATI has the explicit function of conducting nonformal education, with its regional training center. Dost-PCARRAAD, DAR, and SUCS are also engaged in extension work. Extension services are fragmented and based on commodities, with the rice program (35%) on top, followed by livestock (22%), high-value crops (21%), and corn (17%) (Baconguis, 2023).

In order to oversee the R&DE system, AFMA established the Council for Extension, Research and Development in Agriculture and Fisheries (CERDAF). The law and its implementing regulations set the budget for extension services at 1% of gross value added in agriculture and fisheries, with another 1% also earmarked for R&D. However, CERDAF was unsuccessful, and AFMA was unable to address the complex and cumbersome bureaucracy of the public agricultural R&DE system due to inadequate funding and a lack of priority. The effectiveness of LGUs extension services has been minimal (Briones, 2023).

As a result, agricultural or aquacultural extension activities face challenges in securing adequate funding, particularly for the recruitment, training, and equipping of extension workers. This hinders their ability to deliver quality services to small-scale farmers or fishermen. Although BAR's Human Resource Development Program contributes to improving the human resource pool of agriculture research, development, and extension professionals, there is a shortage of well-trained extension workers.

A significant challenge is the absence of connections between research institutions and extension services, which limits the dissemination of new technologies and practices to the field. Additionally, the use of modern training and communication methods is still limited, with extension services relying on traditional communication channels that do not reach a wide audience. There is a need to integrate modern information and communication technologies (ICT) to improve knowledge dissemination. All these hinder the implementation of modern practices tailored to climate change in the agricultural and fisheries sectors, which in turn affects the productivity and sustainability of these sectors. There are 3 general solutions to these problems:

- Increase budgets for extension services to employ better-trained stAF and provide ongoing training, thus improving access to and the quality of extension services for smallholders and fishing communities (Briones, 2023; Otsuka, 2021).
- Strengthen links between research and extension to accelerate the adoption of new technologies.
- Use ICT.

[3] "*The Constitution instituted autonomy for local governments (Article II, Section 25). This was eventually legislated by the Local Government Code (LGC) of 1991 under RA 7160, wherein agricultural extension services were devolved to local government units (LGUs), meeting the fourth Green Book recommendation* » (Briones, 2023 p 49).

More precisely, Briones (2023, p 71) suggests implementing the following measures to improve the effectiveness of R&DE services: mobilizing CERDAF, closing the R&DE funding gap, and establishing a monitoring and evaluation (M&E) system to hold the actors delivering R&DE services accountable. He also suggested (p 77) reallocating expenditure support programs of AF sectors from specific agricultural commodities as rice or corn, to public goods and general services, such as extension services, R&D and market aids. These could also be direct benefits to small farmers, helping them to recover more quickly from climatic shocks.

Government supports to AF and R&DE budgets

DA AF R&DE and Total AF R&DE of the Philippines

The AFMA had set the R&D budget at 1% of GVA in agriculture and fisheries (Briones, 2023), this was to be done in 2001, with an equivalent amount to be allocated to extension services. The budget shall be allocated on a multiyear basis and based on R&D grants. The minimum of 1% was never reached for R&D.

Government support for AF R&D represents a relatively small portion of the government's General Support Service (GSS) for the AF sector. This share, in relation to the overall government budget for supporting the agricultural sector, has fluctuated over time but remains low at around 3 to 4 %, it was 10 % in 2000 and is about 20 % in Europe (see figure below from OCDE GSSE). Over the same period, the share of extension services was maintained at 15-20% of AF GSS.

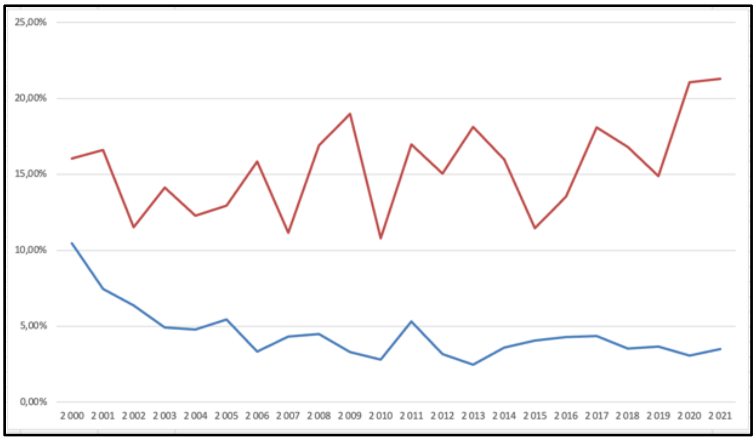

Figure 3: Government support for AF RDE: ratio of R&D expenditures (in blue) or Extension (in red) on AF General support service GSSE (Sources OCDE)

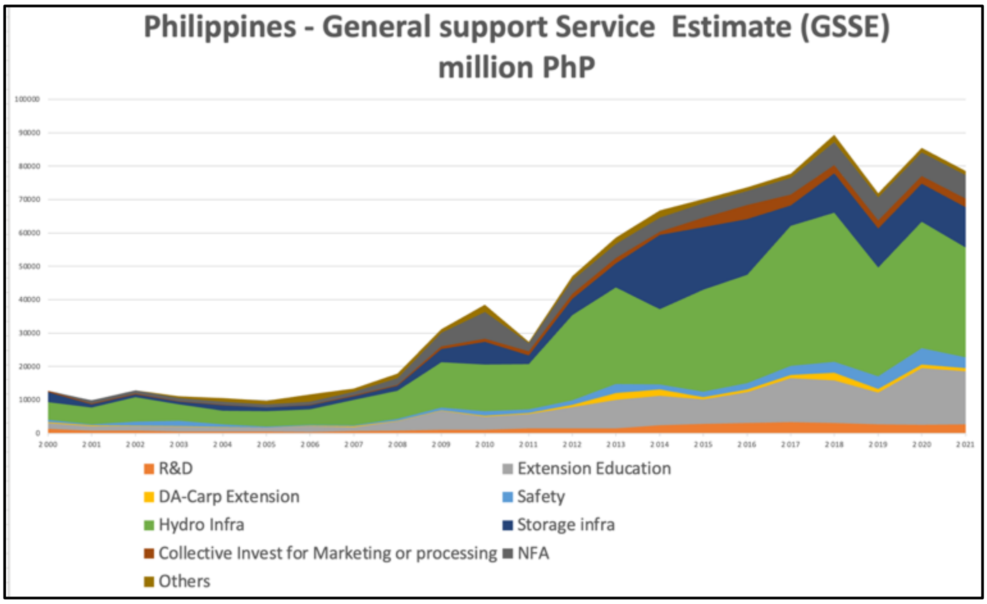

Figure 4: Breakdown of General support service Estimate (GSSE) for The Philippine agriculture and fisheries sector at current prices. Source of data: OECD (2022).

Government support for R&D represents only a portion of total R&D expenditure in the Philippines. In addition to government support, higher education institutions (HEIs), the private sector, and non-governmental non-profit organizations contribute to national AF R&D efforts. In 2018, this government share represented 63% of total R&D expenditure (See figure 5 - Source DOST).

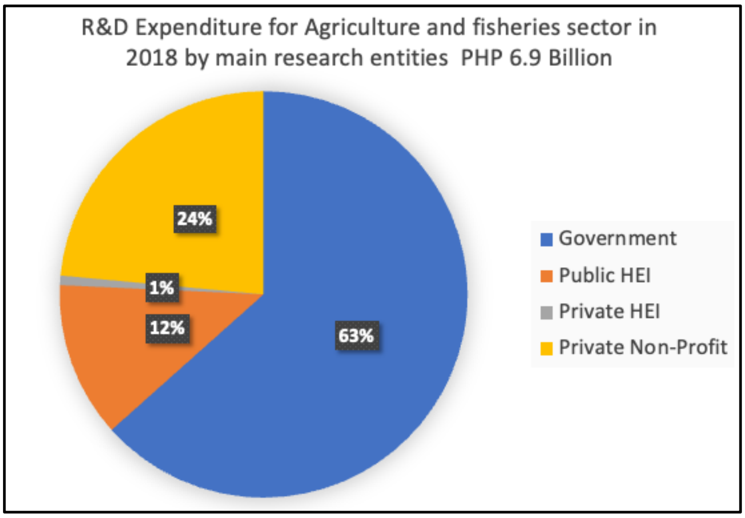

Figure 5: AF R&D expenditure by research entities in Philippines (calculated from DOST 2018 data)

However, government support for AF R&D consists mainly of the AF R&D budgets of the Department of Agriculture through its research office, DA-BAR, the DOST through the PCAARRD, and to a lesser extent, of the DENR.

In recent years in absolute and relative terms, especially since 2018, R&D spending has declined. Expenditures on extension has remained at a level proportional to overall government spending on agriculture (Figure 3).

Planned R&D budget

As the agriculture and fishery sector is a major priority for the Philippines, while the trade deficit makes the country increasingly vulnerable to the international food market given fragile global food security system, series of health and geopolitical crises, and the long-term risk posed by climate change the government is planning to increase its AF R&D budgets. This is reflected in the DOST agenda, Harmonized National Research and Development Agenda 2022-2028 (HNRDA, 2022).

It is evident from graph 6 that the R&D focus remains on crops, the aquaculture, livestock and environment. R&D budgets remain relatively stable, and research into climate change is emerging slowly (HNRDA, DOST, 2022). The budget proposed by DOST represents a significant increase in the budget for AF R&D in the coming years.

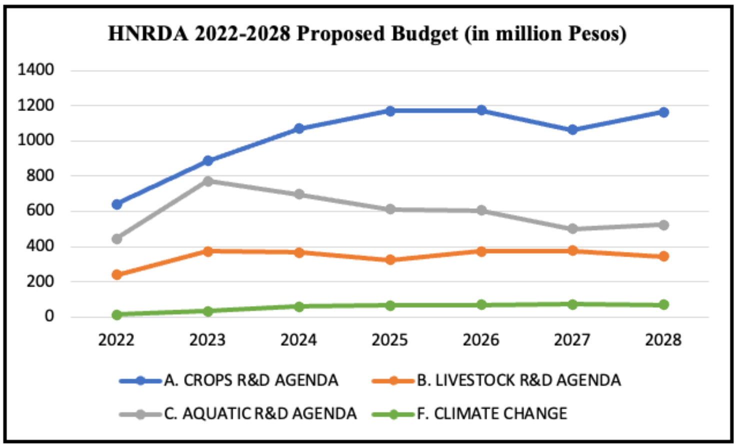

Figure 6: HNRDA 2022-2028 proposed AF R&D budget (in million Pesos) (Source HNRDA)

Philippines AF R&D budget is below international standards

The R&D budget in the agriculture and fisheries sector in the Philippines is below international standards. Significant yet achievable increases in R&D budget are needed to make the sector competitive, innovative, impactful and resilient to climate change impacts.

From 2018-2022, the R&D budget of the Department of Agriculture (DA) of the Philippines ranges from P3.12 billion (2021) to P3.93 billion (2018) out of the total annual budget of P85.6 billion (2021) and P103.07 billion (2018), respectively. By standard definition, R&D expenditures basically include current and capital and MOOE[4] expenditures to implement various types of research work may it be basic, applied and experimental or combinations thereof. If by any indication, a declining trend of the R&D budget for the DA Bureau of Agricultural Research (BAR)--the major research arm of the department, has been noted particularly from 2018 onwards (Figure 6 & 7). The role of the government spending on R&D remains crucial as it constitutes a major share in the overall R&D spending of the country. In a report by OECD (2022), the breakdown of the General Support Services Estimate (GSSE) in the Philippines reached about P90 B in 2018 but the R&D budget is small accounting to 3.5% only (Figure 4 and 7).

[4] Maintenance and Other Operating Expenses (MOOE) refers to the expenditures to support the operations of the research project or program, such as, but not limited to supplies and materials, transportation, travel, utilities, repair, etc..

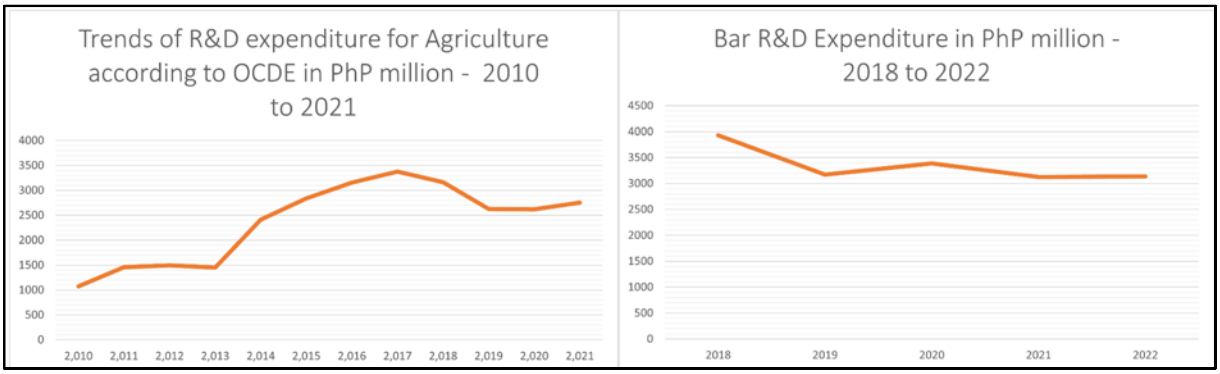

Figure 7: DA-BAR Expenditure (on right) and OECD R&D budget estimate (on left) for the Philippines Agriculture and fisheries sector at current prices. Sources of data: OECD (2022) and DA-BAR (2023)

Overall, while the Philippine government's spending on R&D in agriculture and fisheries sector is at $3.5 for every $100 it spends to support its agriculture, it is $6 in Vietnam, $10 in Brazil, $11 in China, and $21 among OECD countries (OECD, 2022) (Figure 9).

Additionally, the total public spending for R&D as a percentage of national production of the Agriculture and Fisheries sector (AgGDP) is another commonly used indicator to measure the country's research intensity. In the Philippines, this ratio is very low pegged at around 0.15 % (OCDE, 2022), while an earlier report puts it at 0.41 in 2017 (Stads 2021). In contrast, this ratio reaches between 1 to 2% in Malaysia, 2% in Brazil, and 3 to 4 % in most OECD countries. In effect, the Philippines faces a significant deficit of attainable investment for agriculture R&D, as measured by the difference between actual research intensity (public research expenditure/AgGDP) and potential attainable research intensity (Figure 8).

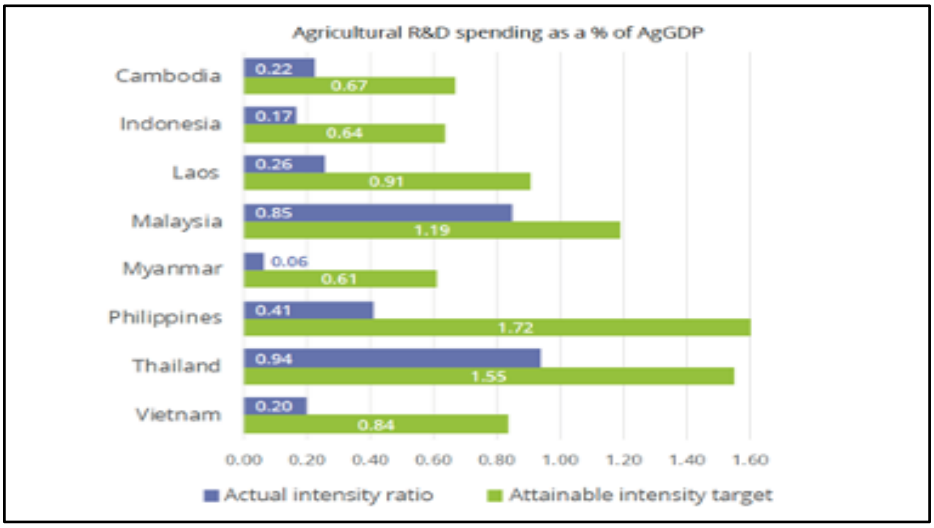

Figure 8: Agriculture research intensity ratios and attainable targets in 2017 for different countries of South-East-Asia. Sources of data: ASTI and Nin Pratt in Stads G.J. & al. (2020)

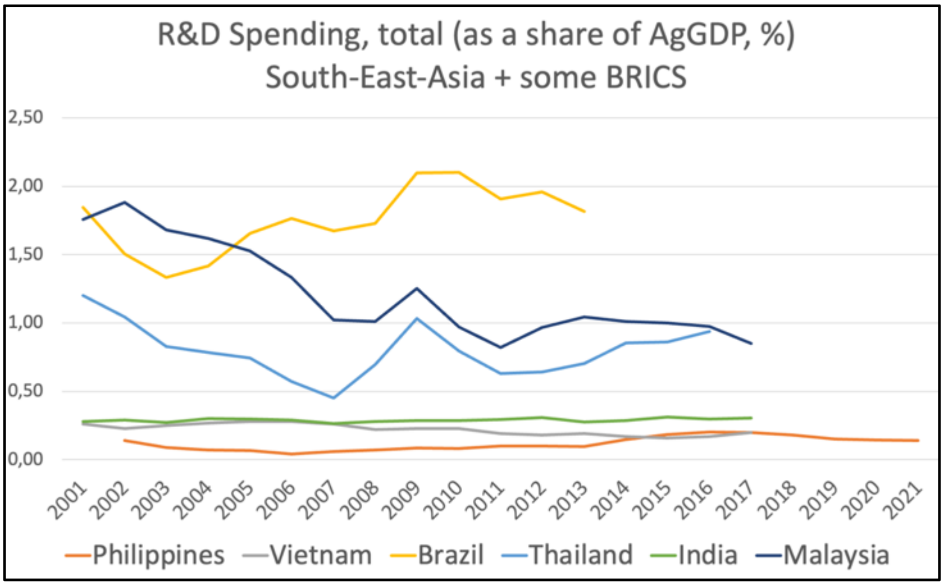

Figure 9: R&D budget spending in % of AgGDP for different countries around the world. Source of data: ASTI: https://www.asti.cgiar.org/data-graphics and OECD (2022)

There are ways in the Philippines for increasing the R&D budget without imposing significant strain on the national budget (Figure 4). Shifting producer support policies from market price support to expenditure support would be a more efficient use of public funds. A broader and deeper appreciation by all of the value of R&D and extension as public goods thereby meriting government spending would be strategic (Briones, 2022).

In addition to the usual administrative and procurement concerns, recent studies have highlighted the slow growth of the number of researchers and a huge fragmentation of research (Dikitanan & al 2022, and Stads G.J., 2021) as among the major issues of the agriculture research system in the Philippines. This means that any increase in the budget must also consider the absorptive capacity of the agriculture and fishery sector research system.

Why R&D is the best government investment for supporting AF resilience?

The R&D investment in the agriculture and fisheries sector in the Philippines pays off and promises huge potential for economy-wide impacts should systemic changes be achieved, with increased budget playing a crucial role in unlocking this potential.

There is ample evidence that public investment in agricultural R&D ushers in significant returns and has been a key element in yield increases and rural poverty reduction in the South (OECD 2022; Alston 2021; Piesse & Thirtle 2010). The R&D is making it possible to produce more food per hectare with the same or fewer inputs that cause pollution and greenhouse gas emissions. Based on a meta-analysis of $60 billion in R&D spending around the world, Alston (2021) was able to show that the cost-benefit ratio is on average 1 to 10, making R&D the best investment a government can make to support its agriculture sector.

In addition, investments in research in the Philippines yields significant results in terms of the rate of return. The R&D investments are generally more profitable than other investments, and for the primary sector such as agriculture, rates of return are around 60% (Cororaton, 1999).

Improvements to increase resilience to Climate Change in AF sector

Climate solutions are increasing but would require more R&D investment to make it bigger, smarter, and more impactful.

As among a major response could be Climate-Smart Agriculture (CSA) that for years have gained national interest. The CSA makes the link between climate change and food security.

The presence of climate change has added additional layer to making the agriculture and fishery sector of the Philippines competitive and resilient. Sombilla (2018) noted the importance of stronger climate change-related R&D particularly in the agriculture and fishery sectors in the Philippines. Of particular interest are science-based knowledge on climate change adaptation and mitigation approaches, best practices, and technologies that must be all aimed towards increasing productivity while enhancing lowland and upland ecosystems through land, soil and water conservation and mitigation (Sombilla 2018). Systematic, comprehensive and across the value-chain R&D, extension and innovation system is needed to enhance breeding and improved farm and productive practices, information and public awareness campaigns, and the adoption of effective regulatory measures and policies to correct human-and industry-induced malpractice.

AF R&D Budget Calibration Guidelines and Recommendations

Sufficient, sustained, and regular R&D budget must be strategically allocated by aligning it with the existing national agriculture and fisheries modernization and industrialization plans and roadmaps (NAFMIP, AFMA, etc) along with the National Harmonized R&D Agenda.

Undoubtedly, achieving the necessary transformation in the agriculture and fishery sector requires innovation that can be made possible by significant R&D support. Despite the Philippines' longstanding support for the agriculture and fisheries sectors, policymakers must further appreciate that their decisions today regarding resource allocation to R&D will enable their envisioned agricultural productivity and sustainability. This becomes especially crucial in anticipating and addressing the escalating challenges posed by climate change.

In 2017, total R&D expenses in the Philippines, excluding extension and education according to international definitions, was 6.9 billion. Research intensity, which is the ratio of A&F research expenditure to AgrGDP, was estimated at 0.41% in 2017 (Stads, 2020). To date, this research intensity ratio has been declining, with the total DA R&DE budget reaching 3.1 billion in 2021 (DA-BAR, 2023), indicating a drop in A&F research intensity to around 0.27%.

Under the National Harmonized R&D Agenda, the DOST analyzed the R&D needs and calculated the needed budgetary requirement to be at PhP 401 billion over 7 years for the Agriculture, Aquatic and Natural Resources sector, which includes R&D in forestry, natural resources and the environment (DOST, 2022). The PhP 44 billion budget required by the HRNDA for A&F R&D would amount to 0.055% of the NAFMIP budget. In other words, the government needs to allocate $5.5 to A&F R&D for every $100 it spends. This is approximately two dollars more than the business-as-usual approach, allowing the A&F R&D gap identified by ASTI to be addressed in alignment with Philippines' targets.

The research priorities set by DA-BAR and DOST require an ambitious R&D budget. All indicators suggest that the current investment in A&F R&D and innovation in the Philippines is inadequate. To achieve the country's food security objectives, enhance the well-being of the rural population, and proactively address the compounding challenges posed by climate change, a significant increase in the R&D budget for the agriculture and fisheries sector is imperative. To realize this, the following considerations are highlighted:

- The increase in the R&D budget of the A&F sector may be accompanied by a reorganization of the R&D agencies and reforms in accounting, auditing procedures and procurement system to increase their absorptive capacity so that these budgets can be used more effectively and efficiently. Simultaneously, measures should be taken to attract talented young researchers.

- The budget increase can be implemented gradually, aligning with the Philippine National Development Plans. A phased approach, clearly directed towards the required R&D budget increase over specified periods, would made the target more achievable.

- Addressing the fragmentation of A&F R&D in the Philippines requires ongoing efforts to harmonize and rationalize relevant policies, plans, programs and activities among all concerned agencies. This includes better understanding of the budgets allocations, enhanced allocation strategies to avoid duplication, and establishment of more platforms for sharing, learning and complementing R&D results. Coordination efforts between DOST-PCAARRD and DA-BAR should be continued, deepened, and expanded. International cooperation, particularly with ASTI, which allows the Philippines' efforts in A&F R&D to be compared with what is being done internationally, is essential to inform decisions at the time of budgetary choices.

- The Philippines devotes a considerable and growing budgetary effort in supporting its agriculture and fisheries sector, and rightly so, as it is a strategic and essential sector that is regularly exposed to multiple crises. A strategic budget reallocation could reconcile short-term and long-term interests, in particular by significantly increasing the share of AF R&D, which currently amounts to about 3 to 4 $ per 100 $ spent on supporting the sector. By ensuring that the share of R&D in A&F increases progressively to $4 and then to $5 for every $100 spent, today's decision-makers could ensure that the objectives of national plans for food security, climate change adaptation, and rural poverty reduction can be met. Another potential indicator is the target set by NAFMIP: 1% of AgrGDP for R&D and 1% of AgrGDP for Extension. This target has not yet been reached for R&D. To achieve this, a monitoring system to measure R&D expenditures would be required. This approach also facilitates future stabilization of budgets supporting agriculture and fisheries.

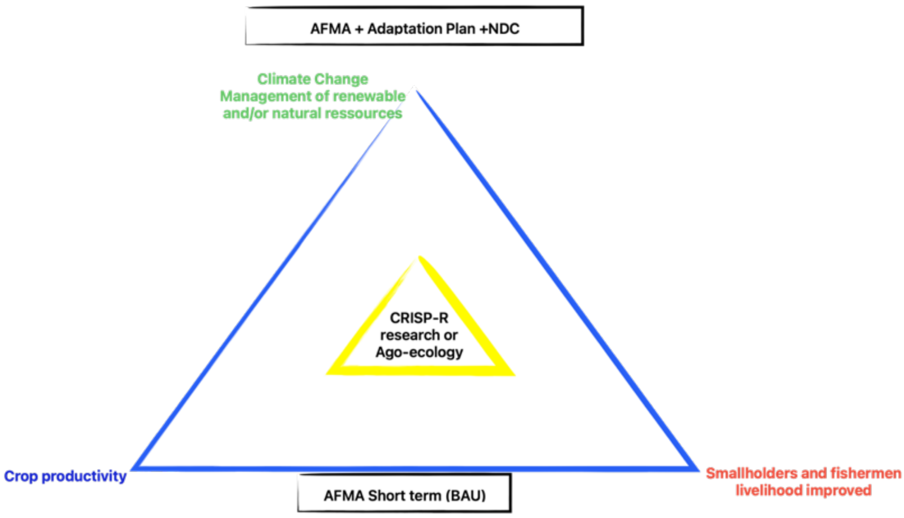

Figure 10: The R&D priority setting triangle

Component 2

2.1 Genetic expert CRISPR/Cas9 -Training in France

Objectives of 2.1 on genome editing

AF R&D project on the climate-related crop breeding for productivity growth should increase efficiency in the use of less water and land. It included genome editing research and capacity building. The action focused on non-GMO applications (identification of important genes, gene editing, gene screening, etc.). Its other activities included: (a) Preparing and implementing local training courses on gene editing for crops, (b) Organizing 3 training fellowships of Philippine specialists in CIRAD Montpellier on crops.

Targeted mutagenesis tools, such as CRISPR-Cas9 and derived, in agronomy are used to introduce specific modifications into the genome of cultivated plants. Thanks to their precision and the wide range of possibilities for genome modification they offer, these new classes of GMOs differ greatly from traditional GMOs. They are not considered to be genuine GMOs by some legislations, because, contrary to traditional GMOs, genes from other plants are not introduced, but rather the genome is modified gene by gene, which brings these mutations closer to natural mutations, it can be considered as non-GMO. CRISPR/Cas9 makes it possible to introduce precise modifications into the genome of the plant, considerably shortening the time to obtain an improved variety compared to traditional mutagenesis methods which induce random and uncontrolled modifications. As these tools make it possible to create precise mutations in specific genes, they can have numerous applications in agronomy. It is now possible to accelerate the development of cultivated plants, that could almost resemble a variety obtained by traditional methods, with improved agronomic traits and even performing several services at the same time.

For example, targeted mutagenesis tools can be used to modify genes improving 1) tolerance to environmental stress, allowing a greater resilience against unfavorable climatic conditions, such as heat, drought, so it would be possible to maintain agricultural productivity in changing environments 2) plant resistance to disease, to maintain good performance while reducing the use of chemical pesticides, 3) crop quality, nutrient content and biomass production by modifying genes involved in the composition of cultivated plants, such as those responsible for oil, protein, vitamin or mineral content. This can lead to crops with better nutritional quality, thus meeting the specific needs of consumers, 4) the use efficiency of resources such as water, nitrogen, phosphorus, etc making the farmer less dependent on external resources.

In summary, these tools are a valuable aid to counter the effects of climate change, the scarcity of many precious resources for agronomy. This can help to reduce the need for fossil fuels, for chemical fertilizers and other agricultural inputs, making farming less polluting, more sustainable and economically viable.

UPLB-CIRAD 2.1 team

The team was composed of Christophe Périn, Anne Cécile Meunier, Matthieu Chabannes researchers at CIRAD’s Genetic Improvement and Adaptation of Plants (AGAP), and Prof. Maria Genaleen Diaz, researcher at the UPLB Institute of Biological Sciences (IBS). They identified 3 Genome specialists from Philippines who went later in France for a 3 weeks training courses: Dr Roanne Ripalda (rrripalda@up.edu.ph), Dr Roanne Gardoce (rrripalda@up.edu.ph), Dr Neilyn Villa (novilla2@up.edu.ph).

Mission in Philippines of CIRAD CRIPSR Researchers[5]

From September 25th to 28th, in Philippines, twenty-nine researchers and scientists from different research centers linked to UPLB, and two CIRAD researchers, shared their common interest in developing climate change resilient crops. They exchanged about future possibilities for pooling their respective skills in collaborative projects. These discussions took place during the first phase of the Technical Assistance project for the research and development (R&D) policy reform for the Philippines on Climate Change Action Program (CCAP).

Combined with visits to the laboratories and various infrastructures of the Institute of Plant Breeding (IPB), the Institute of Biological Science (IBS) and the Institute of Crops Science (IcropS), the discussions highlighted the many strengths and skills available to these research laboratories for projects involving genome editing tools in the Philippines. Christophe Périn and Anne Cécile Meunier identified numerous assets that will enable the success of genome editing projects: an excellent mastery of various cutting-edge In Vitro Culture techniques; numerous collections of plants with biological data from multiple associated disciplines, a range of specialised laboratories grouped on the UPLB campus but also promising areas of research.

Training and support needs from CIRAD to implement genome editing research projects were also identified during these meetings. CIRAD researchers have met the 3 candidates identified to follow the 3-week training which has been later provided in 2024 at CIRAD and could propose adjustments in order to meet their needs as closely as possible. Thus, in addition to the training "Applying CRISPR/Cas9 technology in plants: from theory to practise" which is provided by the Functional Analysis and Genome Editing platform (AFEG) since 2018, and which consists of 35 hours of theoretical lectures and supervised work on a computer, the 3 specialists who has been hosted, carried out a series of practical workshops in the molecular biology and in vitro culture laboratories adapted to their needs. This later allowed them to become familiar with many techniques that are used in genome editing projects, as well as to exchange with specialists of these techniques.

Finally, this contact with institute directors, their representatives, as well as numerous UPLB researchers, allowed the two CIRAD researchers to identify multiple possibilities for collaboration between CIRAD or UPLB research teams. The three specialists hosted have been also able to meet potential future partner teams during their stay in Montpellier. Pooling everyone's skills and areas of expertise has result in projects, which will accelerate the varietal selection scheme for plants of agronomic interest in the Philippines, through the use of these genome editing technologies.

CRISPR training at CIRAD Montpellier Hosting 3 UPLB Philippine researchers

In a second phase of the project, 3 researchers, each with different specialties, and belonging to three different UPLB institutes, have follow a tailor-made 3-week training course at CIRAD - Montpellier, aiming at their autonomy in the implementation of projects involving genome editing tools. The training program comprised various sequences, some of which are outlined in detail in an online document[6]. The curriculum included:

- 35 hours of theory and practical tutorials for hands-on practice,
- Laboratory practice: a total of eight half-days spread over 3 weeks,

[5] https://www.cirad.fr/en/worldwide/our-regional-offices/southeast-asian-islands/news-southeast-asian-islands/pooling-skills-to-support-varietal-innovation-of-major-species-in-the-philippines

[6] Please follow the link: https://drive.google.com/drive/folders/1tEgekyFI2hJe2VtqBGp1fOt-FWT_8Xvp

- 28 h of laboratory practice for CRISPR cloning (a) design of a simple mutagenesis experiment, design of a simple sequence deletion experiment, i.e. removal of a gene coding sequence, b) design of a complex sequence deletion experiment, i.e. removal of a protein domain with restoration of the reading phase,
- In-depth course on 3 CRISPR tools: CRISPR/cas9, CRISPR/Cas12a/Base Editor, with examples of applications for plant breeding,
- Course on legislation and controversies related to these tools,
- Course on protoplast tool (a rapid and inexpensive testing platform),
- Practice in characterizing a CRISPR/Cas9-induced SANGER mutation.
- Course on the range of available tools (CRISPR-based tools),
- Course on basic Editing tools,
- Work on implementing a Base Editor tool,

The trainees met various CIRAD teams, including the SEG team (UMR AGAP), which introduced them to molecular cytogenetics technology on banana over four half-days. This allowed the group from the Philippines to gain insight into the work being done in genome editing at UMR AGAP and to identify potential collaboration opportunities.

The objective was to identify projects that could facilitate collaboration and accelerate research on advanced themes in the Philippines. Four projects were identified, and the banana project was developed in greater depth and was the subject of a DA-BAR format XL sheet and another detailed descriptive sheet.

Proponent/Institution	Project title/Description	Cost estimates (PhP)	Duration
UPLB	Stable and transitory transformation of tropical species for genome editing of agronomical genes of interest	4 800 000	1 year
UPLB	Molecular characterization of resistance genes for TR4, BBTV, BSV pathogens to develop banana tolerant cultivars	11 000 000	3 years
UPLB	Genome editing for developing climate resilient coconuts	5 600 000	2 years
ULPB	Germplasm screening and identification of resistance genesagainst HLB and CTV in citrus	6 000 000	2 years

R&D projects proposals

1) *This project aims to contribute to existing efforts on enhancing banana germplasm resources towards resilience to biotic and abiotic stress factors including climate change.*

Technology: Mutants identified on TR4 and BBTV (UPLB mutagenesis) and BSV elimination techniques by GE (M Chabannes UMR AGAP CIRAD). Identification of corresponding genes providing GE targets in other banana varieties.

Description: The Philippines is one of the leading producers and exporters of bananas in the world. Fresh bananas are among the consistent top export commodities of the country (see component 1: main report, part 2 section on banana value chain). The industry is dominated by multinational companies and large-scale growers which produce Cavendish owing to around 50% of the national production. Small-scale growers cultivate other varieties like Lakatan, Saba and Latundan for domestic consumption. The sustainability and profitability of the Philippine banana industry is threatened mostly by diseases primarily the fusarium wilt of banana which is caused by the soil-borne fungus *Fusarium oxysporum* f.sp. cubense (Foc) 'Tropical Race 4' (TR4). In the 1950s, Fusarium wilt of banana caused by *Foc* race 1 (R1), commonly known as Panama disease, led to the decimation of banana plantations in the Latin Americas prompting the shift from the original export susceptible variety Gros Michel to the naturally resistant Cavendish. Nowadays, an impending epidemic is posed by TR4 which has spread across countries and continents despite strict quarantine regulations. The disease is present in the Mindanao Island group of the Philippines where 80% of the national banana production is situated. Cavendish and Lakatan are susceptible to TR4. As a known diversity hotspot for Musa, the Philippines hosts the greatest diversity of the wild banana progenitor *Musa balbisiana* (BB) including a number of natural hybrids of varying genomic constitution and ploidy level. The B-genome bananas exhibit resilience to abiotic stress like drought. Breeding programs would benefit from the incorporation of these desirable genes to elite cultivated banana varieties. However, this germplasm resource has been untapped for cultivar improvement. One of the biggest drawbacks on the use of these resources is the knowledge gap on endogenous banana streak virus (eBSV) in the Philippine B-genome bananas. Previous studies showed that *M. balbisiana* harbors eBSV which restricts its use in breeding and germplasm exchange and utilization. In addition, BSV is activated by abiotic stress and therefore poses a threat as an emerging disease together with the looming climate change crisis.

This project aims to contribute to existing efforts on enhancing banana germplasm resources towards resilience to biotic and abiotic stress factors. Specifically, the banana industry would greatly benefit from the improvement of TR4 response of elite banana varieties Lakatan and Cavendish through precise technologies like CRISPR. The technology could also be used to understand gene function of previously identified differentially expressed genes (DEGs). The development of TR4 resistant lines and its eventual deployment and utilization in major banana growing regions in the Philippines would not only secure the profitability of the banana industry but would also prevent the incursion of TR4 into the other island groups of the country and arrest strain evolution in the process. Simultaneously, the project aims to address the knowledge gap on the Philippine Musa germplasm with respect to endogenous BSV (eBSV). Evaluation of the diversity and presence of eBSV or lack thereof in priority B-genome containing Philippine banana accessions will be conducted towards the identification of its utility in breeding. Knowledge on BSV strain diversity in the Philippines will also contribute to preparedness efforts for this emerging disease. Finally, knocking-out the eBSV in thesegermplasm through CRISPR will enable the use of these germplasm materials in breeding and also for equitable germplasm access and use by banana researchers. Genetic improvement of banana has proven to be arduous and requires decades of research. With the use of modern tools, this project aims to increase the precision and speed with which parentals and improved varieties can be developed towards addressing the threats and challenges that climate change imposes on the world's favorite fruit.

2) Citrus genome editing project

<u>Technology</u>: Identify HLB and CTV resistant lines, which to validate the corresponding genes by Genome

Figure 11: Dr Roanne Ripalda, Dr Roanne Gardoce, Dr Neilyn Villa with some CIRAD colleagues at Montpellier, during their training mission.

Editing.

<u>Description:</u> This project could involve two CIRAD UMRs, one focusing on the genome editing community

UMR AGAP, the other UMR DIADE specializing in Plant Diversity, Adaptation and Development. It involves two components:

- Training to acquire cell biology skills for the use of genome editing on UPLB species (transformation of protoplasts, callus, prerequisites for GE use. InCell AGAP tray training / SEAPAG.
- Germplasm screening and identification of resistance genes against HLB and CTV in Citrus.

3) Coconut genome editing project

Technology: Develop Genome Editing for coconut for introduction of alleles of agronomic interest. A half-day round-table discussion was held with AGAP and DIADE specialists to explore other possible areas of collaboration on Genome Editing of rice, oil palm and coffee.

2.2 Mango data acquisition, analysis - (Pixfruit & Soyield).

Objectives of 2.2 on Mango - digital technology.

The initial idea of the TA Component 2.2 “Mango - Just-in-time digital technology that can integrate farm-level digitalization up to regional level production management”, was to evaluate the necessary conditions for transferring these CIRAD existing digital solutions to Philippines’ mango sector. Measuring, estimating and predicting yields is a challenge shared by players in agricultural sectors around the world. Uncertainty and lack of information have major logistical, organizational, agronomic and economic repercussions. Several levels are impacted along the value chain, from the plant to the production basin. SoYield® is a decision support tool (DST) for estimating mango yields at orchard and regional level. It meets the needs of growers and players in the sector, as well as those of public policy support services. PixFruit®'s expertise from CIRAD enables yield estimates to be acquired and made accessible: from the scale of the plant to the scale of production basins and countries, via the plot. Yield estimates are obtained by taking images and calculations tailored to each species, cropping system and soil and climate conditions. On a regional scale, all this information, gathered as close as possible to the reality on the ground and based on scientific data processing, provides a more accurate picture of the level and variability of regional production. PixFruit® combines three major skills developed at CIRAD:

- image recognition using artificial intelligence trained by neural network;
- crop forecasting calculations adapted to fruit species and growing areas, mastered by our scientific experts;
- co-constructed digital solutions tailored to the needs of the various players in the sector.

UPLB-CIRAD 2.2 team

This analysis was conducted by three experts:

- Pr. Calixto M. PROTACIO, researcher on perennial plant production and mango consultant at the University of the Philippines Los Baños (UPLB) in the Philippines
- Dr. Emile FAYE, researcher on digital and spatial agroecology at CIRAD HortSys lab in France
- Dr. Julien SARRON, researcher in agronomy of tropical fruit crops at CIRAD HortSys lab in Madagascar

Mango CIRAD mission in Philippines

A CIRAD mission was organized to gain a comprehensive understanding of the local conditions and assess the potential applications of this digital technology in the Philippines. The objectives of this mission were twofold: 1) Identify the need of the mango value chain actors and priority research areas and topics, 2) Assess the potentiality of developing and deploying a PixFruit®-based solution for the mango sector

State of the Art of the mango value chain in the Philippines and R&D priorities

High value- added fruits such as banana, coconut, pineapple, or mango have the potential to boost the Philippines' agriculture sector, which continues to underperform compared to its regional peers. The fruit production sector is an important sector for the Philippines, worth 5.3 billion$ (13.4% of agricultural value added) or around 1.3% of the country's GDP in 2021 (FAOSTAT, 2023; World Bank, 2022a). Coconut and banana are the two most cultivated fruit crops, with 3.6 million ha and 450,000 ha, respectively (PSA - OpenSTAT, 2023). The mango is the fourth most- produced fruit in the Philippines and is an important source of income for around 2.5 million producers (Department of Trade and Industry, 2017). According to FAOSTAT (2023), Filipino mango exports reached 16,300 t in 2021, representing around 40 million$ in value. The Philippines is the 11th largest mango exporter in the world. In 2022, Filipino mango production reached approximately 712,000 t. The mango production area was 184,000 ha (Fig. 1). The Philippines is the 8th largest mango producer in Asia, and the 4th largest in Southeast Asia, behind Indonesia (3.5 million t), Thailand (1.6 million t), and Vietnam (1.4 million t), but above Malaysia (76,000 t) and Cambodia (65,000 t) (Fig. 2).

Mango tree harvested area has increased between 1961 and 2010 from 17,000 to 198,000 ha (+ 747%). In addition, mango yields increased substantially between 1960 and 1998 from 3.89 $t.ha^{-1}$ to 7.41 $t.ha^{-1}$ (+90%).

However, since the end of the 1990s, mango production in the Philippines has stagnated and then declined. A stagnation phase was observed between 1997 and 2007, with production fluctuating around an average of 968,000 t (± 60,000 t sd.). During this stagnation period, the mean annual growth rate of production[1] was 1.90%. Since 2007, mango production in the Philippines has been gradually declining, from 1,041,000 t (2007) to 712,000 t by 2022. The mean annual growth rate of production is therefore negative over the 2007-2022 period (-1.78%), with a clear acceleration in the decline since 2016 (-3.49%). Similarly, the mango harvested areas have stagnated since 2010, with a mean annual growth rate of area of -0.10%. Hence, over the 2010-2022 period, harvested areas have stagnated at around 196,000 ha (± 1,200 ha sd.). The harvested area even seems to have decreased since 2016 with an annual growth rate of -0.21%.

As a result, mango yields in the Philippines have been declining steadily since 1997 showing a negative average annual growth rate of -2.40% (Fig. 3). Mango yields in the Philippines in the 2020s were similar to those in the 1960s, between 3.7 and 4.2 $t.ha^{-1}$, while yields could have reached 9.6 t.ha in 1980. Of the six major mango-producing countries in Southeast Asia, the Philippines has the lowest yield over the 2011-2021 period. Indeed, while Philippine mango orchard yields stood at 4.1 $t.ha^{-1}$ on average, it was more than three times higher in Indonesia (12.6 $t.ha^{-1}$) and Cambodia (13.3 $t.ha^{-1}$) compared to the Philippines during 2011-2021 (Fig. 2).

Several factors might explain the stagnation of mango production in the Philippines: the climate (typhoon, rainfall), pests and diseases, especially the cecid fly, inadequate orchard management, and high production costs that reduce competitiveness of the mango industry.

A high-potential export market - A small part of the mango produced in the Philippines is exported in fresh or processed forms. In 2021, mango exports reached 16,300 t or 2.2% of the national production. The Philippine fresh mango export sector is mainly driven by the 'Carabao' mango, appreciated by consumers in importing countries for its taste and sweetness. According to Mango Industry Roadmap (2022), processed mango represented around half of the total mango product exported. Processed mango products include dried mango, mango puree, frozen mango, and other prepared and/or preserved mango products.

The countries importing Philippine mangoes are mostly China via Hong Kong, the USA, and Japan. Hong Kong, the first importer of Philippine mangoes, alone accounts for 64% of mango exports in volume, but 'only' 24.8% in value (ITC, 2022). The USA and Japan are interesting markets, as mango is better valued there. Canada and South Korea are secondary importers, with around 10% of the value share each. Finally, other neighboring countries are minor importers: Singapore, Australia, Thailand, etc.

A dominating local market- Local market remains the major market for mango in the Philippines, accounting for around 98% of mango produced. On the local market, mango is consumed as fresh fruit – both in ripe and unripe form - or as a processed food (Department of Agriculture, 2022). The processed mango-based products for the local market come from fruits which failed to pass the quality and visual standards of the market for fresh. They act as substitutes, particularly during mango off-season

Figure 12: The two main mango farming systems in the Philippines. A. and B. Large farms (2% of the Filipino orchards). C. and D. Small farms (98% of the Filipino orchard) (photo credits @Cirad E. Faye).

Large farm: A small proportion of farms (3%) are large estates of more than 10 ha in size according to HVCC in 2006 (Fig. 12). These farms often combine several fruit crops or other agricultural activities such as livestock (e.g., poultry) or agro-tourism (resort). Some farms can be several hundred hectares in size (two farms of 200 and 300 ha. In these farms, the mango trees are entirely managed by the owner, who has the means to invest in inputs (chemicals, etc.) and workforces. Large farms have direct links with exporters. Some of them handle their own mango sorting and packaging.

Small farms engaging contractors: Around 85% of the mangoes in the Philippines were produced in small farms in 2013 (Esguerra & Bautista, 2013). In the Philippines, 73% mango-based farms are small farms (less than 3 ha) while 24% are between 3-10 ha (HVCC, 2006). According to the Department of Trade and Industry (2017), mango-based small farms have an average size of 1.34 ha (Department of Trade and Industry, 2017). It is estimated that there are 1.9 million farms that own an average of 10-12 mango trees (Department of Agriculture, 2022). Due to the high cost of production, most small-scale farmers are unable to finance farming operations (in particular the crop protection aspect). Therefore, they hire contractors or contract-sprayers to spray and manage the fruiting of their trees. The latter take charge of the investment in inputs (chemicals and bags for fruit bagging) and the workforces for implementing the management practices (application of chemicals, fruit bagging, spraying, harvest). The contractors also take care of harvesting operations. The contractors receive a share of the harvest, generally 70-80%, with the remaining 20-30% going to the field owner. The share can vary depending on the negotiation between the farmer and the contractor.

A well-structured mango value chain - The supply chain is composed of input suppliers (planting materials, agricultural inputs and post-harvest suppliers), producers (farmers, spray contractor, spotters), traders, processors, exporters and retailers. Indirectly, the value chain is supported by Filipino government agencies (PSA, High Value Crop Bureau at the Bureau of Plant Industry), research Universities (e.g., UPLB, BPSU), and by mango associations (e.g., Zambales Mango Producer Association, United Luzon Mango Stakeholders Association, Philippine Mango Industry Foundation…). It is estimated that around 60% of mango farmers are members of an association (Department of Agriculture, 2022).

Issue of Climate Change - Climate change is already having an observable impact on many crops in the Philippines, and is not exempting the mango tree. While the species has good resistance to drought and tropical cyclones, thanks to its very deep root system, higher temperatures, reduced water availability, and extreme winds impact production levels by changing flowering and fruiting patterns (Makhmale et al. 2016). Water and temperature stress can have an impact on fruits' number and size, as well as on production regularity. Tropical cyclones, on the other hand, will cause fruits to fall and may destroy harvests. Climate change will also increase the incidence of pests and diseases, which can impact mango fruit production and quality.

Issue of cecid fly - Since 2010-14, cecid fly (or mango gall midge) has become a major problem for the industry. Cecid flies are tiny, delicate insects that belong to the family of gall-forming midges, Cecidomyiidae (Diptera). Several species of the Cecidomyiidae family feed on several parts of the mango tree: fruit, leaves, flower, and shoot. Infestation that occurs during fruit-set results in premature fruit drop while infestation that occurs late in fruit development results in fruit of poor quality. The other species found in the Philippines (P. pustulata) infests the shoots that will not fruit at all. Damage of cecid fly can reduce yield by as much as 95% under heavy infestation.

There are currently no pesticides that can effectively combat this insect. Farmers are therefore forced to add physical control to chemical control by bagging all the fruit. This operation generates considerable costs for the sector, making small growers unable to invest in inputs: chemicals (flower inducers and pesticides) and bags. It is recognized that the cecid fly has increased the production cost by two in the two last decades (Department of Agriculture, 2022).

The fact that the sector is based on a single cultivar ('Carabao'), whose phenology corresponds to the pest's reproduction cycle (cecid flies), makes it totally vulnerable to this insect. Intensification and simplification of the cropping systems, in particular by reducing the plant biodiversity, and by applying pesticides that suppress auxiliary insects and natural enemies, can also be blamed. In fact, these ecosystem levers, which can be activated through agroecology, can significantly reduce the incidence of pests, including cecid flies.

High input costs and dependence on contractors - The climatic conditions in the Philippines are totally prone for pests and diseases development. Since external appearance of the fruit is an important criterion for most farmers, impacting the mango price, pesticides still represent the most readily available solution to control fruit quality (Esguerra & Bautista, 2013). As a result of the increased incidence of cecid flies, production costs have soared.

Some large and commercial farms have been able to absorb these costs and maintain their mango production by investing in control techniques. Some others are gradually abandoning mango production, which is becoming less and less profitable. This type of farming system, however, still enables higher yields by controlling cultivation practices.

For the most part, small-scale farmers have become totally dependent on spray contractors. The contractor system, while facilitating the work of farmers who do not have to take risks linked to the purchase of inputs, leads to minimal maintenance of mango orchards and ultimately to a stagnation in their yield.

Users of crop protection products, both farmers and sprayers, lack access to knowledge and reliable information about the dangers and use of crop protection products. Phytosanitary products are mainly applied on the basis of the calendar, in systematic application, rather than on the basis of observations (presence of disease), in curative application (Esguerra & Bautista, 2013). As a result, several studies have highlighted the poor economic performance and low incomes obtained by mango farmers in the Philippines (e.g., Aguinaldo et al., 2013). This phenomenon is exacerbated for small-scale farmers who are dependent on contractors and obtain only a small share of the production income.

Recommendation 1: Strengthening mango resilience to climate change:

Climatic variables (temperature, rainfall, extreme events, CO2 concentration) play a key role in the growth, productivity and pest levels of fruit crops. The team has identified three areas for further research and development to strengthen the resilience of mango to climate change in the Philippines.

a. **Impacts of climate change on the mango physiology and yields:** Climate change will therefore affect mango production (flowering will be altered by increases in temperature or more frequent rainfall, reduced rainfall will reduce mango growth, etc.). Furthermore, the effects of repeated or cumulative abiotic stresses on fruit trees remain poorly understood. Therefore, the aim here is to conduct research on mango ecophysiology that will help tropical perennial fruit cropping systems adapt to climate change and improve their productivity and resilience. The questions to be answered are: What are the effects of climatic factors (CO2 concentration, temperature, water availability) on the mechanisms underlying the development of mango yield and quality? How do these impacts affect water and carbon functioning at the whole-plant level and the long-term sustainability of production? What strategies and levers can be mobilized to adapt systems to future environments?

b. **Modern mango orchard management**: a national plan of improvement of the management practices should be developed in collaboration with research institutes, technical services and the stakeholders of the sector. Improvement of mango management practices should aim to enhance production while integrating farmers into low input and integrated orchard management strategies to sustainably manage their orchards. This plan should include the identification of practices that improve fertilization, tree pruning and size maintenance, orchard design (planting density), selection of new varieties, grafting, and rejuvenation of orchards (planting new trees). New management practices must first demonstrate their effectiveness through the establishment of trials at research stations and on farmers' orchards in a co-conception process. After testing and demonstrating the effectiveness of these practices, farmers and contractors should be trained so that these practices can scale to a larger audience. The ultimate goal of such a project would be to revitalize mango production on a national scale and enable the sector to increase its added value. Moreover, innovative practices can be envisaged to adapt mango cultivation to climate change, including biotechnical adaptation of the system (more stress-tolerant varieties and rootstocks) and the implementation of practices that improve, for example, canopy microclimate (e.g. manipulation of tree architecture), water use efficiency (e.g. soil mulching) or flowering (e.g. management of phenology through pruning).

c. **Agro-ecological control of the cecid flies**: Considering the significant constraints and costs associated with the cecid flies despite the extensive use of pesticides and fruit bagging, we recommend that the sector explore new methods of controlling this pest. One approach that has been tested in other contexts is to make use of agro-ecological control of the cecid flies, which can include integrated pest management and additional strategies to reduce pesticides use. A preliminary study has indicated that effective management of pests and diseases in mango orchards can improve yields by about 33%, whereas integrated pest management would reduce the costs of production by 16%, derived from a 75% reduction in chemical control cost (Preciados et al., 2013). Such results need to be reinforced to move towards sustainable management of mango pests. Numerous agro-ecological methods for the cecid flies have been tested, particularly at CIRAD. Several studies have shown the effectiveness of managing ground cover in controlling this pest, allowing for significant reduction of its incidence at low human, environmental and financial costs through natural regulation. Agro- ecological management should enable farmers to reduce pesticide use while increasing yields. The reduction in pesticide use will indirectly lead to a decrease in pesticide residues and contribute to the improvement of the quality of mangoes. Finally, the development of new techniques to control the cecid flies would make it possible to reduce the fruit bagging technique, which is costly and time-consuming for the farmers and contractors.

Recommendation 2: Digital tools for climate change adaptation and mitigation

Digital tools for climate change are in an early stage of development in the Philippines. However, we noted various initiatives of "climate change tools" that should be considered in future development. For digital tools to help scale-up resilience to climate change, especially for smallholder farmers, we propose to focus on three points:

d. **Quantify the needs of smallholders and other stakeholders** of the value chain to relevantly develop digital tools of technical advice (weather forecast, water use efficiency, pest and disease detection &

warning…) or on-farm performance assessment (farmers communication systems, yield estimates, GHG calculators, mitigate waste, sustainability indicators…) that address climate change mitigation or adaptation. Indeed, farmers are more likely to use tools that provide clear benefits (improve incomes or productivity, time saving, input reduction, sharing of knowledge, seize market opportunities…) and directly address their operational needs with a strong understanding of the context in which they are working (Alexandre et al. 2023).

e. **Scaling-up of digital tools resulting from the SARAI project** (Smarter Approaches to Reinvigorate Agriculture as an Industry in the Philippines): building of digital decision support tools in the Philippines (SARAI project up-scaling). The Institute of computer science of the UPLB has already developed several digital solutions for farmers including: weather forecast, pest and disease identification (similar to Plantix), irrigation monitoring, coffee advisory app (estimation of harvest date and production based on crop model). Based on the comments of the stakeholders of the SARAI project at the UPLB, some digital solutions developed during the project and that achieved their proof of concepts, lack of human-centered IT deployment and improvements of computer development to ensure successful scaling-up and high adoption rate at national and even regional levels.

f. **Evaluation of mango size, color grade and pest & damage levels at harvest through a PixFruit-based digital decision support tool**: currently small-scale producers of fruit trees, especially mangoes, have no other means to monitor the quality and damages of their fruits than performing a rough visual estimate at harvest; estimates that provide low accuracy and repeatability. And these estimations are critical for producers to sell their fruits because the size and color of the fruit and the visual aspect (pest & diseases damages or malformation) define the markets and the value of the fruits.

R&D Project proposal

These recommendations led to R&D project proposals which were issued in the form of an XL file in DA-BAR format.

2.3 Research project on aquaculture

The TA Component 2.3: “Research project on aquaculture in order to propose climate - related adaptation or mitigation to the issue of the “migrationshift” of catch-fish resources due to climate change”, aims at evaluating the factors that are required to the adaptation to the issue, develop climate smart technologies/R&D breeding.

Characterizing the challenges of climate change related to aquaculture can provide significant knowledge on how to adapt the sector, particularly through ecological intensification and climate smart aquaculture. Ecological intensification can also include the use of new or more resilient species and thus R&D activities in breeding programs. Cirad-UPLB expertise help characterizing the situation and proposing opportunities in research action to adapt the situation in the Philippines to climate change.

Objectives of 2.3

Phase 1 of the TA Component 2.3 includes a review of the Philippines inland freshwater and brackish aquaculture. The results obtained from this expertise is to propose climate-related adaptation or mitigation project to the issue of the “migrationshift” of catch-fish resources due to climate change. The project did a value chain analysis, identified the factors that are required to the adaptation to the issue, develop climate smart technologies/R&D breeding.

Phase 1 of the TA Component 2.3 was carried out in two steps. In the first step, an analysis of the available state of the art (literature, reports, data) was carried out in the office by the experts. These data and information were either provided by UPLB or found on databases available online. This work is contextualizing the second phase of this expertise.

In the second step, a field mission to the Philippines has been undertaken to implement a workshop with key stakeholders, data collection and analysis of the situation in the field. The information obtained with both state of the art and the field mission has been used to write the final report for perspectives research to be implemented to propose climate -related adaptation or mitigation to the issues of the “migrationshift” of catch-fish resources due to climate change.

UPLB-CIRAD 2.3 team

This analysis is conducted by two experts:

- Pr Ma. Vivian DC. Camacho, curator for freshwater fishes in the Museum of Natural History of UPLB, seconded from the Institute of Biological Sciences-Animal Biology Division where she is a Professor.
- Dr Jean-Michel Mortillaro, researcher in aquatic ecology and integrated aquaculture in Cirad at the mixed research unit of the Montpellier Institute of Evolution Science where he leads the aquaculture team.

Aquaculture in the Philippines

Aquaculture is a critical component of food security and economic livelihoods in the Philippines, serving as a primary source of protein and income for millions of individuals. According to Guerrero and Fernandez (2018), the Philippine fisheries sector contributed 1.6% to the GDP of the country in

2014, with a production of 4.69 million metric tons valued at PhP 242 billion (Fig. 1). Of the production, the farming of aquatic organisms, contributed 49.9%, followed by municipal fisheries with 26.7% and commercial fisheries, 23.7%. The major species farmed are seaweeds (66.29%), milkfish (16.69%), tilapia (11.09%), shrimps (2.17%), oysters and mussels (3.76%), and others (DA-BFAR, 2015, Fig. 2). Milkfish (*Chanos chanos*) is cultured in brackishwater ponds, freshwater pens and marine pens/cages. The Nile tilapia (*Oreochromis niloticus*) is raised in freshwater ponds and cages in lakes and reservoirs. Shrimps (*Penaeus monodon* and *P. vannamei*) are produced in brackishwater ponds. Oysters (e.g., *Crassostrea iredelai*) and mussels (e.g., *Perna viridis*) are grown in estuaries and coastal marine waters with bamboo poles staked into the bottom or floating rafts with suspended ropelines.

Impact of Climate Change on Philippine Aquaculture, Fisheries, and Freshwater Ecosystems

The changes in temperature and extreme weather events brought about by climate change have adversely impacted aquaculture, fisheries, and freshwater ecosystems in the country. According to Capili et al. (2005), after the 1998-99 El Niño-Southern oscillation event, the total estimated loss was PhP 7.25 billion. The aquaculture sub-sector suffered approximately 85% economic loss followed by marine fisheries (14.8%) and inland fisheries (0.3%). El Niño and La Niña are naturally occurring climate phenomena where global temperatures typically increase and decrease, respectively. However, their interaction with climate change, driven by increasing greenhouse gas emissions, has resulted in more extreme and unpredictable weather patterns affecting the various regions and various cultured species differently (Ramirez et al., 2019).

The increase in water temperature leads to the decrease in overall oxygen content which makes the water less conducive for optimal growth of cultured species. Specifically, during the hot weather months of March to April and drought periods (El Nino), growth and survival of various cultured species are decreased. The unfavorable conditions such as high salinity, high temperature, and lack of nutrients brought about by this season may result in "Ice-ice disease" in the top cultured species in the Philippines, the seaweed (Guerrero, 2017). This disease affects seaweed farms during the hot-dry season of March to May and is characterized by the bleaching of the thallus and disintegration of the affected tissues, which ultimately results in a loss of biomass (Ward et al., 2022). Simultaneously, cultured species in earthen ponds such as milkfish and tilapia are also adversely affected by this increase in global temperatures brought about by climate change from the lack of water from the irrigation source and high-water temperature in shallow ponds. Another impact observed by pond growers in cultured Tilapia are the few cases of darkened eyes, presence of lesions, and presence of crystallized salts on the scales, which may affect marketability of said species (Ramirez et al., 2019).

Comparably, typhoons have been destructive in the aquaculture sector in the Philippines. Specifically, the Super Typhoon Yolanda which struck the Philippines in November of 2013 has destroyed more than 2,000 hectares of seaweed farms in various regions of the Philippines (Guerrero, 2017). Simultaneously, fish cages and fish ponds are also adversely affected by this from flooding of fish farms due to heavy rains which results in the escape of cultured fish, such as Milkfish and Tilapia. Similarly, rainfall levels and production risks have a direct relationship, this includes the risk of losing cultured species from ponds during floods, possible invasion of unwanted species, and destruction of the walls of the man-made ponds (Bell et al., 2010). These can negatively affect the environmental sustainability of aquaculture production, primarily by introducing invasive fish species and degrading water quality (Maulu, 2021).

The unpredictable climatic change has also brought extreme effects such as phytoplankton blooms to the aquaculture and fisheries industry leading to massive fish kills. Massive fish kills in fish pens and fish cages of Milkfish aquaculture in Bolinao, Pangasinan occurred simultaneously with the algal bloom along with the lack of oxygen brought about by the increased temperatures. Losses from dead culture milkfish alone amounted to around six million pesos (Azanza et al., 2005).

Mitigation and Adaptation Strategies, Policy and Governance Measures

Various strategies have been employed to address and proactively act on the impacts of climate change in the aquaculture and fisheries sector in the Philippines. Mitigation strategies aim to lower greenhouse gas emission and sequester carbon, while adaptation strategies are measures that allow the fisheries and aquaculture sector to cope with the impacts of climate change (Guerrero, 2017).

Effective policy and governance frameworks for promoting climate-resilient aquaculture practices in the Philippines include the integration of climate change considerations into national and local development plans, regulations to mitigate environmental degradation from aquaculture activities, and incentives to promote sustainable practices. The Philippines, aiming for a sustainable aquaculture requires some environmental assessment before a license to operate is given, this is the Environmental Impact Assessment (EIA). The EIA is a process implemented by the Department of Environment and Natural Resources (DENR) under the Environmental Management Bureau (EMB) which ensures that the proponent is committed to implementing its approved Environmental Management Plan to address any environmental impacts (Bunye, 2019).

According to Vista (2014), a fishery policy-response scenario that would target an increasing production in the fishery sector (ocean fishing, freshwater/coastal fishing, and aquaculture) is viewed as a potential policy response given climate change impacts on the selected subsectors of Philippine agriculture. This scenario is described by Vista (2014) as a possible policy response to climate change impacts since the Philippine fishery sector is less vulnerable to the impacts of climate change compared with those in 137 other economies (Allison et al., 2009). Furthermore, the Philippine Government's increased provision of grants in the form of agri-fishery inputs, equipment and facilities, including farm-to-market road projects, which are expected to further boost the development of the agricultural and fishery sector and increase the productivity of fisherfolks and small farmers to selected provinces and local government units in the country (Vista, 2014). In the fishery policy-response scenario, it is assumed that fishery production could be increased by 10%.

Technological Innovations

Technological innovations can enhance the resilience of aquaculture systems to climate change by improving production efficiency, resource management, and disease control. For example, seaweed culture is commonly grown through fixed monolines in shallow waters, however, in order to avoid high sea surface temperature and minimize the occurrence of "Ice-ice disease", a method of growing seaweeds with floating monolines in deep coastal waters have been employed (Guerrero, 2017). In order to prevent escape of cultured species during typhoons, the regional director of BFAR Region 1, Nestor Domenden, led the development of a submersible cage — the "rope-framed floating fish cage" (RFFC). This technology is also more cost-effective as the rope-framed cage costs half the price of a Norwegian-type frame.

Community-Based Approaches.

According to Vista (2014), climate-induced impacts will result in a net loss to the Philippine economy and its key agricultural sectors in the short run. Since production would be greatly affected and would have ripple and multiplier effects in the economy, it is imperative for Philippine farmers to employ adaptation measures to lessen the impacts of climate change. Several communities have already experienced but are not fully aware of the interplays of climate change, natural hazards, and waste problems (Yoshioka et al. 2021). It is expected that community-based approaches play a crucial role in implementing policy measures and answering challenges of climate change. From these, a vulnerability assessment tool to understand resilience of fisheries (VA-TURF, Mamauag et al., 2013) was developed to identify major concerns from the communities and prioritize strategies that could be implemented by the communities. Aside from strategies for implementing enforcement activities to deter illegal fishing practices and establishing marine protected areas, several socio-economic strategies were prioritized by the communities emphasizing the latent capacities to be enhanced. These include seaweed farming, milkfish pond and cage culture, mud crab fattening culture, rabbitfish and grouper fry grow-out culture, sea cucumber culture, backyard-scale hog and goat raising, and hand-weaving handicraft from Nipa. Other sources of income such as small-scale rice farming, coconut farming-related activities (e.g., copra and charcoal from coconut shell), and other short-term labor-oriented jobs (e.g., factory work, carpentry, house construction jobs, public work, public transportation services) were also determined in each site, which is crucial for identifying alternative livelihood options.

Main results on aquaculture (2.3)

The mission conducted jointly with Cirad and UPLB scientist allowed for a better understand of the field situation and challenges. The mission identified several constraints and opportunities regarding milkfish and tilapia production as well as for prawn, although the later production was not explored in the field. Discussion with key stakeholders such as academic institutions and government agencies provided insights on the strategy already implemented to answer climate change as well as on the opportunities to be strengthened. These included a scope on small scale aquaculture together with mudcrab, ricefish farming and associated mangrove aquaculture, but also promoting empowerment of youth and women. Thus several projects were proposed for mitigation and adaptation of aquaculture to climate change considering both the technical and socioeconomical aspects and focusing on sustainability of aquaculture.

The results were divided into two categories:

- the first category was a synthesis of value chains available in the general report produced by this team[7].
- the second category was project proposals. There were three project proposals:
    - One was on the circular economy in the context of aquaculture.

[7] See 2.3 main report at: https://drive.google.com/drive/folders/1M8vZ7-5QwpJMvC6Vp76ZnKLpz3qVg2Zm

- Another was on integrating several types of small-scale aquaculture. This integration would be adapted to small-scale producers.
- The third project was on a genetics program. This program would enhance the value of local species.

These projects are detailed in the following paragraphs.

Project on circular economy in aquaculture

Circular approaches in aquaculture provide opportunities for adaptation/mitigation of aquaculture to climate change. The concept includes new ways to increase resource use efficiency, lower production cost as well as carbon emission and thus the footprint of aquaculture to climate. The concept is developed toward 1) the reduction of feed inputs through smart diets adapted to fish or shrimp requirements (e.g., species, season) as well as to the environment where they are produced (e.g., pond *vs* cages; Fig. 14). Reduction of feed inputs provide thus a decrease in waste production and improve the impact of aquaculture on climate change. The concept includes also 2) the recycling of the remaining waste into new commodities such as seaweeds, black soldier fly meal and organic fertilizers (Fig. 14). These new commodities can thus be 3) reused *in situ* by the food web or *ex situ* into new feed formulations or fertilizers for aquaculture or other crops (Fig. 22).

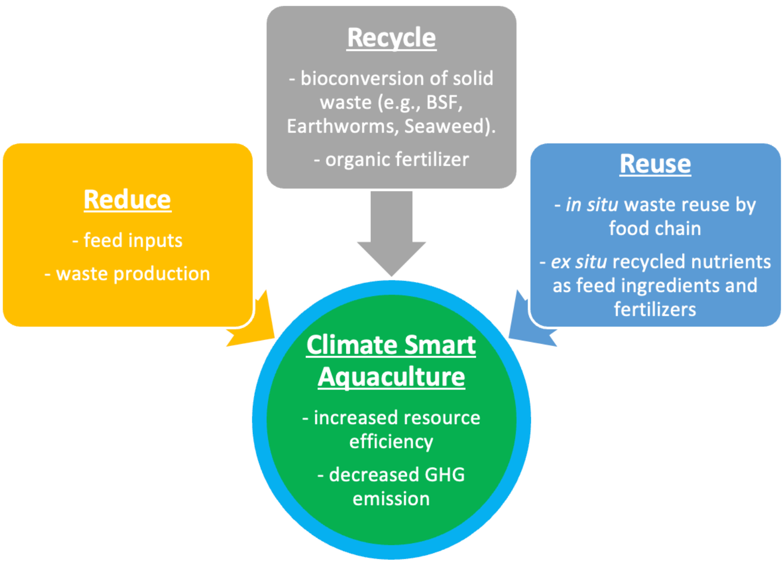

Figure 13: Conceptual diagram for 3R in aquaculture

The four main production models in Philippine (i.e., seaweed, milkfish, tilapia and prawns) are highly relevant for the implementation of this concept where intensive black tiger prawn produced in inland pond can be integrated with tilapia/milkfish ponds and subsequently with inland seaweed production in ponds (Fig. 15). It creates an opportunity to stop wastewater discharge to the environment, promote carbon storage, and increase ecosystem stability improving the sanitation of shrimp pond and thus decrease the occurrence of diseases. This model work also with extensive or semi-intensive black tiger prawn system and can improve the livelihood of small-scale producers and particularly woman and youth. The concept of circular economy in aquaculture has been developed and validated in Vietnam within the FSPi 3R4CSA and now proposed for upscaling in

South East Asia (i.e., Thailand, Laos, Cambodia) with French Ministry of Foreign Affairs for a Regional “Fond Équipe France” and in Vietnam with AFD and European Union.

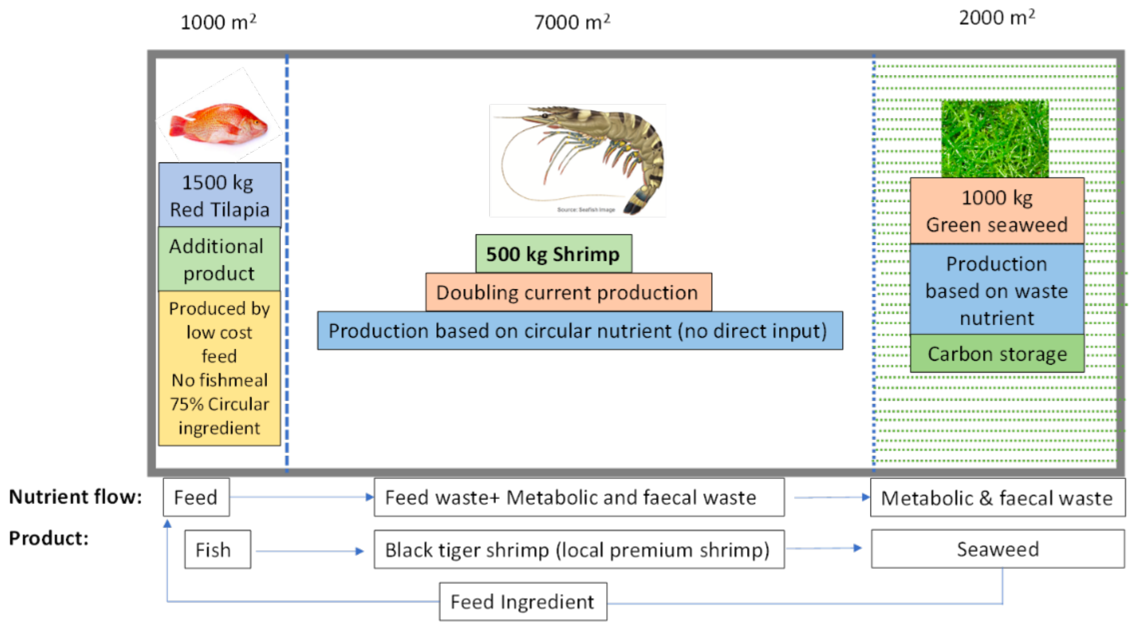

Figure 14:Experimental design for semi-intensive Tilapia-Shrimp-Seaweed system as implemented in the FSPI 3R4CSA in Vietnam

Project of integrated small-scale aquaculture (ricefish, mud crab and mangrove)

This project connects with the FAO country program, for synergies on aquaculture (mud crab, rice fish). It supports young people and women and applies to the value chain and processing of seaweed (carrageenates). It has applications for both mangroves and biodiversity conservation. Ricefish or associated mangrove aquaculture provide opportunity to increase system production and system efficiency. For ricefish, introduction of fish in paddy field (4,8Mha in Philippines) provide opportunity to increase rice production of up to 20% and save water for dual production of rice and fish. Additionally, the integration helps decreasing the need on chemical inputs such as pesticides and fertilizers. Fish or other organisms such as freshwater prawns, crayfish or crabs (for those consumed locally) can be integrated with rice providing an opportunity for diversification of the production system and increasing income for farmers. Pilots were implemented in Cambodia to answer challenges of climate change with IRRI in the context of the CapFish Aquaculture program supported by European Union and AFD.

Associated mangrove aquaculture is also relevant with the previous project on circular economy in aquaculture where prawn production can be better integrated in the mangrove landscape for its conservation and recovery. Mangrove and rice integrated aquaculture can thus provide several ecosystem services such as shelter for biodiversity and carbon storage. Dutch cooperation through Wageningen University and Research has started advising the wetland International Philippines in the framework of the To Plant or Not To Plant project (TPNTP) where synergies can be identified with fish farming and mitigation of climate change.

Project on updated genetic programs and valorization of indigenous species

Philippine aquaculture has been leading in selective breeding programs for tilapia such as GIFT strain. Saline Molobicus tilapia is also a product of Philippine National Fisheries Development Center together with the collaboration with Cirad and INRAE. Saline tilapia provide an opportunity for adaptation and mitigation of aquaculture to climate change particularly in the context of sea level rise and salinization of inland waters. Saline tilapia is also selected for their growth performance providing an opportunity to improve the production systems of Laguna da Bay and Taal lake. Similarly, valorization of indigenous species and selection toward growth and adaptation to the impacts of climate change, such as increased temperature and salinization, is also a challenging target to improve the aquaculture value chain in Philippine. For instance, species such as silver perch and freshwater sardine are investigated by UPLB. These species could be promoted in integrated systems (Projects 5.1. and 5.2.) providing an added value on conservation and valorization of local biodiversity as well as improving the income of farmers.

2.4 Research on biomass and lignocellulosic wastes and by products

Objectives of 2.4 on biomass and lignocellulosic wastes

These activities are related to research on ready-to-transfer existing technology and the use of by-products. The main objective of the mission is the assessment of the existing R&D capacities for the development of biomass energy, associated technical, scientific and financial needs and to produce corresponding recommendations.

During the mission three main types of activities were done:

1. Visits to R&D centres and/or laboratories involved in biomass valorisation, meetings and exchanges with the managers and stAF of these structures.
2. Visits to biomass processing units and facilities for multiple valorisation purposes, meetings and exchanges with the managers of these units.
3. Field visits to crops generating lignocellulosic wastes and related by-products.

This mission has led to the definition of specifications for a feasibility study for the implementation of one biomass energy production unit(s) by thermochemical conversion of lignocellulosic biomass consisting of related products and by-products of the agricultural and forestry sectors, for the production of biofuels.

UPLB-CIRAD 2.4 team

The main participants in this 2.4 activities were Dr. Jean Gérard and Dr. Patrick Langbour, both CIRAD experts from France, and Dr. Fernando Paras, Jr., the national expert.

Key research centers visited on biomass for energy and circular economy

In a relatively short period of time, the CIRAD team, with the support of UPLB, visited a significant number of research and development institutions in the Philippines that are already engaged in research related to the recycling and valorization of agricultural and lignocellulosic waste:

- Department of Science and Technology - Forest Products Research and Development Institute - DOST-FPRDI

FPRDI generates, improves, and disseminates technologies and information to enhance the efficiency of forest-based product utilization to boost local industries' competitiveness in both domestic and global markets for the benefit of the public. The institute's is doing research on forest residues and wood waste, leading to the development of technologies for biomass valorisation until processing wood waste into charcoal and briquettes. FPRDI developed both batch and continuous carbonizers lacking heat recovery systems, a deficiency identified during the discussions, which was deemed a potential area for further study and improvement.

- *The Municipal Government of Los Baños (MGLB).*

Their program, “LB Veggie Move” is a multi-awarded program that helped local farmers especially during the pandemic. The Municipal Environment and Natural Resources (MENRO) has at Los Baños an Eco-Waste Processing Centre and Materials Recovery Facility (MRF) with composter Grinder & mixer. The visit to the facility opened up possible avenues for collaboration pertaining to possible TA on rapid composting and digestion technologies. If a successful pilot plant can be installed in the LGU-LB, it can be a learning facility for other LGUs.

- *UPLB, National Institute of Molecular Biology and Biotechnology –BIOTECH*

The R&D program efforts encompass the production of bioethanol and biodiesel from renewable resources, utilization of microorganisms for the degradation of plastics and plastic-containing compounds, microbial degradation of oily/lipid-containing agro-industrial wastes, production of biomass and biomolecules (biosurfactants, enzymes) from yeasts for industrial and environmental applications, and the development of microbial-based technologies for agro-industrial waste management. BIOTECH is a facility with a high degree of R&D capability, attributed to its proficient scientists and laboratories capable of conducting research at the molecular level.

- *International Rice Research Institute – IRRI.*

IRRI is the main international agency dedicated to studying the valorisation of rice production waste. IRRI has programs in R&D for effectively utilizing rice biomass waste. These programs aim at transforming rice straw and husks into bioenergy, reintegrating nutrients into agricultural systems, curbing climate change by discouraging straw burning, and innovating value-added products such as bioplastics and biochar.

Of particular interest was the potential for rice straw carbonization, as emphasized in a study by Hohenheim referenced during the presentation. IRRI’s comprehensive approach to rice straw management serves as a potential model for valorizing other agricultural wastes, such as those derived from corn, wheat, and other lignocellulosic wastes.

- *UPLB, Center for Agri-Fisheries and Biosystems Mechanization (BIOMECH) and Institute of Agricultural and Biosystems Engineering – IABE.*

These units have various research on waste valorization with capabilities, rendering them as potential partners for implementing R&D initiatives within the South Luzon. This unit developed a biomass atlas for the Philippines in the early 2000s which was funded by the National Renewable Energy Laboratory (NREL) of USA. There are potential benefits of updating this resource for informed policy and strategic planning.

- *UPLB, The Department of Chemical Engineering - DChE*

The Biomass and Energy Research Laboratory is doing research on plant biomass waste valorisation, including pre-treatment methodologies, enzymatic hydrolysis, and biorefinery processes.

- *Los Baños Folia Tropica*

This enterprise produces different products from plant biomass waste by optimizing conditions for natural aerobic processes, supplies a big local client with his different soil amendment products. It has a good collection of nematodes, insects, fungi, etc that works 24/7 to make various compost products. His green production system is an ingenious approach for low carbon footprint production is very inspiring.

- *Straw Innovations Ltd*

Straw Innovations in Pila, Laguna, is a company concerned by urgent environmental issues linked to its rice production methods, especially concerning straw management. The aim is to stop farmers from burning rice straw after harvest by providing harvesting services and to remove the straw from fields at no cost. Straw Innovations, alongside institutions like IRRI and PhilRice, offers promising prospects for joint research on rice straw utilization. Collaborative efforts could lead to innovative solutions that reduce the environmental impact of current agricultural practices and promote sustainable alternatives with lower carbon emissions.

- *Los Baños Municipal Agricultural Fisheries Council*

Is involved into different agricultural sectors, including rice, tropical fruits, cut flowers, vegetables, and pig farming. Even for small-scale operations, there's the potential for an integrated, circular production system. The farmers explained how they are utilizing their plant waste by either composting it to create soil amendments or using the biomass waste as fuel for drying and cooking.

Local Government Unit (LGU) has a crucial role, it provides guidance and capacity-building support to small-scale farmers within the municipalities. It underscores the importance of municipal-level initiatives in empowering farmers and facilitating sustainable agricultural practices.

- *Philippine Center for Postharvest Development and Mechanization*

(PHilMech) uses hydrothermal carbonization process, which is a potential solution for valorizing plant biomass waste with high moisture content. Next step for them is to upscale and make a continuous fed system. This is seen as a possible point of collaboration. It would be explored if CIRAD can provide support and TA on how to accomplish this.

- *ALCOM's NuevaChar*

Alcom is currently operating a retrofitted gasifier in Palayan City, Nueva Ecija, and is utilizing rice husk to provide the local government with free heat for grain drying while making biochar in the process. Biochar production process from rice hull and the many advantages documented in utilizing their biochar across various agricultural ventures is promising. ALCOM facility encompasses entire production cycle from the receiving and loading of rice hulls to their meticulous storage and packaging procedures. The sheer scale of their operation left a lasting impression, underscoring their firm foothold in the carbon credit market in the Philippines through their rice hull biochar production.

ALCOM is expanding its operations to different regions within the Philippines and are poised to establish similar production facilities overseas with added energy generation prospects in the mix. This expansion underscores their commitment to sustainable agricultural practices and signifies their readiness to cater to a broader market. With a well-established presence and a forward-looking approach, ALCOM is poised to make significant strides in the realm of biochar production, both domestically and internationally, contributing to the global effort towards environmental sustainability and agricultural development.

- *The Department of Agriculture - Philippine Rice Research Institute - DAPhilRice*

The team visited DA-PhilRice which is a government research institute under DA dedicated to advancing rice science and technology in the Philippines. The institute has developed Biochar-based technologies for enhanced productivity, efficiency, resilience and adaptive capacity for smallholder rice-based farming communities in the Philippines. PhilRice has a Continuous type Rice Hull Carbonizer (CtRH) and its 'Palayamanan system', a systems approach to make the rice farmer more productive and resilient to the effects of climate change. Complete diversified use of biochar in the farm was discussed. The CtRH is already an established technology for processing rice hull into biochar in the farm. However, this technology might even be more promising if it could be efficiently used to produce rice straw biochar in-field or near the farmer's house. Unlike rice hull which accumulates in the rice mill and are now used by many stakeholders, rice straw waste is left in the farmer's field. Hence, it might be a good idea for a decentralized system to address the issue of rice straw management. Unique feature of CtRH is the heat recovery system or heat cogeneration for various applications. This feature was suggested to be incorporated in the FPRDI carbonizer design, which the designer acknowledged and agreed to look into. It seems appropriate to incorporate heat recovery principles in any thermal systems that CIRAD would suggest (wood carbonization, Hydrochar, Biochar).

- *Central Luzon State University - CLSU*

The final stop was in the Science City of Muñoz in the CLSU. The university has significantly contributed to agricultural development in the Philippines through its research and development (R&D) initiatives. CLSU's agricultural research programs focus on enhancing crop productivity, improving farming practices, and promoting sustainable agricultural systems, thereby addressing food security challenges and improving the livelihoods of farmers. Additionally, CLSU has been actively involved in R&D work on renewable energy, particularly in the utilization of agricultural biomass for bioenergy production. Through innovative projects and partnerships, CLSU has advanced technologies for converting agricultural residues into biofuels, biogas, and other forms of renewable energy, contributing to energy security, environmental sustainability, and rural development in the Philippines.

- *Benguet State University - BSU*

An operation of the Benguet Agri-Pinoy Trading Center (BAPTC) concerns disposal of high moisture content, lignocellulosic waste from vegetables. CIRAD can provide some technical assistance on how to deal with this problem. Definitely, whatever solution that could be proposed may also be applicable to all vegetable trading posts with similar problems. The accumulation of high moisture content plant biomass waste from vegetables and trimmings, when left to decompose naturally, it promotes an assortment of problems like foul odor, infestation of flies and other insects, and the pilings slowly limits the facility or the farm's usable space. These are not only present in the trading posts but are also found in the farms. Composting and digestion are some of the technologies that they have tried but according to them, it takes a lot of space and takes a long time for the processing of compost or biogas. Furthermore, they have technical difficulties with digestion because of the drastic change in temperature in the region. Note that this might also be a good point for TA and collaboration for CIRAD.

Main results (2.4)

The results were divided into two categories:

- the first category was two different reports:
    - The first report is an interim report, it focuses on the mission results, assess existing R&D facilities and capacities regarding biomass energy in Philippines (see[8]),

[8] See 2.4 interim report at: https://drive.google.com/drive/folders/11ms8nAFdGxvxIw1HWs2SLKJcVRc5RHmj

- The second is the final report: an assessment of the existing R&D capacities for the development of biomass energy, the associated technical, scientific and financial needs and corresponding recommendations produced by this team[9], this report focuses on the following project proposals.

- the second category was project proposals. There were 4 project proposals that has been have been summarized in an XL-format DA-BAR format. More details on these proposals are following:

Project biomass and wastes (2.4)

The project has four components, as follows:

- Component 1: Updating and improving the Biomass Energy Resources Atlas of the Philippines,
- Component 2: Establishment of decentralized rice husk biochar production units in other producing regions,
- Component 3: Decentralized heat production from rice straw: pellets and briquettes production,
- Component 4: Establishment of one or more hydrochar production pilots and methanisation units, using wet waste from vegetable production.

These components can be separated into sub-projects if required. It has been the subject of an XL sheet according to Department of Agriculture format.

[9] See 2.4 final report at: https://drive.google.com/drive/folders/11ms8nAFdGxvxIw1HWs2SLKJcVRc5RHmj

2.5 Sugarcane technologies transfer and R&D

Objectives of 2.5 on sugarcane

The objectives of this component were to:

- Produce a state of the art of Sugarcane value chain, identifying priority research areas and topics in Philippines (2.5.1).
- Organize a mission in Philippines to take stock of the sugar industry in the Philippines and its technological development needs with field visits & discussions to identify technology needs of R&D in the field of sugar value chain (2.5.2).
- Organize a study tour in Réunion Island for a Philippinos expert to study the technologies currently used in the sugar industry for identifying the most appropriate technologies to be transferred to the Philippines (2.5.3).
- Produce a bankable R&D project by identifying suitable and available technologies that can improve the Sugarcane sector, which includes the necessary conditions for transfer to Philippines (2.5.4).

UPLB-CIRAD 2.5 sugarcane team

The main participants in this 2.4 activities were Dr Manny Samson, the National expert from UPLB, and Dr. Christophe Poser (CIRAD - AIDA, France).

Sugarcane missions in Philippines and Réunion Island (France)

Mission in Philippines

Dr. Christophe Poser and Dr Samson went to Negros Occidental, Philippines from April 13 to 19, 2024. The main visits were at:

- Northern Negros up to Cadiz City on sugarcane areas
- Victorias Mill Site and Lopez Mill site, and transloading areas along the road.
- Large sugarcane plantations on the Cities of Talisay City, Silay City, EB Magalona Town, Victorias, Cadiz City and Sagay City on the northern side of Negros Occidental.

At the Transloading Zone, they went to **Philippine Sugar Research Institute Foundation, Inc.** (PHILSURIN) is a private research entity. Philsurin has:

- 20-25 technicians and 150 workers,
- 1,300 variety collection both from Local and Foreign sources include 150 varieties from CIRAD,
- Germplasm collection consists of 64% local and 36% international,

- Changing variety to new HYV will deliver yield increase by 20%,
- They train farmers on sugarcane production technology-Practical ways in the field,
- Need to increase the germplasm collection,
- With 27 varieties released, 16 have parents of foreign varieties,
- Want to exchange varieties to eRcane,
- High Yielding Varieties (HYV) are promoted to every mill and nursery planting materials established,
- Tissue culture plantlets and cuttings available to farmers.

The priority of Philsurin program is to address the decline in yield of sugarcane, adapted to waterlogging, mechanized harvesting and site-specific varieties. Philsurin aims to have more collaboration with the University of the Philippines Los Banos (UPLB) and with ABPM-ADB and DOST-PCAARRD. It will continue developing varieties for seed farm, extending ratoons, adapted to flooded and drought conditions, sweet and high tonnage for ethanol, energy and fiber. Philsurin have a tissue culture laboratory which provide 350 000 plants per year. These plants are used for cultivation in their nurseries or distributed directly to their member plants and growers.

First Farmers Holding Corporation (FFHC) is an agro-industrial business enterprise with interests' primarily in sugar milling, refining and recently, power generation for export. The priority needs of the industry right now are good ratooning varieties with high yield coupled with improve cultural practices technology. The President is also interested in the varieties developed in the Reunion Islands. He also suggested to look into the 'sharing system of the industry '. The current system gives back 30% to millers and 70% to growers. This distribution could discourage millers from investing. The President of the First Farmers Milling suggested the following:

- Conduct trainings on Agriculture and practical sugarcane agronomy
- Conduct seminar on sugarcane cultural technologies two times a month in the district

Other discussions later brought the following issues:

- Conversion of sugarcane lands to residential areas resulted to increase in the transport costs,
- Lack of labor during harvesting operations,
- Present varieties are ratooned twice only,
- Varieties that perform well in elevated areas will not perform well in lowland areas,
- First Farmers is a small mill threaten with cane supply, Co-gen can maximize income from power supply,
- Use of one-eye planting materials,
- Limit soil tillage especially in high slope areas to prevent soil erosion,

The team visited also diverse plantations (Brgy. Bagtic Hacienda, Puyas with 130 hectares Hacienda Bugatong with 400 hectares planted to sugarcane) and could exchange with workers.

At **Victorias Milling Company** (VMC) at Victorias City the team learnt:

- The objective of the VMC mill is the production of sugar and fiber for C0-generation of electricity,

- Research and development priorities are a) Varieties that are tolerant to drought, waterlogging, high sucrose and sites specific adapted varieties, b) Soil improvement and cultural practices, c) More collaboration with local and international agencies that can help the industry.

At **Lopez Milling Company,** the team could note the following R&D needs:

- Need to classify the performance standards of the flat areas and sloping areas planted to sugarcane. The varieties to be used should be tested on these topographical variations includes high yields, more ratoons during 5-7 years, with yields of 100 ton and LKG/TC of 2.0 or more,
- Improve the propagation of varieties thru Tissue Culture and reproduce and propagate in the district over topography, soils and climate,
- Monitor disease symptoms in the district,
- Use of self detrashing varieties, detrashing machines to improve purity.

At **Hacienda Esperanza Cooperative Agrarian Reform Beneficiaries Association** (HECARBA) Hda. Esperanza, La Carlota, for small farms, the R&D priorities are the following:

- High yielding varieties, with good tonnage and longer ratoons. The present varieties are good only for 1-3 ratoons[10],
- Varieties adapted for Muscovado production[11].

At **Sugar Regulatory Administration** (SRA) **La Granja Research and Extension Center** (LGAREC) the following priority R&D issues discussed were:

- Most sugarcane soils are acidic, this problem should be addressed by Liming Program or other proven agricultural practices to reduce acidity,
- Lack of organic matter due to soil degradation with lack of support from the government,
- Need of climate resilient varieties thru breeding,
- Need more materials for breeding from other countries thru variety exchange eg. Japan, geographical location are the same, with ownership, and mechanization for government program,
- Labor competition for manual labor in sugarcane production,
- Government regulation-sugar is expensive compared to Thailand.

Mission in reunion Island

Dr. Emmanuel G. Samson met Dr. Christophe Poser at Réunion Island the June 27, 2024. Dr. Samson visit the CIRAD office, got information on the Sugarcane program at La Reunion and went to the Research station La Mare on CIRAD trial “SoerPro” manage by Recycling and Risks unit. The organic

[10] Ratooning means leaving the roots and lower part of the Sugarcane stalk in the field after the cane has been harvested. This allows the plant to regrow and produce subsequent crops without the need to replant.

[11] Muscovado is a type of unrefined sugar with a rich molasses content. It is produced by extracting juice from Sugarcane and then boiling it to create a thick syrup. This syrup is then allowed to cool and crystallize. Unlike refined white sugar, muscovado retains many of the natural minerals and flavors from the Sugarcane due to its minimal processing.

trial is very important source of information for future use and effects of different sources of organic matter on the long-term basis.

They got presentations on the breeding of sugarcane at eRcane and visit the facilities and equipment used in the breeding. They got other presentation on the conduct of the field trials on the breeding process.

Later, they visited the western part of the Highlands planted on sugarcane and other crops by farmers in the area. The farmer who previously planted sugarcane shifted to other crops such as, Pittaya (dragon fruit), Pechay, corn, Geranium.

They got presentation on MASH (Mapping Sugarcane Harvest) which is a web application designed to facilitate the mapping of sugarcane harvest progress through the use of optical and radar remote sensing techniques. It offers the ability to observe the sugarcane harvest in semi-real time across an entire territory, thereby enabling the optimization of supply chain operations for processing units.

They went to Etang sale, ERcane and made a tour on the mechanization equipment and sugarcane plantations. They visited, later, sugarcane harvesting operation with the use of two types of small sugarcane mechanical harvesters “coupeuse Péï” of eRcane which is a machine designed to facilitate sugarcane harvesting.

Results of the mission

The different meetings and discussions made by Dr. Christophe Poser and Dr. Emmanuel G. Samson with the different stakeholders of the sugarcane industry in Negros Occidental are summarized as follows:

- There is great need of variety with high yields and longer ratoons (6-7 compared to 2-3 ratoons with resistant to pests and diseases at present) according to the General Managers of First Farmers Milling Company, Victorias Milling Company, Lopez Milling Company, Philsurin, SRA and sugarcane planters. A demand foreRcane varieties
- Training and capacity development of people involved in the industry in the technical level is needed and should be addressed.
- Practice of sugarcane production could be improved to be more agro-ecological and sustainable farming system employing practices such as trash management, small mechanization, use of organic fertilizers, etc.
- The proposed Just-in-time digital technology that can integrate farm-level digitization up to regional level production management in Sugarcane is not the priority of the industry at present. It can be implemented later.

Sugarcane value chain review

Sugarcane, a Major Crop for Philippines

Since the 19th century, sugarcane production has had a great impact on both society and the country's economic structure. The industry has successfully achieved economic goals by expanding commercial cultivation areas and reducing production costs. However, its success is mostly measured on an economic standpoint rather than compared to other crops (Mirbakhsh & Zahed, 2023).

Sugar is one of the most important produced crops in the Philippines cultivated in the different parts of the country, however it is most abundant in the Negros Island, Western Visayas Region. As per 2020 data records, the total production of sugarcane reached the amount of $815 million, thus belonging to the fifth largest crop in terms of value following rice, bananas, corn, and coconuts.

In order to maintain and improve the effectiveness of the sugarcane value chain in the Philippines, there is a need to conduct research and development (R&D) initiatives. The analysis of the sugarcane/value chain conducted by the Sugar Regulatory Administration (SRA) and the University of the Philippines-Los Baños (UPLB) highlights the best way to strengthen and revitalize the industry is to make the entire sugarcane supply chain work well which includes eliminate the bottlenecks and sources of inefficiencies in all nodes of the supply chain from input suppliers to end users.

According to Briones (2020), the Philippine sugar industry includes a comprehensive value chain with farming as a starting point up to processing and distribution resulting in different products and catering to end-users. Cultivation of sugarcane is being considered as the backbone of the sugar industry in the country from smallholder to large-scale farms and continuing to expand in the different areas. The process begins in the preparation of lands, then planting of the sugarcane stalks, this also includes the proper provision of irrigation/watering and application of fertilizers. By the time the sugarcane reaches its maturity, the sugarcane is harvested and transported to processing plants or mills. Processing of the cane results in several outputs:

- Raw sugar comes from the partially purified cane juice undergone a process of centrifugation and crystallization and it consists of sucrose crystals covered with a thin film of cane molasses.
- Molasses is the by-product of the raw sugar production in a form of syrup and it also contains sugar and other compounds present from the extracted cane juice.
- Muscovado sugar has a rich flavor and moist texture undergone a non-centrifugal process from the evaporation of fresh cane juice until it achieves the desired consistency (PNS–BAFS 144-2015). With the presence of molasses, it results in a dark and moist product being used in various culinary applications.
- Refined or white sugar is raw sugar that has undergone further purification and crystallization, achieving polarity not less than 99.5 degrees at mill grade (PNS-BAFPS 82-2010). It also undergoes strict quality control measures to ensure its uniformity and purity.
- Bagasse is obtained as a by-product of crushing of sugarcane with diverse applications. It is typically burned and used as fuel by the sugar mill and serves as another potential source of renewable energy feedstock being converted into ethanol.
- Ethanol is produced from the fermentation of sugars, either in the cane juice or in molasses. Following fermentation, the distillation process can be aimed at producing either potable ethanol (for the beverage industry), or non-potable ethanol, as biofuel, or for household or industrial uses.

At present, there are 27 sugar mills and 8 sugar refineries, majority of which are in the Visayas, which accounts for approximately 73% of sugar production. Mindanao and Luzon account for about 17% and 10% of production respectively. The said areas were attributed to the favorable climatic conditions, water resources, and even its history in sugar production. Seventeen provinces across eight regions in the country grow sugarcane. Western Visayas (55%) is one of the top-producing regions by value of total production followed by Northern Mindanao (14.9%) and Central Visayas

(13.4%)[12]. Majority of the sugar produced are consumed domestically primarily by industrial users, households, and institutions. A decline in exports, particularly to the United States, the primary export market, was observed as a result of the country's increasing domestic demand and low production rates[13].

Philippines Sugarcane Production

Cultivated area: The total land area utilized for sugarcane production across the country is more than **420,000 ha** and with average yield of **57 tons/ha**. In terms of land holdings, most **landowners own less than 5 hectares** while only a **few owns 100 hectares**[1] (see Figure 1). Around 65% of the country's total Sugarcane area is located in the Visayas region, more specifically on the island of Negros (55% of the country's total area), 20% in Mindanao and the remaining 15% in Luzon.

Policies

Sugarcane Industry Development Act of 2015 (SIDA)- SIDA is a program that maximizes the sugarcane resources including the improvement of incomes of farmers and farm workers through improved productivity, product diversification, job generation, and increased efficiency of sugar mills. There are five (5) pillars under this program namely:

- Infrastructure Program - includes the facilitation of the sugarcane transport until it reaches the mills and distilleries, also to enhance marketing and sugar export including other products from sugarcane and to complement productivity improvement measures,

- Block Farm Program - since majority of the sugarcane farms are small farms, this aims to consolidate the small farms including the agrarian reform beneficiaries, as one larger farm, with a minimum area of thirty (30) hectares within a two-kilometer radius to take advantage of the economies of scale, efficiency in machineries, maximizing the workers, volume purchase of inputs, financing, and other operations; it also includes recognition of the sugar mills, government financial institutions, private investors, however, the ownership of the small farms remains to the original landowners,

- Scholarship Program - a program to those in need and deserving of college and postgraduate students taking up courses in agriculture, agricultural engineering and mechanics, chemical engineering/sugar technology; and vocational courses and skills developments,

- Socialized Credit Program - it is made possible through the Land Bank of the Philippines (LBP) for the acquisition of inputs, machineries, and implements crucial for the production of sugarcane,

- R&DE Program - it aims to intensify sugarcane high-yielding or flood-resistant varieties; pest control and prevention; latest farming, milling, refining, and biomass co-generation

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[12] Tobias, A. M. (2020, July 16). *Initiatives and implications of Philippine sugar liberalization*. FFTC Agricultural Policy Platform (FFTC-AP). https://ap.fftc.org.tw/article/1841

[13] United States Deparment of Agriculture Foreign Agricultural Service.(2021). Sugar Annual https://fas.usda.gov/

technologies; soil analysis and fertility mapping of sugarcane areas; weather monitoring and climate change adaptation measures; sugar and sweetener consumption; and other products from sugarcane.

Sugar policy is controlled by the SRA, in particular trade and domestic prices. In addition, the SRA supervises and controls domestic sugar supply and demand every year. They control supply under the "Quedan System", which allocates the percentages of local production that should be supplied to the domestic, US and international markets. It was set up primarily to protect local sugarcane growers against unstable prices by controlling sugar supply and imports.

The Sugar Regulatory Administration (SRA) accomplishments achieved on R&DE were 15 completed Research Projects and 25 still on-going in implementations. Notable Completed Research Projects were:

- Distribution of climate-resilient varieties to several Mill Districts
- Planters' guide on sugarcane diseases in the Philippines published by UPLB.
- UPLB has guided SRA on techniques in the identification of sugarcane drought and water-logging tolerant varieties.

Recent Production Decrease

The sugar industry competitiveness had dwindled over time. During the second quarter of 2023 (April - June), the recorded production was at 2.83 million metric tons, reflecting **a decline of 11.3 percent** compared to the output of 3.19 million metric tons in the corresponding quarter of 2022[3]. This reduction in plantation area can be explained by the conversion of Sugarcane plantations to plantations for other crops: generally maize, but they also change permanently to rubber, pineapple and banana, particularly in Mindanao. Growers do this for reasons of profitability, due to the low and unpredictable price of sugar, and for meteorological reasons. Unfavorable weather conditions in certain sugarcane-growing regions have led to a reduction in tonnage, but the absence of field irrigation can have a major impact on sugarcane production, since around 80% of sugarcane fields are not irrigated.

Impacts of Climate Change in the Philippines on sugarcane

This year the temperature has reached record highs in Negros. For example, in April 2024, a week before C. Poser's arrival, the maximum temperature was 42 to 44°C, rising to 45°C afterwards.

Sugarcane is a tropical crop but varieties used from production are very sensitive to environmental conditions. The main parameters are temperature, solar radiation, soil texture and quality. Certain temperature changes and extreme events can affect or stimulate processes such as germination (C. Poser, 2020) or cane growth (M. Christina 2021).

Sugarcane following project and next steps:

Sugar cane varietal selection for adaptation to climate change.

This R&D project with Philippine sugarcane sector stakeholders and CIRAD could first of all provide access to the best-performing cane varieties developed by eRcane, a breeder partner in Réunion Island.

These varieties are appreciated and in demand in the Philippines, for their good resistance to ratooning after harvesting: 8 to 10 ratoons compared with 2 to 3 at present in the Philippines fields. The latest varieties available on Reunion Island would provide better resistance to disease and high temperatures, as well as an opportunity to broaden the genetic base available to Filipino breeders from public and private research centers.

The aim is not only to improve the performance of ratooning, but also to increase, in a longer term the capacity of Filipino sugarcane breeding centers to withstand drought and high temperatures in a context of climate change.

Access to these varieties, subject to agreement with the breeder eRcane, could be provided officially via CIRAD's international quarantine greenhouse Viasacane, in the form of a few cuttings, or via CIRAD's subsidiary Vitropic, in the form of larger quantities of vitroplants with maximum phytosanitary guarantees.

The introduction of new varieties is an opportunity to steer agricultural practices towards more agroecology, i.e. reduced pesticide use, and greater consideration for soil health and biodiversity. This project could include French and Filipino private stakeholders, ensuring the sustainability of this R&D initiative beyond the CCAP program.

Annex 1: Terms of Reference component 1

<u>**Component 1: comprehensive policy review and appraisal of the agriculture R&D landscape in the Philippines.**</u>

TORS:

This component will comprise the following generic tasks which have been mostly covered by the Briones report "How Modern is Philippine Agriculture and Fisheries?". Thus, the added value of the TA component 1 is to extract the salient points of this report as well as other existing reports in order to specifically focus on R&D expenditure increase to climate change adaptation and resilience for each of the following points. Along these points the key activities will be to analyse policies, identify of policy gaps, and recommend reform agenda for climate-resilient/climate smart R&D for agriculture. This will include:

1.4. <u>Overview and contributions of the Philippine R&D policy to its agriculture commodities</u> (crops, livestock, poultry, fisheries), comprising: Cereal (Palay, corn), Fruits (Bananas, pineapple, mango, other fruits), Non-food & industrial (Abaca, coconut, coffee, tobacco, sugarcane, cacao, others), Vegetables & root crops (Ampalaya, cassava, eggplant, mong beans, onions, sweet potatoes, potatoes, tomatoes, others), Farming system (Monocrop, diversified, clustering approaches), Agro-based value chains (Upstream, farm production, midstream, downstream), Swine/Hog, Carabao, Goat, Chicken, Duck, Chicken eggs, Duck eggs, Marine capture, Inland capture, Aquaculture, Freshwater, brackishwater.

1.5. <u>Review and Analysis of the R&D demand</u>: who are the clients (regions, type of workforce, gender disaggregation, value chain segment players), and what relevance of the R&D on their production, incomes, and capacity to adapt and mitigate climate change, what are the feedback mechanism to suppliers of R&D on addressing R&D needs/wants, both actual and perceived, what is the extent of R&D outreach of R&D in agro-based value chains.

1.6. <u>Review and Analysis of the R&D extension and agriculture services</u>: bridge of supply and demand: Nature and extent as well as funding allocation of extension services/agriculture service delivery system as provided by LGUs considering that extension services have been devolved, Effectiveness and efficiency of extension services by LGUs in disseminating climate change related R&D (information, climate-smart technology and practices,) and as feedback mechanism (from consumers of R&D to suppliers of R&D; relation of DA with LGUs; have LGUs been effective link of the R&Ds provided by DA/DOST/state colleges and universities and the consumers of the R&D), Impact of Mandanas ruling that starting 2022 would increase the funding of LGUs.

Experts: Philippe Guizol UR F&S - Dr John Pulhin and Prof Rico Ancog

Annex 2: List of deliverables by activities & timeline

Phase 1

Component 1

	Product type	Contents: (UPLB is involved in data collection and product design & drafting).	UPLB deadlines
1.4.1	Policy brief (version 1)	To defend R&D financing	**Delivered** (18 August 2023)
1.4.2	Intermediary report	1.1 Overview R&D policy per agro or fishery commodities; 1.2 Review and Analysis of the R&D demand; 1.3 Review and Analysis of the R&D extension and agriculture services:1.4 Policy and governance recommendations	**Delivered**
1.4.3	Policy brief II	Policy brief updated	**Delivered** 20 January 2024
1.4.4	Full final report	Full final reports + synthetic report	**Delivered** 10 June 2024

Main Missions for Coordination & Component 1

Purpose	Tentative Periods
Inception: meetings with AFD, partners (UPLB), collecting data for 1.1	**Delivered** 11 – 23 June 2023
Coordination + Finalizing with partners Policy Brief, data collection for 1.1, 1.2, 1.3 and ToRs for UPLB partners	**Delivered** 29 July to 12 August 2023
Working and finalizing with partners 1.4.1 and preparing 1.4.2	**Delivered** 5 to 16 December 2023
Report presentation in Philippines	June 2024

Component 2 (phase 1)

	Milestones	Contents: (UPLB is involved in data collection and product design & drafting).	UPLB deadlines
2.1	R&D project on the climate-related crop, livestock & poultry, and fishery breeding for productivity growth, and increased efficiency in the use of less water and land.		
2.1.1	Mission in Philippines	Conferences & discussions to identify training needs of R&D in the field of "Applying CRISPR/Cas9 technology in plants: from theory to practice"	**Delivered** 24 – 29 September 2023Product: mission report
2.1.2	Mission in Philippines	Identification of training candidates	**Delivered** 24-29 September 2023 Product: mission report
2.1.3	R&D project	A bankable R&D project draft is available in the Philippines, concerning CRISPR/Cas9 technology in plants.	**Delivered** 22 March 2024 Product: Specifications for a R&D project on CRISPR/Cas9 ready.
2.2	Just-in-time digital technology that can integrate farm-level digitalization up to regional level production management – Mango, PixFruit, Soyield.		
2.2.1	Mission in Philippines	Field visits & discussions to identify technology needs of R&D in the field of fruit value chain.	**Delivered** 16 – 23 September 2023 Product: mission report
2.2.2	Research in Philippines	A state of the art of mango value chain, identifying priority research areas and topics in Philippines.	**Delivered** 25 January 2024 Product: a report on mango value chain and R&D priorities.
2.2.3	R&D project	Identify suitable and readily available technologies that can improve the	**Delivered**

		Mango sector, and produce a bankable R&D project draft which includes the necessary conditions for transfer to Philippines.	19 April 2024 Product: R&D specifications and digital technology transfer for a project on Mango value chain, available.
2.3	Research project on aquaculture in order to propose climate -related adaptation or mitigation to the issue of the "migrationshift" of catch-fish resources due to CC.		
2.3.1	Research in Philippines	Preliminary aquaculture chain analysis, with bibliographic review, identifying the factors that are required to adaptation to Climate change.	**Delivered** Product: Draft of a bibliographic review on aquaculture in Philippines and adaptation issues to climate change.
2.4	Research on ready-to-transfer bioenergy technology for the use of by-products		
2.4.1	Inception report	Preliminary review of 1) technologies in operation in the Philippines to produce biomass energy and identification, 2) related R&D centers, 3) identification of one or two target regions for the study and of associated crops producing unused lignocellulosic biomass.	**Delivered** Product: A draft review report
2.5	Just-in-time digital technology that can integrate farm-level digitalization up to regional level production management – Sugarcane		
2.5.1	Research in Philippines	A preliminary state of the art of Sugarcane value chain, identifying priority research areas and topics in Philippines.	**Delivered** Product: a draft report on Sugarcane value chain and R&D priorities.

Phase 2

Component 2 (phase 2)

	Milestones	Contents: (UPLB is involved in data	UPLB deadlines

		collection and product design & drafting).	
2.1	R&D project on the climate-related crop, livestock & poultry, and fishery breeding for productivity growth, and increased efficiency in the use of less water and land.		
2.1.4	Training of 3 people in Montpellier	Training on CRISPR/Cas9 technology in plants: from theory to practice.	**Delivered** 29 January to 16 February 2024 Product: Trainees mission report
2.3	Research project on aquaculture in order to propose climate -related adaptation or mitigation to the issue of the "migrationshift" of catch-fish resources due to CC.		
2.3.1	Research in Philippines	Doing aquaculture chain analysis, with bibliographic review, identifying the factors that are required to adaptation to Climate change.	**Delivered** 8 March 2024 Product: a bibliographic review on aquaculture in Philippines and adaptation issues to climate change.
2.3.2		Mission in Philippines (March 2024): Identifying the factors that are required to adaptation and develop climate smart technologies/R&D breeding.	**Delivered** 15 May 2024: Product: R&D specifications and technology transfer for a project on adapted aquaculture to Climate change.
2.4	Research on ready-to-transfer bioenergy technology for the use of by-products		
2.4.1	Inception report	Review of 1) technologies in operation in the Philippines to produce biomass energy and identification, 2) related R&D centers, 3) identification of one or two target regions for the study and of associated crops producing unused lignocellulosic biomass.	**Delivered** 8 March 2024 Product: A review report
2.4.2	Interim report Report	Mission March 2024: Assessment of the existing R&D capacities for the development of biomass energy, of the associated technical, scientific and financial needs, and corresponding recommendations	**Delivered** 15 April 2024 Product: mission report

2.4.3	Specifications for a biomass energy production unit.	Specifications for a feasibility study for the implementation of one (or more) biomass energy production unit(s) by thermochemical conversion of lignocellulosic biomass consisting of related products and by-products of the agricultural and forestry sectors, for the production of biofuels;	**Delivered** 10 May 2024 Product: R&D specifications for a technology transfer project for biomass industry, available.
2.5	Just-in-time digital technology that can integrate farm-level digitalization up to regional level production management – Sugarcane		
2.5.1	Research in Philippines	A state of the art of Sugarcane value chain, identifying priority research areas and topics in Philippines.	**Delivered** 8 March 2024 Product: a report on Sugarcane value chain and R&D priorities.
2.5.2	Mission in Philippines	Take stock of the sugar industry in the Philippines and its technological development needs. Field visits & discussions to identify technology needs of R&D in the field of sugar value chain.	**Delivered** March 2024 Product: mission report
2.5.3	Study tour to Réunion Island	The Philippinos expert will visit Réunion Island to study the technologies currently used in the sugar industry. This visit will help to identify the most appropriate technologies to be transferred to the Philippines.	**Delivered** April 2024 Product: a trip report
2.5.4	R&D project	Identify suitable and readily available technologies that can improve the Sugarcane sector, and produce a bankable R&D project draft which includes the necessary conditions for transfer to Philippines.	**Delivered** 15 May 2024 Product: R&D specifications for a digital technology transfer project for Sugarcane value chain, available.

Expected Timeline

Timeline

Expert not available	
Availability	
Imperative mission with national experts	
National experts activities alone	
Final deliverable	X
Delivered	Mission done X Output delivered
Training in France or Study Trip in Réunion Island	T

	2023															2024											
Activities		**6**		**7**		**8**		**9**		**10**		**11**		**12**		**1**		**2**		**3**		**4**		**5**		**6**	
Coordination																	X										X
1 Review and Analysis of the R&D for agriculture							X												X								
Policy brief							X										X										X
2 R&D project on climate-related crop, livestock & poultry, and fishery breeding																											
2.1 Genetic expert -Training CRISPR/Cas9																	T	T			X						
2.2 Mango data acquisition, analysis - (Pixfruit & Soyield).																	X						X				
2.3 Research project on aquaculture																			X		X				X		
2.4 Research on Lignocellulosic wastes and by products																			X		X				X		
2.5 Sugarcane technologies transfer and R&D																			X		X		T		X		

Annex 3: Project reports and communication

1 Component 1 on R&D policies

(1.4.2 & 1.4.4) Policy review and appraisal of the agriculture R&D landscape in the Philippines in context of Climate Change.

https://drive.google.com/drive/folders/1H0p7ExH_q01Bn9iHvkQUQKs95kEQM9oe

(1.4.1 & 1.4.3) Policy brief updated (Dec 23)

https://docs.google.com/document/d/1MIPqY36OB_Tj56m3sIWNS1cnqC0OLsJL/edit

The synthetic report is this report

Communication: Strategical analysis of Philippines policies and research and development (R&D) policy reform:

https://www.cirad.fr/en/worldwide/our-regional-offices/southeast-asian-islands/news-southeast-asian-islands/agricultural-r-d-policy-in-philippines

2.1 Genetics

Communication about CIRAD mission in Philippines: Pooling skills to support varietal innovation of major species in the Philippines: genetics for the Climate Change Action Program:

https://www.cirad.fr/en/worldwide/our-regional-offices/southeast-asian-islands/news-southeast-asian-islands/pooling-skills-to-support-varietal-innovation-of-major-species-in-the-philippines

2.1.3: Project for obtaining banana plants better adapted to environmental stresses (detailed description, 7p):

https://docs.google.com/document/d/1XmmmafiM3GHAbhf5TYnf2ClbcTyS6njs/edit

2.1.4: **Communication** about training on CRISPR at CIRAD-Montpellier of 3 researchers from Philippines:

https://drive.google.com/drive/folders/1tEgekyFI2hJe2VtqBGp1fOt-FWT_8Xvp

2.2 Mango value chain

2.2.1 & 2.2.2: State of the Art of the mango value chain in the Philippines: main constraints and research & development priorities – version 2 :
https://drive.google.com/drive/folders/1gqNftPDzdXKQcVfJD-nvwDW9jm1HT0dU

2.2.1 & 2.2.2: Same, ppt presentation:

https://drive.google.com/drive/folders/1ZuREMR7Y3EpnI4H3qStrxBLoMwYFC61C

Communication: Experts from UPLB & CIRAD assess the constraints and needs of the Philippines' mango value chain.

https://www.cirad.fr/en/worldwide/our-regional-offices/southeast-asian-islands/news-southeast-asian-islands/mango-value-chain-in-the-philippines

2.3 Aquaculture

2.3.1: Research project on aquaculture in order to propose climate -related
adaptation or mitigation to the issue of the “migrationshift” of catch-fish resources due to climate change:

https://drive.google.com/drive/folders/1M8vZ7-5QwpJMvC6Vp76ZnKLpz3qVg2Zm

2.3.2: Technical Assistance to Strengthen R&D for Climate Change Resilience of Agriculture in the Philippines (PPT following the mission):

https://docs.google.com/presentation/d/1LHHsEMOpsiYJcUswdoq0Fb9UMa4Q92i4/edit#slide=id.p1

2.4 Biomass energy

2.4.1: Inception report:

https://drive.google.com/drive/folders/11ms8nAFdGxvxIw1HWs2SLKJcVRc5RHmj

2.4.2: Interim report with mission report

https://drive.google.com/drive/folders/11ms8nAFdGxvxIw1HWs2SLKJcVRc5RHmj

2.4.3: Final report. 2. Assessment of the existing R&D capacities for the development of biomass energy, the associated technical, scientific and financial needs, and corresponding recommendations:

https://drive.google.com/drive/folders/11ms8nAFdGxvxIw1HWs2SLKJcVRc5RHmj

2.4.2 Communication following the mission:

https://www.cirad.fr/en/worldwide/our-regional-offices/southeast-asian-islands/news-southeast-asian-islands/agricultural-by-products-and-co-products-for-energy-production

2.5 Sugar value chain

A state of the art of sugar cane value chain, identifying priority research areas and topics in Philippines.

https://drive.google.com/drive/folders/1Vh9vpaYIz6BKM-FbzmEPYhf_Cxrx0WMo

Annex 4: AF R&D projects proposed by UPLB-CIRAD teams

2.1 Genetics - R&D project on the climate-related

Following contacts made in the Philippines and training sessions held in Montpellier, 4 projects were proposed, the first of which is explained below:

1. 211 Molecular characterization of resistance genes for TR4, BBTV, BSV pathogens to develop banana tolerant cultivars
2. 212 Stable and transitory transformation of tropical species for genome editing of agronomical genes of interest
3. 213 Genome editing for developing climate resilient coconuts
4. 214 Germplasm screening and identification of resistance genes against HLB and CTV in citrus

2.1.1 Molecular characterization of resistance genes for TR4, BBTV, BSV pathogens to develop banana tolerant cultivars : In Philippines, banana production is hampered by a number of pathogens, including the fungus Fusarium oxysporum tropical race 4 and the banana streak virus (BSV) which has the particularity to be integrated into some banana genomes. Under biotic or abiotic stresses, like climate change these integrated viruses are reactivated and develop disease which can lead to the death of the plant in extreme cases. Molecular markers for genotyping the different BSV species have been developed and genome editing tools for deactivating them are under development at CIRAD. This R&D project is a way of adapting to climate change without having to use chemical products.

2.2 Mango value chain - digital technology

The team identified 6 R&D projects, 3 on the resilience of Mango production in the context of climate change and 3 related to digital tools for climate change adaptation and mitigation. The mission revealed that the most urgent R&D needs for the mango sector in the Philippines were not necessarily the digital technology as a priori envisaged.

Climatic variables (temperature, rainfall, extreme events, CO_2 concentration) play a key role in the growth, productivity and pest levels of fruit crops. CIRAD-UPLB team has identified three areas for further research and development to strengthen the resilience of mango to climate change in the Philippines.

2.2.1 Mango resilience- Impacts of climate change on the mango physiology and yields: Climate change will affect mango ecophysiology and production (flowering will be altered by increases in temperature or more frequent rainfall, reduced rainfall will reduce mango growth, increase of pest and diseases, etc.). Furthermore, the effects of repeated or cumulative abiotic stresses on fruit trees remain poorly understood. Therefore, the aim here is to conduct research on mango ecophysiology on the main cultivars that will help tropical perennial fruit cropping systems to adapt to climate change and improve their productivity and resilience. The questions to be answered are: What are the effects of climatic factors (CO2 concentration, temperature, water availability) on the mechanisms underlying the development of mango development, production and fruit quality? What will be the future impact of climate change on the plant and its productivity? How do these impacts affect water and carbon functioning at the whole-plant level and the long-term sustainability of production? What strategies and levers can be mobilised to adapt systems to future environments?

2.2.2 Mango resilience- Modern mango orchard management: this project a national plan on improvement of the mango management practices in collaboration with research institutes, technical services and the stakeholders of the sector. Improvement of mango management practices will enhance production while integrating farmers into low input and integrated orchard management strategies to sustainably manage their orchards while experiencing climate change. This plan will include the evaluation of different practices of fertilization, tree pruning and size maintenance, orchard design (planting density), grafting, and rejuvenation of orchards (planting new trees) ; and selection of new varieties,. Moreover, innovative practices will be envisaged to adapt mango cultivation to climate change, including biotechnical adaptation of the system (more stress-tolerant varieties and rootstocks) and the implementation of practices that improve, for example, canopy microclimate (e.g., manipulation of tree architecture), water use efficiency (e.g., soil mulching) or flowering (e.g., management of phenology through pruning). New management practices will first demonstrate their effectiveness through the establishment of trials at research stations and on farmers' orchards in a co-conception process. After testing and demonstrating the effectiveness of these practices, farmers and contractors will be trained so that these practices can scale to a larger audience. The ultimate goal of such a project would be to revitalize mango production on a national scale and enable the sector to increase its added value.

2.2.3 Mango resilience- Agro-ecological control of the cecid flies: Climate change will increase pest infestation and damage in the major part of the world. Considering the current constraints and costs associated with the cecid flies despite the extensive use of pesticides and fruit bagging, we recommend that the sector explore new methods of controlling this pest. One approach that has been tested in other contexts is to make use of agro-ecological control of the cecid flies, which can include integrated pest management and additional strategies to reduce pesticides use. Numerous agro-ecological methods for the cecid flies have been tested, particularly at CIRAD. Several studies have shown the effectiveness of managing ground cover in controlling this pest, allowing for significant reduction of its incidence at low human, environmental and financial costs through natural regulation. In the Philippines, a preliminary study has indicated that effective management of pests and diseases in mango orchards can improve yields by about 33%, whereas integrated pest management would reduce the costs of production by 16%, derived from a 75% reduction in chemical control cost (Preciados et al., 2013). The aim of this project will be to reinforce this results to move towards sustainable management of mango pests. Trials on agro-ecological management practices to control pest and disease (especially the cecid fly) will be conducted and tested as based on current practices developed in other areas. These practices will enable farmers to reduce pesticide use while increasing their yields. The reduction in pesticide use will indirectly lead to a decrease in pesticide residues and contribute to the improvement of the quality of mangoes. Finally, the development of new techniques to control the cecid flies would make it possible to reduce the fruit bagging technique, which is costly and time-consuming for the farmers and contractors.

Digital tools for climate change are in an early stage of development in the Philippines. However, we noted various initiatives of "climate change tools" that should be considered in future development. For digital tools to help scale-up resilience to climate change, especially for smallholder farmers, we propose to focus on three points:

2.2.4- Digital tools for climate change adaptation - Quantify the needs for digital tools: the aim is to assess the needs from smallholders and other stakeholders of the value chain regarding climate change issues to develop digital tools of technical advice (weather forecast, water use efficiency, pest and disease detection & warning...) and on-farm performance assessment (farmers communication systems, yield estimates, GHG calculators, mitigate waste, sustainability indicators...) relevant to help them mitigate and adapt to climate change. Indeed, farmers are more likely to use tools that provide clear benefits (improve incomes or productivity, time saving, input reduction, sharing of knowledge, seize market opportunities...) and directly address their operational needs with a strong understanding of the context in which they are working. Quantifying stakeholders needs and adoption factors is a key step in co-designing digital tools or adapting existing projects/tools that have not yet been scaled up due to various bottlenecks

2.2.5- Digital tools for climate change adaptation - Scaling-up of digital tools resulting from the SARAI project (Smarter Approaches to Reinvigorate Agriculture as an Industry in the Philippines): building of digital decision support tools in the Philippines (SARAI project up-scaling). The Institute of computer science of the UPLB has already developed several digital solutions for farmers including: weather forecast, pest and disease identification (similar to Plantix), irrigation monitoring, coffee advisory app (estimation of harvest date and production based on crop model). Based on the comments of the stakeholders of the SARAI project at the UPLB, some digital solutions developed during the project and that achieved their proof of concepts, lack of human-centered IT deployment and improvements of computer development to ensure successful scaling-up and high adoption rate at national and even regional levels. The aim of this project is to help the adoption and scaling up of the solutions already built within the SARAI project.

2.2.6 - Digital tools for climate change adoption – PixFruit based-digital solution: PixFruit is an expertise currently developed by CIRAD to evaluate fruit yield variables (production, fruit size, maturity, etc.) based on digital tools. The aim of this project will be to assess the development potential of a PixFruit-based tool for evaluation of mango size, color grade and pest & damage levels at harvest . Currently small-scale producers of fruit trees, especially mangoes, have no other means to monitor the quality and damages of their fruits than performing a rough visual estimate at harvest; estimates that provide low accuracy and repeatability. These estimations are critical for producers to sell their fruits because the size and color of the fruit and the visual aspect (pest & diseases damages or malformation) define the markets and the value of the fruits. This project will setting-up tests and collect calibration data for image analysis tool. The project will also evaluate feasibility and co-design a tool adapted to the mango value chain in the Philippines

2.3 Aquaculture

2.3.1 <u>Project on circular economy in the aquaculture value chain</u>

Circular approaches in aquaculture provide opportunities for adaptation/mitigation of aquaculture to climate change. The concept includes new ways to increase resource use efficiency, lower production cost as well as carbon emission and thus the footprint of aquaculture to climate. The concept is developed toward 1) the reduction of feed inputs through smart diets adapted to fish or shrimp requirements (e.g., species, season) as well as to the environment where they are produced (e.g., pond *vs* cages). The concept includes also 2) the recycling of the remaining waste into new commodities such as seaweeds, black soldier fly meal and organic fertilizers. These new commodities can thus be 3) reused *in situ* by the food web or *ex situ* into new feed formulations or fertilizers for aquaculture or other crops. The four main production models in Philippine (i.e., seaweed, milkfish, tilapia and prawns) are highly relevant for the implementation of this concept where intensive black tiger prawn produced in inland pond can be integrated with tilapia/milkfish ponds and subsequently with inland seaweed production in ponds. It creates an opportunity to stop waste water discharge to the environment, promote carbon storage, and increase ecosystem stability improving the sanitation of shrimp pond and thus decrease the occurrence of diseases. This model work also with extensive or semi-intensive black tiger prawn system and can improve the livelihood of small-scale producers and particularly woman and youth. The concept of circular economy in aquaculture has been developed and validated in Vietnam and now proposed for upscaling in South East Asia (i.e., Thailand, Laos, Cambodia) with French Ministry of Foreign Affairs and in Vietnam with AFD and European Union.

2.3.2 Project of integrated small-scale aquaculture (ricefish, mud crab and mangrove)

This project connects with the FAO country program, for synergies on aquaculture (mud crab, rice fish). It supports young people and women and applies to the value chain and processing of seaweed (carrageenates). It has applications for both mangroves and biodiversity conservation. Ricefish or associated mangrove aquaculture provide opportunity to increase system production and system efficiency. For ricefish, introduction of fish in paddy field (4,8 Mha in Philippines) provide opportunity to increase rice production of up to 20% and save water for dual production of rice and fish (up to 500 kg/ha). Additionally, the integration helps decreasing the need on chemical inputs such as pesticides and fertilizers. Fish or other organisms such as prawns, crayfish or crabs (for those consumed locally) can be integrated with rice providing an opportunity for diversification of the production system and increasing income for farmers. Associated mangrove aquaculture is also relevant with the previous project (1) on circular economy in aquaculture where prawn production can be better integrated in the mangrove landscape for its conservation and recovery. Mangrove and rice integrated aquaculture can thus provide several ecosystem services such as shelter for biodiversity and carbon storage. Dutch cooperation through Wageningen University and Research has started advising the wetland International Philippines in the framework of the *To Plant or Not To Plant project* (TPNTP) where synergies can be identified with fish farming and mitigation of climate change.

2.3.3 Project on updated genetic programs and valorization of indigenous species

Philippine aquaculture has been leading in selective breeding programs for tilapia such as GIFT strain. Saline Molobicus tilapia is also a product of Philippine National Fisheries Development Center together with the collaboration with Cirad and INRAE. Saline tilapia provide an opportunity for adaptation and mitigation of aquaculture to climate change particularly in the context of sea level rise and salinization of inland waters. Saline tilapia is also selected for their growth performance providing an opportunity to improve the production systems of Laguna da Bay and Taal lake. Similarly, valorization of indigenous species and selection toward growth and adaptation to the impacts of climate change, such as increased temperature and salinization, is also a challenging target to improve the aquaculture value chain in Philippine. For instance, species such as silver perch (*Leiopotherapon plumbeus*) and freshwater sardine (*Sardinella tawilis*) are investigated by UPLB. These species could be promoted in integrated systems

(Projects 1 and 2) providing an added value on conservation and valorization of local biodiversity as well as improving the income of farmers.

2.4 Biomass energy technology

This team proposed 4 projects:

1. Updating the Biomass Energy Resources Atlas of the Philippines;
2. Establishment of decentralized rice husk biochar production units in other producing regions;
3. Decentralized heat production from rice straw (pellets, briquettes);
4. Establishment of one or more hydrochar production pilots, i.e. using wet waste from vegetable production to produce a product that improves soil.

These projects are developed below:

2.4.1 - Biomass Energy atlas project: The project proposes to update the national map of biomass resources produced 10 years ago, with different biomasses typologized according to the source of waste or agricultural residues. This update is necessary due to the evolution of technologies and the development of applications as energy or as new materials or uses. In addition, the project will specify the limits of the economic viability of each of these biomass resources, for certain valorization scenarios (e.g. energy production in a large city or a medium-sized town), this will allow mapping the logistical costs and GHG emissions linked to the collection of this biomass.

2.4.2 - Establishment of decentralized rice husk biochar production units in other producing regions: The production of biochar from rice husks has now been technically mastered. It is now a reality in the Philippines with the ALCOM unit in operation.

The project will involve studying the feasibility of setting up 1 or more other biochar production units, the sizing and corresponding technology of which will have to be studied in relation to the volume of rice husk resources available (maximum 100 km supply radius). The choice of site(s) will be based on an analysis of availability resulting from project 2.4.1. The production of this biochar is fully in line with the Philippines' Climate Plan, as the Intergovernmental Panel on Climate Change (IPCC) has classified it as a "negative emissions" technology, which it considers essential for removing CO_2 from the atmosphere.

2.4.3 - Decentralized heat production from rice straw (pellets, briquettes): The use of rice straw is more problematic than that of rice husks because of the dispersed nature of the resource. For this reason, the proposed project focuses on increasing the energy densification of the rice straw resource through the decentralized production of pellets or briquettes in the main producing regions (link with project 2.4.1). A comparative inventory of the main existing devices and systems will be used to select those best suited to the local socio-economic context. The domestic market will be targeted, as well as that of VSEs, SMEs and SMIs, which currently have difficulty securing their energy supply. One of the aims of the project will be to test the acceptability, production and marketing of these products in real-life conditions. Briquettes and pellets will be effective solutions for decarbonizing energy in the Philippines, in line with the Philippine Development Plan 2024-2028.

2.4.4 - Establishment of one or more hydrochar production pilots, i.e. using wet waste from vegetable production to produce a product that improves soil: Producing energy from wet to very wet lignocellulosic waste is complicated by the need for energy to remove this moisture. The production of hydrochar (hydrothermal carbonization process, HTC, by converting biomass in water superheated to between 250 and 300°C under autogenous pressure) makes it possible to overcome this problem by adapting to a wide range of raw materials. The project will involve studying the technical and economic feasibility of 3 to 5 pilot hydrochar production units using existing technologies, following a preliminary study of the availability of wet lignocellulosic by-products, mainly by-products from market garden production (see project 2.4.1). The preliminary study will determine the choice of sites for the installation of these units, which will have to be optimized according to the distance to the resource. As with biochar (project 2.4.2), the production of hydrochar is in line with the objectives of the Intergovernmental Panel on Climate Change (IPCC) as a "negative emissions" technology essential for capturing CO_2 from the atmosphere, in line with the Philippines' Climate plan.

2.5 Sugar value chain - ready to transfer varieties for productivity growth and adaptation to Climate Change.

2.5.1 - Sugar cane varietal selection for adaptation to climate change.

This R&D project with Philippine sugarcane sector stakeholders and CIRAD could first of all provide access to the best-performing cane varieties developed by eRcane, a breeder partner in Réunion Island.

These varieties are appreciated and in demand in the Philippines, for their good resistance to ratooning after harvesting: 8 to 10 ratoons compared with 2 to 3 at present in the Philippines fields. The latest varieties available on Reunion Island would officially provide better resistance to disease and high temperatures, as well as an opportunity to broaden the genetic base available to Filipino breeders from public and private research centers.

The aim is not only to improve the performance of ratooning, but also to increase, in a longer term the capacity of Filipino sugarcane breeding centers to withstand drought and high temperatures in a context of climate change.

Access to these varieties, subject to agreement with the breeder eRcane, could be provided officially via CIRAD's international quarantine greenhouse Viasacane, in the form of a few cuttings, or via CIRAD's subsidiary Vitropic, in the form of larger quantities of vitroplants with maximum phytosanitary guarantees.

The introduction of new varieties is an opportunity to steer agricultural practices towards more agroecology, i.e. reduced pesticide use, and greater consideration for soil health and biodiversity. This project could include French and Filipino private stakeholders, ensuring the sustainability of this R&D

initiative beyond the CCAP program.

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