Oscar M. Lopez Center
Science for Climate Resilient Communities

SEAMEO SEARCA
50
1966-2016

Learning and Coping with Change:

Case Stories of Climate Change Adaptation in Southeast Asia

Editors:

Percy E. Sajise
Maria Celeste H. Cadiz
Rosario B. Bantayan

Learning and Coping with Change:

Case Stories of Climate Change Adaptation in Southeast Asia

Oscar M. Lopez Center
Science for Climate Resilient Communities

50 SEAMEO SEARCA 1966-2016

The **Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA)** is one of the 21 regional centers of excellence of the Southeast Asian Ministers of Education Organization (SEAMEO). Founded on 27 November 1966, SEARCA is mandated to strengthen institutional capacities in agricultural and rural development in Southeast Asia through graduate scholarship, research and development, and knowledge management. It serves the 11 SEAMEO member countries, namely, Brunei Darussalam, Cambodia, Indonesia, Lao People's Democratic Republic, Malaysia, Myanmar, the Philippines, Singapore, Thailand, Vietnam, and Timor Leste. SEARCA is hosted by the Government of the Philippines on the campus of the University of the Philippines Los Baños (UPLB) in Laguna, Philippines. It is supported by donations from SEAMEO members and associate member states, other governments, and various international donor agencies.

Learning and Coping with Change:
Case Stories of Climate Change Adaptation in Southeast Asia
Editors: Percy E. Sajise, Maria Celeste H. Cadiz, and Rosario B. Bantayan

Published by SEARCA
Printed in the Republic of the Philippines
First printing 2016

This publication was peer reviewed.

Cover photo credits: Phanuwat Moonjuntha; Adi Fakhrurrazy; Neil Palmer; Rita T. Dela Cruz; Badan Meteorologi, Klimatologi dan Geofisika; Erik Pratama

ISBN: 978-971-560-176-4

Learning and Coping with Change:

Case Stories of Climate Change Adaptation in Southeast Asia

Editors:
Percy E. Sajise
Maria Celeste H. Cadiz
Rosario B. Bantayan

Southeast Asian Regional Center
for Graduate Study and Research in Agriculture
(SEARCA)

2016

Table of Contents

List of Tables

Appendix Tables

List of Figures

Foreword

The Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA) is proud to present this pioneering work, featuring selected case stories on climate change adaptation initiatives that are being implemented in Southeast Asia. This book *Learning and Coping with Change: Case Stories of Climate Change Adaptation in Southeast Asia* is the outcome of the First Regional Knowledge Sharing Writeshop on Climate Change Adaptation (CCA) in Inclusive and Sustainable Agricultural and Rural Development (ISARD) held on 15–17 April 2015 at SEARCA, Los Baños, Laguna, Philippines. Organized by SEARCA in partnership with the Oscar M. Lopez Center for Climate Change Adaptation and Disaster Risk Management Foundation Inc. (OML Center), the event brought together leading scientists and researchers from Cambodia, Indonesia, the Philippines, Thailand, Vietnam, and five international agencies and academic institutions working on agriculture and climate change.

This book is intended to enrich knowledge and enhance awareness among various stakeholders and policy and decision makers that adaptation efforts not only address the challenges brought by climate change, but the implementation of these CCA initiatives also fulfills goals that greatly benefit society, such as sustainable agricultural and rural development, disaster risk reduction, and improvements in quality of life. Although there is no "one-size-fits-all" adaptation, there are similarities in approaches, methodologies, and processes involved in identifying and implementing CCA goals and strategies as narrated in the 13 case stories featured in this book.

We thank and congratulate the case story writers and their co-authors who willingly shared with us their climate change adaptation strategies, the challenges they experienced in implementing them, as well as lessons learned along the way. We commend their ongoing efforts and commitment to deliver science-based solutions, options, and best practices for climate change adaptation. We also thank the editors for their time and effort in reviewing the case stories.

We would also like to express our sincere appreciation to the OML Center, a long-time SEARCA partner, for their support and invaluable inputs toward the successful implementation of the writeshop.

Although our major stakeholders are the policy and decision makers from the Southeast Asian region, SEARCA is likewise committed to reach out to other relevant stakeholders—agricultural and rural development practitioners, researchers, the academe, civil society organizations, and business groups—that stand to benefit from having access to robust and science-based climate change adaptation strategies; and use these for well-informed decision making and adaptation actions.

We also hope that this book will be used as a teaching material so that the common methods, approaches, and processes involved in CCA will be multiplied and scaled up for adoption and generate many more similar efforts in Southeast Asia.

Gil C. Saguiguit, Jr.
Director, SEARCA

Contributors

EDITORS

Percy E. SAJISE is an Honorary Research Fellow of Bioversity International and a Senior Fellow of the Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA). He is the former Regional Director of Bioversity's Office for Asia, Pacific, and Oceania from 2000 to 2008 and Director of SEARCA from 1994 to 1999. He is an Adjunct Professor of the School of Environmental Science and Management (SESAM) of the University of the Philippines Los Baños (UPLB). He also served as Dean of UPLB's College of Human Ecology and College of Arts and Science as well as Director of the Institute of Environmental Science and Management (the forerunner of SESAM). Dr. Sajise has authored, co-authored, and edited numerous publications. He is a member of the editorial board of several research journals, including the *Asian Journal of Agriculture and Development, Environmental Science Journal, Journal of Environmental Science and Management*, and *Wageningen Journal of Life Sciences*. He has worked as a consultant for many international organizations and national agencies. He was recently appointed as a member of the Advisory Group to the Secretariat of the Commission on Genetic Resources for Food and Agriculture of the UN-FAO. He is also a member of the advisory body of the Center for Biodiversity and Indigenous Knowledge in Yunnan, China. He obtained his PhD in Plant Ecology from Cornell University; had been a Research Fellow at the Environment and Policy Institute, East-West Center, Hawaii, USA; and a Visiting Professor at Leiden University, the Netherlands.

Maria Celeste H. CADIZ is the Program Head of SEARCA's Knowledge Management Department. Dr. Cadiz also serves as an Adjunct Associate Professor and was the first Dean of the College of Development Communication, UPLB. She served as project leader in a number of national and international action-research programs in development communication; authored two books, a monograph, and several articles published in professional publications, as book chapters, or presented in international and national conferences; and produced more than 40 communication materials in various media formats, from print to audiovisual.

Rosario B. BANTAYAN has more than 15 years of experience in coordinating and organizing international and local training courses and learning events related to environment and natural resources management. As Program Specialist at SEARCA, she assists in the development, marketing, coordination, implementation, and evaluation of the Center's training programs. Prior to joining SEARCA, Ms. Bantayan was a University Extension Specialist at the Department of Forest Products and Paper Science, College of Forestry and Natural Resources (CFNR), UPLB. She also served as Program Development Associate at the Office of the Chancellor, UPLB.

CASE STORY AUTHORS

Alma Lorelei ABEJERO is a licensed chemist with seven years of experience in a pharmaceutical firm as Quality Assurance Analyst and one year in an environmental service laboratory. She has working knowledge in analytical methods, microbiological techniques, and environmental testing. She specializes in water quality assessment and air quality assessment. Her research interests include environmental chemistry, toxicology, environmental health, epidemiology, and disaster risk reduction and management.

Sofia A. ALAIRA is a licensed forester and currently a University Researcher at SESAM, UPLB. She obtained her MS in Environmental Science from UPLB. Ms. Alaira's areas of specialization include biodiversity assessment, environmental code development, and environmental impact assessment.

Antonio J. ALCANTARA is a retired Professor and Adjunct Faculty of SESAM, UPLB. As a soil and environmental scientist, he has various involvements in solid waste management, industrial ecology and landscape ecology, environmental impact assessment, and environmental resource planning and management. Currently, he is a consultant of the Municipality of Los Baños, Laguna, Philippines and acting as the Municipal Environment and Resource Officer.

Nicasio S. BAUCAS is connected with the Cordillera Administrative Region Regional Field Office of the Department of Agriculture (DA-CAR) where he serves as the DA-CAR's focal person on climate change. Currently, he is working on applied researches on climate change adaptation (CCA) initiatives for crops with special focus on insect pest problems, at the Cordillera Integrated Agricultural Research Center, the agency's research division, based in Baguio City, Philippines.

Stephane BOULAKIA is agronomy engineer at the French Agricultural Research Centre for International Development (CIRAD), where he specializes in tropical conservation agriculture. For 10 years, he worked in several R&D projects on cropping systems design in Madagascar, Gabon, and Vietnam. He transferred to Cambodia in 2004–2013 and served as an agronomist and principal technical assistant in the Support Project to the Cambodian Agriculture, a project of the Cambodian Ministry of Agriculture, Forestry, and Fisheries funded by the French Development Agency and the United States Agency for International Development (USAID). He led R&D programs that focused on cropping systems development through participatory and multi-scale approaches for rain-fed upland and lowland field crops. He came back to CIRAD headquarters in Montpellier and took the coordination of the Cropping System Design and Ecological Intensification team of the Research Unit on Agro-ecology and Sustainable Intensification of Annual Crops. Currently, he is conducting support missions to several smallholders and industrial projects in West and Central Africa.

Vida Q. CARANDANG is an Assistant Professor at the Institute of Renewable Natural Resources, CFNR, UPLB. For the past 18 years, she has been teaching and doing research and extension works in the fields of environmental forestry, forest rehabilitation, and watershed management. She is also actively involved in upland development projects in the Philippines, working with smallholder farmers and communities in the rural areas of the country.

Wilfredo M. CARANDANG is a Professor of Silviculture at CFNR, UPLB. For the past 35 years, he has been teaching and doing research and extension works in the fields of plantation forestry, forest rehabilitation, and agroforestry. In the past 20 years, he has been involved in many upland development projects in the Philippines, working with smallholder farmers and communities in the rural areas of the country. He is currently the Executive Director of the Southeast Asian Network of Agroforestry Education, which is an aggrupation of educational and research institutions in Malaysia, Indonesia, Lao PDR, the Philippines, Thailand, and Vietnam that promotes the education and the science and practice of agroforestry in the region. He has authored and co-authored about 30 peer-reviewed journal publications.

Rex Victor O. CRUZ holds the rank of Professor 12 and Scientist III at CFNR, UPLB. He is a renowned expert in watershed management and in climate change mitigation and adaptation. His expertise and research interests include ecosystem and landscape planning and management, upland development, and integrated natural resources management. He has published close to 100 scholarly journal articles and has been involved in various development projects. He was a member of the Intergovernmental Panel on Climate Change (IPCC) of the UN that won the 2007 Nobel Peace Prize with former US Vice President Al Gore. He served as a principal lead author and convening lead author of the *Assessment of Climate Change Impacts and Adaptation, Intergovernmental Panel on Climate Change, Second, Third and Fourth Assessment Reports*. He is currently leading three national research, development, and extension (RDE) programs in the Philippines: the Monitoring and Detection of Ecosystem Change for Enhancing Resiliency and Adaptation, the National Research and Development Program for Watershed Management, and the National Conservation Farming Village (CFV) Program.

Erik DELAQUIS is a Canadian agronomist and agro-ecologist at the International Center for Tropical Agriculture Asia (CIAT-Asia) in Hanoi, Vietnam. Mr. Delaquis holds an MS in Plant Science from McGill University and has worked in biomass crop development in Eastern North America and village-cluster level agro-ecology in West Africa. He joined CIAT in March 2015 after completing a community agroforestry and vegetable production project in Senegal and The Gambia funded through an OceanPath fellowship.

Catherine C. DE LUNA is University Researcher II at the Interdisciplinary Studies Center for Integrated Natural Resources and Environmental Management, CFNR, UPLB. She is currently involved in watershed management and agroforestry research and extension initiatives. She has also been actively involved in a number of RDE projects, including CFV that uses the watershed/landscape approach in advancing sustainable natural resource management. The lessons and experiences in the project implementation and the results of the researches conducted by Ms. De Luna have been properly disseminated, as indicated in the number of her publications in various forms. She obtained her MS in Forestry in 2008 and is currently pursuing her doctorate in watershed management at UPLB.

Caitlin CORNER-DOLLOFF was a Climate Change Adaptation Specialist in the Decisions and Policy Analysis (DAPA) research area of CIAT while conducting the research related to the case story written in this book. She is now a Climate-Smart Agriculture (CSA) Program Manager at the USDA Foreign Agricultural Service. At CIAT, she led research initiatives in collaboration with the CGIAR Climate Change, Agriculture, and Food Security (CCAFS) Research Program in over 25 countries across Africa, Latin America, and Southeast Asia where she built interdisciplinary teams to explore the synergies and trade-offs between productivity, resilience, and low-emissions development. She led the development and implementation of participatory processes and tools, such as the CSA Prioritization Framework (CSA-PF) and CSA Profiles, aimed at increasing evidence-based decision making and building capacity for integration of climate change, natural resource management, stakeholder engagement, and learning processes into agriculture development planning. She holds an MS in Environmental Change and Management from the University of Oxford and a BA in Participatory Environmental Management from the College Scholar Program at Cornell University.

Anton EITZINGER is a Geospatial Modeler and Climate Change Adaptation Specialist in the DAPA research area of CIAT. During the last few years, he has been leading several projects quantifying the potential impact of climate change on crop systems and the vulnerability of farming communities in Latin America. Currently, he is testing information and communications technology tools for tracking and monitoring of local adaptation processes and for crowd-sourcing of agricultural-related information in Spatial Data Infrastructures for Latin America and East Africa. He obtained his MS in Economy and Information Management from The University of Applied Sciences in Salzburg in Austria and holds a degree in geospatial modeling from the University of Salzburg. He is currently finishing his PhD at the University of Munich in Germany, where he is studying farmers' perceptions of climate risks in the context of livelihood goals.

Decibel F. ESLAVA is a geologist with research interests in climate change impacts, adaptation, disaster risk reduction and management, bio-geology, environmental geology, geologic hazards, geochemistry, paleo-magnetism, and tectonics. She coordinates and co-teaches ecosystem structure and dynamics, contemporary issues in environment and development, and environmental impact assessment at UPLB. Dr. Eslava has published numerous articles and academic papers on various subjects related to her expertise. She is currently the Dean of School of Environmental Science and Management, UPLB.

Ma. Victoria O. ESPALDON is a human geographer and Professor at SESAM, UPLB. She is the current Chair of the UPLB Climate Risks Study Center. She is the former Vice Chancellor for Research and Extension of UPLB from 2011 to 2014, and the former Dean of SESAM from 2006 to 2011. Her major research works are in the areas of CCA, human dimensions of environmental changes, environmental and social impact assessment, program monitoring and evaluation, and ecosystem assessment. Dr. Espaldon has published numerous articles on various subjects related to her expertise.

Leonardo M. FLORECE is a full-time Professor at UPLB. He is a forester and University Scientist 1 whose research interests include forest succession, assisted natural regeneration, marginal land rehabilitation, biodiversity conservation, and invasive alien species. He has been involved in various projects that deal with climate change, rapid systems appraisal, community-based natural resource management, environmental security, environmental planning and management, environmental impact assessment, and environmental audit. Dr. Florece has published numerous articles on various subjects related to his expertise.

Genevieve A. GALAPIA is the project researcher in the implementation of the CFV project in the Philippines from 2009 to 2015. She is a graduate of BS Forestry from UPLB, and is the topnotcher during the Forester Licensure Examination in July 2010 given by the Board of Foresters of the Philippine Professional Regulation Commission.

Dixon T. GEVAÑA is an Assistant Professor at the Department of Social Forestry and Forest Governance, CFNR, UPLB. He obtained his BS in Forestry and MS in Community Development from UPLB, and PhD in Forest Environmental Science from Seoul National University, Korea. His major fields of research include community forestry, climate change mitigation through forestry, and ecological restoration.

Oliver GONZALES is the Environment and Natural Resources Officer of Batangas City, Philippines and the current national treasurer of the Philippine League of Local Environment and Natural Resources Officers. For over 15 years, Mr. Gonzales has represented Batangas City in various local and international environmental trainings, conferences, and forums. He is one of the authors who formulated the the Batangas City Environmental Code, which won the city in 2011 the prestige of being the "Most Livable Community" in the International Award for Livable Communities. He also received a citation for the Best Paper Award conferred by the Philippine Network of Educators on Environment when he co-authored the paper regarding the University-LGU partnership model for co-designing sustainable futures. Mr. Gonzales holds a BS in Chemical Engineering and also finished a course on Environmental Monitoring and Modelling from the Water Institute of Technology, Delft, the Netherlands. Mr. Gonzales has also worked with different international organizations and NGOs such as the USAID, International Council for Local Environmental Initiatives, and Clean Air Asia in the areas of climate change and clean energy projects.

Vichien KERDSUK is a researcher at the Research and Development Institute (RDI), Khon Kaen University (KKU). As an agronomist, he was involved in the project (1981–1986) of Khon Kaen University that focused on the cropping and farming systems in Northeast Thailand. He transferred to the Agricultural Extension Department of the Ministry of Agriculture and Cooperative in 1987–1988, and served as a consultant in the Small Farmer Participation Project of the department. From 1989 to date, he is a government officer at RDI, KKU. His expertise includes crop modeling, vulnerability assessment, and development of farmer adaptation measures to climate change in the Mekong region. He obtained his doctorate degree from Suranaree University of Technology, and has authored and co-authored various peer-reviewed publications.

KONG Rada is an agronomist and agro-economist specializing in tropical agrarian systems and conservation agriculture. After obtaining his MS in Sustainable Development in Agriculture (Agris Mundus), he has since worked as a coordinator of research and development projects on conservation agriculture in Cambodia at the Ministry of Agriculture, Forestry, and Fisheries, and at CIRAD. He is actively involved in cropping system development through multi-scale and multi-stakeholder participatory approach for rainfed upland and lowland field annual crops. He is finishing his PhD research entitled "Landscape and Livelihood Changes in the Northwestern Uplands of Cambodia: Impacts on Ecosystem Services and Opportunities to Build Resilient Farming Systems" at Montpellier SupAgro.

Peter LÄDERACH is currently the team leader for Climate Change at CIAT. For the last 10 years, Dr. Läderach has led the expansion of CIAT's DAPA Research Area to Central America, East-Africa, and Southeast Asia where he has established interdisciplinary research groups by forming partnerships, raising funds, implementing research projects, and publishing intensively. Dr. Läderach is highly involved in conducting research that leads to visible impacts on the ground; thus, his research supports the private sector, NGOs, governments, and multinational agencies such that evidence-based decisions can deliver impact on the ground. Dr. Läderach holds an MS in Geography and a PhD in Tropical Agriculture.

Rodel D. LASCO has nearly 30 years of experience in natural resources and environmental research, conservation, education, and development at the national and international levels. His work has focused on issues related to natural resources conservation, climate change, and land degradation. He is a member of the IPCC, the 2007 co-winner of the Nobel Peace Prize. He is also a member of the National Academy of Science and Technology in the Philippines. He is the Philippine Coordinator of the World Agroforestry Centre since April 2004. He is also the Scientific Director of the Manila-based Oscar M. Lopez Center for Climate Change Adaptation and Disaster Risk Management Foundation Inc. (OML Center), a privately-endowed foundation working on CCA and disasters risk reduction research. Dr. Lasco is a multi-awarded scientist with over 80 technical publications in national and international journals dealing with the various aspects of natural resources conservation and environmental management. He pioneered research in the Philippines on CCA in the natural resources sector, the role of tropical forests in climate change/global warming, and the policy implications of the Kyoto Protocol. He also spearheaded the Philippines subglobal component of the global Millennium Ecosystems Assessment, which is designed to assess the role of ecosystems and their biodiversity in providing services for human well-being. Dr. Lasco has served as consultant to national and international organizations that work on climate change, natural resources, and environmental conservation projects in the Philippines and other countries.

LENG Vira is an agronomist specializing in conservation agriculture. From 2007 to 2014, he worked at the Conservation Agriculture Service Center, an institute that focuses on R&D of conservation agriculture technology on annual crops production in the upland and lowland ecosystems of Cambodia. He is also involved in cropping system design and development, and has provided technical support to various participatory farmer-led research plots on conservation agriculture technology diffusion. Since 2015, he has been conducting a research project that aims to determine the effects of short-term conservation agriculture on soil organic carbon and nitrogen in the lowland rice agroecosystem in Cambodia. He is currently finishing his MS in Agricultural Science at the Graduate School of Agriculture, Tokyo University of Agriculture and Technology, Japan.

Miguel LIZARAZO conducts research on CSA decision support tools as a Research Assistant in the DAPA area of CIAT, in collaboration with the CGIAR Research Program on CCAFS. He was involved in the design, development, and implementation of the CSA-PF, utilizing his agronomic expertise to establish methodologies for matching CSA practices with specific agroecological contexts and engaging stakeholders in utilizing evidence-based decision making around selecting CSA priorities. Mr. Lizarazo holds a BS in Agronomy from the Universidad Nacional de Colombia, Bogotá, and previously worked at the Research and Rural Extension Centre. He was a member of the university research group on horticulture, specializing in physiology and mineral plant nutrition. Mr. Lizarazo has further explored management of tropical ecosystems from an exchange at the Universidad de Córdoba in Spain, and evaluation of biodiversity and ecosystem services in agricultural systems through the Policy, Legislation, and Support for Decision Making Program at the Alexander von Humboldt Biological Resources Research Institute in Colombia.

LINH Giang Tuan worked as a Geographic Information System (GIS) and Remote Sensing Analyst at CIAT-Asia, where she specialized in remote sensing, spatial analysis, land-use mapping, database management, and crop modeling to assess the impacts of climate change on the suitability of key crops in the Greater Mekong Subregion. Her key areas of interest are spatial analysis and remote sensing for agriculture and the environment.

MAI Van Trinh is the Director of the Institute for Agricultural Environment, Vietnam Academy of Agricultural Sciences. He first became involved in research initiatives in 2009 through the World Bank project Economics of Adaptation in Vietnam Agriculture. He has continued his research through his work on greenhouse gas (GHG) inventory initiatives for the Agriculture and Development Action Plan for GHG Emission Reduction toward 2020; development of Green Growth Strategies for Agriculture together with the Ministry of Investment and Planning and the United Nations Development Programme; development of the Intended Nationally Determined Contribution for Vietnam Agriculture; and development of the Guideline for the Nationally Appropriate Mitigation Actions (NAMA); and the measurement, reporting, and verification systems for Integrated Food-Energy System project of NAMA. He leads components of initiatives aimed at building a CSA compendium, which is associated with two research projects of CIAT, namely, the CSA-PF and the CSA Country Profiles.

Agustin R. MERCADO, Jr., has extensive experience on conservation farming, agroforestry, and forestry research and development projects with the World Agroforestry Centre, working directly with rural communities. He has extensively published various studies related to upland issues. He has been involved in numerous upland projects supported by international research and development organizations in collaboration with government, NGOs, and people's organizations in the Philippines. He is the concurrent Research Manager of World Agroforestry Centre in Mindanao, Philippines. Dr. Mercado obtained his PhD in Agricultural Sciences from the University of Hohenheim. Along with various partners, he developed the Conservation Agriculture with Trees Learning Center in the Philippines, which showcases ways and technologies to mitigate and adapt to climate change in upland farming systems.

Luningning R. MORALES obtained her BS Forestry and MS and PhD in Environmental Science from UPLB. She is the current Division Chief of the Administrative and Management Services of the Provincial Environment and Natural Resources Office, Philippine Department of Environment and Natural Resources in Batangas City.

Kennedy NG'ANG'A is a GIS and Remote Sensing Analyst at CIAT based in Nairobi, Kenya. His work focuses on spatial analysis, modeling, and generation of informative maps. Mr. Ng'ang'a supports the research being done by CIAT in Africa on issues affecting agriculture and the environment. His key areas of interest are ecosystem services, soils, and environmental conservation.

NGUYEN Dinh Cong is a Program Officer at the Agriculture and Irrigation Program of the Mekong River Commission (MRC). Prior to joining MRC, he was a lecturer at the Faculty of Natural Resources and Environment, Hanoi University of Agriculture, Vietnam. He has a PhD in Agricultural Science from the University of Hohenheim, Germany. In the MRC, he works in a broad range of topics such as irrigation database, land evaluation, crop modeling, and agricultural land-use monitoring and climate change impact on food security.

Andreea Cristina NOWAK is an Environmental Policy Specialist at CIAT. She works on decision-support tools for analyzing countries' readiness to adopt and scale-out CSA and for selecting, analyzing, and prioritizing CSA practices. Ms. Nowak currently leads the CSA Country Profiles initiative—a collaboration between CIAT, CCAFS, The World Bank, the Tropical Agricultural Research and Higher Education Center, and the USAID Bureau for Food Security—which aims to identify national and local enabling environments for CSA from agronomic, environmental, social, financial, policy, and institutional points of view in different countries across the globe. She has also been engaged in the methodological design and implementation of the CSA-PF through pilots in Colombia, Ethiopia, Ghana, Guatemala, Mali, and Vietnam. Ms. Nowak previously worked with CIAT on topics related to the analysis of water-food-energy nexus under various climate change scenarios and conservation of ecosystem services for food security. She has undertaken and coordinated research projects and teams in more than 20 countries in Latin America, Africa, South and Southeast Asia, and Europe. She holds an MS in International Development and Project Management with a focus on sustainable development and natural resource management from Lund University (Sweden) and BA in Political Science from the University of Bucharest (Romania).

NURHAYATI is the Director of the Center for Climate, Agroclimate, and Marine Climate of BKMG, Indonesia. In her current position, she is responsible for the implementation of the programs of the Climate, Agroclimate, and Marine Climate Information in Indonesia. The Climate Field School (CFS) program is one of the programs under her supervision.

Louis PARKER is a Geospatial Analyst at CIAT-Asia based in Hanoi, Vietnam. His previous work has focused on crop modeling and mapping, with a strong focus on the potential impacts of progressive climate change on agricultural production systems and food security. He led the team responsible for the crop suitability modeling under different climate change scenarios in the recent *The Africa Agriculture Status Report 2014: Climate Change and Smallholder Agriculture in Sub-Saharan Africa* for the Alliance for a Green Revolution in Africa. He holds an MS in Water: Science and Governance from King's College London, with a strong focus on the use of GIS to provide integrative and informed decision making for natural resource management within an agricultural framework. He hopes to work extensively throughout Southeast Asia, and to develop strong contact, collaboration, and information-sharing with research organizations, stakeholders, and governmental bodies in the region.

Perlyn PULHIN has been working on the areas of environmental research, capacity building and outreach, science policy, knowledge management, and communications and development since 2002. She has performed wide-ranging tasks as program officer/fellow/coordinator, researcher, executive/technical staff, and information planning officer. Ms. Pulhin has established strong links with various universities, government agencies, and organizations at the national and international levels. She is currently the Research and Publications Manager of the OML Center and the Managing Editor of the *Climate, Disaster, and Development Journal*. Ms Pulhin obtained her MS (Environmental Science) and BS degrees (Development Communiation) from UPLB. She has presented papers at national and international conferences, and organized/participated in a number of forums, most of which are climate change-related. She has also co-authored a number of books, conference abstract, scientific paper and poster presentations, peer-reviewed and academic papers, science-policy briefs, and other publications.

Ammapet RAMARAJ is a Senior Research Fellow at the Agro Climate Research Centre, Tamil Nadu Agricultural University and previously worked with CIAT-Asia as a postdoctoral climate impact modeler. He holds a masters and doctoral degree in agricultural meteorology, specializing in crop model applications for decision making. His research focused on dynamical and statistical climate down-scaling for crop model simulations to support better decision making and policy framing.

Nelly Florida RIAMA is the Head of Agroclimate and Marine Climate Division of BMKG, Indonesia. Her educational background is in meteorology. She began her career as a meteorologist at the Meteorological Analysis Subdivision of BMKG. Currently, she oversees the implementation of BMKG's CFS program. From 2010–2014, she served as a member of the expert team in the project Strengthening Operational Agrometeorological Services of the Commission of Agrometeorology (CAgM), WMO. She is still actively involved in the activities of CAgM and in the other commissions of WMO.

Manuel R. REYES is a Professor in biological engineering at North Carolina Agricultural and Technical State University. He has 30 years of experience in water quality modeling and in soil, water, and biodiversity conservation engineering. His education is in biological and agricultural engineering from universities in the Philippines, the United Kingdom, and the United States. For the last 11 years, he has been leading a global research in agro-ecological engineering by growing food while rejuvenating natural resources on rural and urban landscapes through the funding provided by the USAID Sustainable Agriculture and Natural Resource Management; the Horticulture, Sustainable Intensification, Integrated Pest Management, and Small Scale Irrigation Innovation laboratories; and the USDA and the US Environmental Protection Agency.

Andi Eka SAKYA is the Director General of the Agency for Meteorology, Climatology, and Geophysics (BMKG), Indonesia. As Director General of BMKG, he supervises the implementation of the government's activities in meteorology, climatology, geophysics, and air quality information in Indonesia. He is currently the representative of the Government of Indonesia to the World Meteorological Organization (WMO), a member of the Executive Council of WMO, and the President of WMO Region V (2014–2018).

SAR Veng is an agronomist specializing in conservation agriculture. He has combined experiences in adaptive research, cropping system design, implementation of demonstration plots, monitoring and evaluation, organization of farmer's field day and exchange, and community development. He is a site manager of adaptive research and pilot extension in Rattanak Mundol, Battambang province.

Novana SARI is a staff at the Agroclimate and Marine Climate Division of BMKG, Indonesia. With her agrometeorological background, she began her career at the Analysis and Information Section of BMKG Climatology Station in Maros, South Sulawesi. To date, she engages in monitoring and analyzing the drought in Indonesia at BKMG, and is involved in BMKG's CFS program.

Lucien SEGUY is an agronomist and pedologist. He started working in the late 1960s on research and development with small producers of upland rice in Africa, where he began his interest in the conservation of soil fertility. He transferred to Brazil in 1977 where he had been responsible for a rice-growing unit; he soon took charge of the activities relating to the creation and dissemination of cropping systems.

Marisa J. SOBREMISANA is a University Extension Specialist at SESAM, UPLB. She has been involved in implementing SESAM projects, such as crafting the Environmental Code, livestock and environment interaction, water resources management, and climate change initiatives. Currently, she is the project leader of a project funded by the OML Center on rainwater harvesting using collapsible rubber tanks. The use of biogas digester is her special interest as she sees it to have high potential as a remedy for water pollution in areas with high animal population density. She obtained her BS in Agricultural Engineering from UPLB; MS in Resources Engineering from Universität Karsluhe, Germany; and PhD in Environmental Science from UPLB.

Florent TIVET is an agronomist at CIRAD. He holds a PhD in Crop Science and a postdoctorate in Soil Organic C Dynamics. From 2009 to 2012, he was with the State University of Ponta Grossa in Brazil and the C Management and Sequestration Center at the Ohio State University, where he assessed the changes in soil organic C under contrasted no-till cropping systems in the tropics. Since 2002, he has been involved in diverse research and development projects in the region (i.e., Lao PDR and Cambodia), specializing in the field of conservation agriculture and ecological intensification. He is based in Cambodia, and is currently with the Ministry of Agriculture, Forestry, and Fisheries; and with the General Directorate of Agriculture. Concurrently, he coordinates a project on innovative pedagogical resources in agro-ecology and conservation agriculture funded by Agropolis Foundation.

TRAN Dai Nghia is the Director of the Department of Natural Resource and Environmental Economics Studies and head of the Climate Change and REDD+ research group of the Institute of Policy and Strategy for Agriculture and Rural Development under the Ministry of Agriculture and Rural Development of Vietnam. He is also a member of the NAMA for Agriculture taskforce of Vietnam and the country representative for the Global Alliance of CSA. Dr. Tran earned his PhD in Natural Resources and Environmental Management in 2008 from the University of Hawaii and his MS in Agricultural Economics from the University of Arkansas sponsored by the Fulbright program. He has focused on the economics of climate change, climate change policy analysis, and agricultural economics since 1993. Dr. Tran is currently leading a number of climate change projects, and has been deeply involved in reviewing policies and providing advice for policy makers in the areas of Green Growth and Sustainable Development in the Context of Restructuring the Agriculture Sector in Vietnam.

TRANG Sopheak is an agronomist specializing in conservation agriculture. He has combined experiences in adaptive research, cropping system design, implementation of demonstration plots, monitoring and evaluation, and organization of farmer's field day and exchange. Currently, he is a site manager of the ongoing adaptive research in Kampong Cham and Kampong Thom provinces in Cambodia.

Simplicio Q. VELUZ is a University Researcher at SESAM, UPLB and is a home-grown research staff who has passion and excellent skills in photography. His involvement in the documentation of research and extension projects made him well known in his craft. His works as a photographer have already been published in numerous exhibits, newsletters, posters, journals, magazines, books, and other university publications.

Lilian Pagaduan-VILLAMOR is a Senior Science Research Specialist at the Cryobank Unit of the Philippine Carabao Center (PCC), Department of Agriculture (DA). Her main responsibility is to enhance the operationalization of cryobank in areas of molecular identification, cryopreservation, database, and information campaign. She plays a vital role in strengthening linkages to farmers, researchers in the government agencies, private sectors, academe, and other stakeholders in order to maximize the utility of Cryobanking facility for invitro cryoconservation of livestock and related species, as well as indigenous, wild, threatened, and endangered animal genetic traces. She has gained skills in the management and operations of the cryobank through international collaborations with Korea (through the Korean International Cooperation and through the Korean Animal Product Evaluation), Taiwan (through the Taiwan Livestock Research Institute), and with the US (through the National Center for Genetic Resources Preservation of the USDA). She obtained her BS in Biology in 2002 from Brigham Young University-Hawaii through an International Work Experience Scholarship program. She earned her MS in Marine Science with specialization in Marine Biotechnology in 2013 from the University of the Philippines Diliman (UPD) with a thesis grant from the Philippine Department of Science and Technology.

Kris WYCKHUYS is CIAT's Asia Cassava Entomologist. He is a Belgian bioscience engineer and entomologist, and has worked on insect biological control and integrated pest management (IPM) in a wide range of cropping systems: subsistence maize in Central America, soybean in the US Midwest, cotton in Northeast China, and horticultural crops in Colombia. After a two-year postdoctoral assignment at the University of Minnesota (2005–2007) and a three-year position at a Colombian national institution, he joined CIAT headquarters in 2010 and now works with CIAT's cassava program based in Hanoi, Vietnam. He aspires to work with a broad range of collaborators in Southeast Asia, promoting biological control and other IPM tactics directed against a set of invasive pests of cassava in the region. He has a PhD from Purdue University and has authored about 40 peer-reviewed publications.

John Colin YOKINGCO has been involved in research projects involving the application of GIS, flood modeling, and remote sensing techniques in rice agriculture since he joined the OML Center in 2014. He was a research assistant in the Flood Inundation Modeling Using Lidar and GIS (FIMULG) project, and is now a researcher for the Spatial Analysis of Vulnerability, Exposure, and Risk project of the OML Center. He obtained his BS in Geography from UPD. His undergraduate thesis focused on the effects of tourism on the livelihoods of the indigenous people of Subic Bay Freeport Zone in Zambales. He was also part of the team that profiled the livelihood assets of the Kalbaryo-Patapat National Park, and studied the history of coastal tourism resorts in Pagudpud, Ilocos Norte during his undergraduate field class. He has presented the results of the FIMULG project in both local and international conferences, and has co-authored a science-policy brief about the project.

Acronyms

15 MR	1 Must Do and 5 Reductions program
3G3R	Three Gains and Three Reductions
AECID	Agencia Española de Cooperacion Internacional para el Desarrollo (Spanish Agency of International Development Cooperation)
AEZ	agro-ecological zones
ALCAMS	Agroforestry Land Capability Mapping Scheme
AMS	ASEAN Member States
AnGR	animal genetic resources
APN-Capable	Asia-Pacific Network Capacity Building for Sustainable Development
AT	agricultural technologist
AU	animal unit
AusAID	Australian Agency for International Development
BMKG	Badan Meteorologi, Klimatologi dan Geofisika (Indonesia) (Meteorology, Climatology, and Geophysics Agency)
BPTP	Balai Pengkajian Teknologi Pertanian (Indonesia) (Agriculture Research and Development Division)
BSU	Benguet State University (Philippines)
BUCAF	Bicol University College of Agriculture and Forestry (Philippines)
CA	conservation agriculture
CALABARZON	Cavite, Laguna, Batangas, Rizal, and Quezon (Philippines)
CAPS	conservation agriculture production systems
CAR	Cordillera Administrative Region (Philippines)
CAT	conservation agriculture with trees
CBA	cost-benefit analysis
CC	climate change
CCA	climate change adaptation
CCAFS	CGIAR Research Program on Climate Change, Agriculture, and Food Security Agriculture
CCAM	Conformal Cubic Atmospheric Model
CCM	climate change mitigation
CENRO	Community Environment and Natural Resources Office (Philippines

CF	conservation farming
CFS	Climate Field School
CFV	Conservation Farming Village
CH	Central Highlands (region of Vietnam)
CIAT	Centro Internacional de Agricultura Tropical (International Center for Tropical Agriculture)
CSA	Climate-Smart Agriculture
CSA-PF	Climate-Smart Agriculture Prioritization Framework
CT	conventional tillage
CV	coefficient of variation
CWB	cassava witches' broom
DA	Philippine Department of Agriculture
DATE	Diagnosis, Design, Assessment, Training, and Extension
DEM	digital elevation model
DENR	Philippine Department of Environment and Natural Resources
DILG	Philippine Department of Interior and Local Government
DOH	Philippine Department of Health
DOLE	Philippine Department of Labor and Employment
DOST	Philippine Department of Science and Technology
DRRM	disaster risk reduction and mitigation
DTI	Philippine Department of Trade and Industry
E-Code	Environmental Code
ENVI	environment for visualizing images
FC	field coordinators
FGD	focus group discussion
FV	farmer volunteer
GCM	general circulation model
GHG	greenhouse gas
GIS	geographic information system
GIS ILWIS	integrated land and water geographic information system
GISS	Goddard Institute for Space Studies
GMS	Greater Mekong Subregion
GoI	Government of Indonesia
GP	good practices
GP-CCA	good-practice climate change adaptation
GPM	gross profit margin
GPR	ground-penetrating radar

ha	hectare
HH	household
HUDCC	Philippine Housing and Urban Development Coordinating Council
IAE	Institute for Agricultural Environment (Vietnam)
ICM	integrated crop management
ICT	information and communication technology
IDR	Indonesian Rupiah
IfSU	Ifugao State University (Philippines)
ILO	International Labour Organization
IPCC	Intergovernmental Panel on Climate Change
IPSARD	Institute of Policy and Strategy for Agriculture and Rural Development (Vietnam)
IRR	internal rate of return
ISARD	inclusive and sustainable agricultural and rural development
LIB	Livestock Innovations and Biotechnolgy
LiDAR	light detection and ranging
LiDAR DEM	light detection and ranging digital elevation model
LMB	Lower Mekong Basin
LWG	local working group
M&E	monitoring and evaluation
MA	municipal agriculturist
MARD	Ministry of Agriculture and Rural Development (Vietnam)
MASAP	Mekong Adaptation Strategy and Action Plan
masl	meters above sea level
MBMD	Meuang Bua municipal district
MCA	Multi-Criteria Analysis
MoA	Ministry of Agriculture (Indonesia)
MODIS NDVI	normalized difference vegetation index of the moderate resolution imaging spectroradiometer
MONRE	Ministry of Natural Resources and Environment (Lao PDR)
MRB	Mexican rice borer
MRC	Mekong River Commission
MRD	Mekong River Delta (region of Vietnam)
NAFRI	National Agriculture and Forest Research Institute (Lao PDR)
NCC	North Central Coast (region of Vietnam)
NCTL	National Component Team Leaders

NE	Northeast (region of Vietnam)
NEDA	Philippine National Economic Development Authority
NGA	national government agency
NM	Northern Mountainous (region of Vietnam)
NPCMT	National Project Component Management Team
NPK	nitrogen-phosphate-potassium
NPV	net present value
NT	no till
NTB	Nusa Tenggara Barat (West Nusa Tenggara, Indonesia)
NTT	Nusa Tenggara Timur (East Nusa Tenggara, Indonesia)
NVS	natural vegetative filter strips
NW	Northwest (region of Vietnam)
OM	organic matter
OML Center	Oscar M. Lopez Center for Climate Change Adaptation and Disaster Risk Management Foundation Inc.
PAGASA	Philippine Atmospheric, Geophysical, and Astronomical Services Administration
PAR	participatory action research
PCC	Philippine Carabao Center
PCC-CF	Philippine Carabao Center Cryobank Facility
PCF	Performance Challenge Fund
PG-ENRO	Provincial Government Environment and Natural Resources Office (Philippines)
ppm	parts per million
PHP	Philippine Peso
RCP	representative concentration pathways
RP	Republic of the Philippines
RPCMT	Regional Project Component Management Team
RRD	Red River Delta (region of Vietnam)
RWG	regional working group
SARD	sustainable agriculture and rural development
SCC	South Central Coast (region of Vietnam)
SE	Southeast region (Vietnam)
SEA	Southeast Asia
SED	standard error of the mean difference
SGLG	Seal of Good Local Governance
SHP	shape file data format

SMU	Simulation Mapping Unit
SRC	Small Ruminants Center (Philippines)
SOC	soil organic carbon
SU	Silliman University (Philippines)
SUC	state universities and colleges
ToT	Training of Trainers
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UP DREAM	University of the Philippines-Disaster Risk and Exposure Assessment for Mitigation
UPLB	University of the Philippines Los Baños
UPLB SESAM	University of the Philippines Los Baños-School of Environmental Science and Management
USD	United States Dollar
USeP	University of Southeastern Philippines
WC	WorldClim
WMO	World Meteorological Organization

A farmer tries to save his crops amidst the flooded field.
Photo by Adi Fakhrurrazy

1 Introduction

River running dry. Mang Sonny looks down onto the ground where the river used to be. The mountain behind him had been deforested, which caused flash floods into the lowland residential community. This rerouted stream flow and caused rivers to run dry. This river traversing under the Sawmill Bridge in Gabaldon, Nueva Ecija has become barren.
Photo by Jerry James M. dela Torre

Moving Ahead with Climate Change Adaptation in Southeast Asia

Percy E. Sajise[1]

Climate change is a pervasive concern of the current as well as the future generation. It threatens the very survival of what life stands for, including that of the human species. The global community is currently confronting the threat of climate change in two ways (including its various combinations): through reducing greenhouse gas (GHG) emissions and through other forms of mitigation and adaptation.

The global community is still debating on the first strategy in terms of country targets. Meanwhile, another mitigation strategy is now being implemented such that those countries with higher GHG emissions pay those countries with lower emissions; the latter, in turn, plant trees or generate biomass to reduce the level of GHG emissions in the atmosphere. However, such strategy should not be construed as a license for these high-emitting countries to continue with their current GHG emission levels.

For small farm holders and fisherfolk who have less production resources and options for livelihoods, the only available and affordable option for them to deal with this challenge is to adapt to climate change; hence, the importance of the strategies and collective lessons on climate change adaptation (CCA). The Montpellier Panel Report recommends that governments, donors, and the private sector should invest more on initiatives that would scale-up proven community-based resilient adaptation projects, particularly those projects that would enhance soil, water, and nutrient management; conservation technologies; and risk management tools (Agriculture for Impact 2015). This becomes doubly significant as the window of opportunity in addressing the climate change issue is getting narrower, especially for the most affected and most vulnerable groups.

According to the Center for Sustainable Development (2015), sustainable rural development is defined as "improving the life for rural poor by developing capacities that promote community participation and gender equality, health and education, food and nutrition security, environmental protection, and sustainable economic

---

1 Bioversity International

growth, thereby enabling community members to leave the cycle of poverty and achieve their full potential; its dimensions are human development, natural resources and environment, economic growth, infrastructure, science and technology, and policy and administration."

CCA is a means of achieving sustainable rural development. This is also well-elucidated in the context of the recently launched UN 2030 Sustainable Development Goals, which is the continuation of the Millennium Development Goals after 2015.

Based on the above premises, this climate change book provides a collection of actual cases of how this CCA strategy is being implemented in Southeast Asia. It illustrates cases in the Philippines, Vietnam, Cambodia, Thailand, and Indonesia involving various hierarchical levels—from regional, subregional, country, village, to farm levels. It describes the enabling or constraining environments, methods, and processes of how CCA has been developed at one hierarchical level, and subsequently translated at other levels and scales.

This book is a good reference material for researchers, policy makers, NGOs, and development and extension workers involved in pursuing climate change concerns (in particular) and sustainable development (in general).

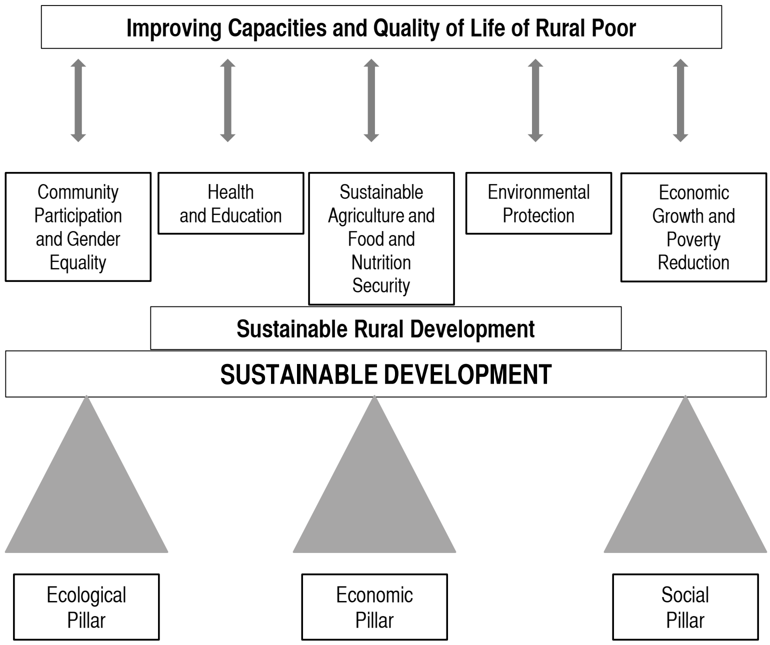
FRAMEWORKS

Sustainable Rural Development

Figure 1 shows the framework on sustainable rural development. At the core of this framework are the three pillars or anchors that support rural sustainable development, defined as follows:

1. *Economic pillar* refers to development that is sustained, inclusive (leaves no one behind) and equitable, while promoting poverty alleviation;
2. *Ecological pillar* refers to development that is sustainable, resilient, and ecosystem-conserving; and
3. *Social pillar* refers to development that is people-centered, gender-sensitive, human rights-based (especially on the rights of access to food), and one that promotes good governance and effective enabling institutions.

Figure 1. Framework on sustainable rural development



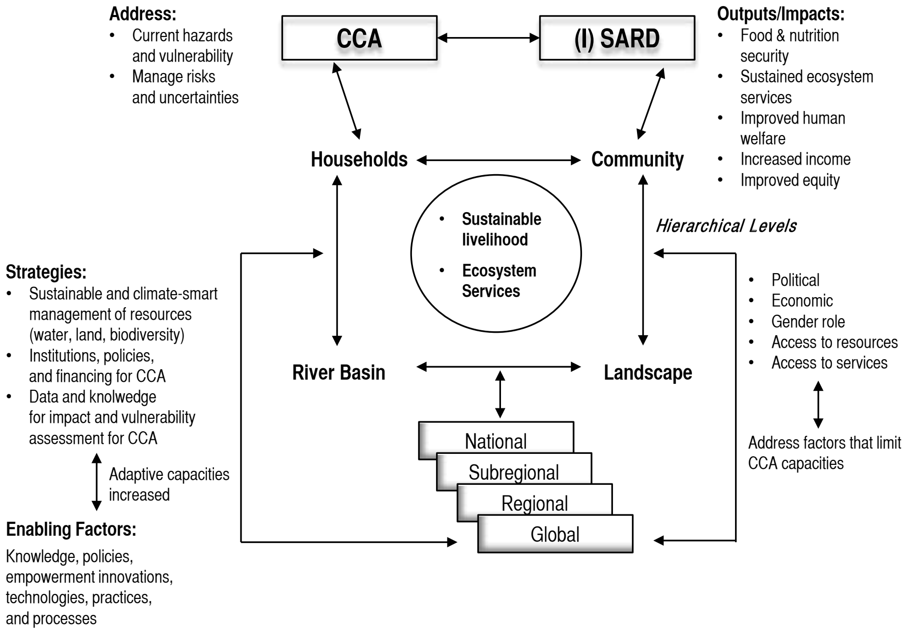
In this framework, the five common areas or conditions that help improve the capacities and quality of life of the rural poor are (1) community participation and gender equality, (2) health and education, (3) sustainable agriculture and food and nutrition security, (4) environmental protection, and (5) economic growth and poverty reduction.

Integrating Climate Change Adaptation and Inclusive and Sustainable Agricultural and Rural Development

There are several modes to achieve sustainable rural development, and this includes CCA that impinges on the five areas earlier indicated. CCA refers to “adjustments that society or/and ecosystems make to limit negative impacts of climate change, as well as taking advantage of opportunities that it creates” (VCCAR 2016).

This definition will be used in further discussing the case stories on CCA in inclusive and sustainable agricultural and rural development (ISARD) included in this book. The framework used in analyzing the different case stories is a combination of frameworks used in sustainable agriculture and rural development (SARD) and by Cancun and Oxfam (Figure 2).

Figure 2. Integrated framework using SARD, Cancun, and Oxford frameworks



Note: CCA = climate change adaptation; (I) SARD = (inclusive and) sustainable agricultural and rural development

So how do the two concepts of CCA and ISARD come together?

In the proposed framework, CCA addresses current hazards and variability while managing risks and uncertainty. Meanwhile, ISARD have outputs and impacts based on food and nutrition security, sustained ecosystem services, improved human welfare, increased income, and improved equity.

One cannot exist without the other, and the interplay of CCA and ISARD brings about the overarching goals of promoting sustainable livelihood and maintaining ecosystem services.

In terms of hierarchical levels of implementation or action, the CCA and ISARD case studies can operate under the first layer of four hierarchical levels, namely, (1) households, (2) communities, (3) river basins, and (4) landscapes. On top of the first layer is the second layer of hierarchical levels of project implementation composed of (1) national, (2) subregional, (3) regional, and (4) global. Nonetheless, a case study that operates on the second hierarchy (e.g., global or national levels) must still reflect its impacts down to the community and household levels because the interplay of factors that can limit adaptation capacities such as political, economic, gender role, resource access, and service access are present across both layers of the hierarchy.

Meanwhile, there are several enabling factors that can help to increase adaptive capacities, such as knowledge, policies, empowerment, innovations, technologies, practices, and processes. These enabling factors help to achieve strategies for adaptation that include (but are not limited to) the following:

1. Sustainable and climate-smart management of natural resources (water, land, biodiversity);
2. Institutions, policies, and financing for CCA; and
3. Data and knowledge for impact and vulnerability assessment for CCA.

Each case study provides a summary that identifies the scales covering a specific or set of different hierarchical levels within the scope and limits of the research implementation, how they are interconnected to the context of the three pillars of sustainable rural development, and the enabling or constraining factors, including the type of CCA intervention or strategy to help achieve the intended outcomes.

Providing context to a study is very important. In many cases, a strategy is viewed as a silver bullet that can be applicable in addressing issues across different environments and for every stakeholder. Experience shows that this may not be always true because the context where the strategy can work is not the same as that where the study lessons are applied.

For example, promoting farmer visits in research extension and information campaign is essential as a research methodology. However, researchers need to be careful in implementing this on the ground, as this strategy should be applied within the correct context in order to achieve positive results. If not done properly, then a farmer stakeholder may pick up a method, apply it back to their farms, and become dissatisfied with the process should it be unsuccessful mainly due to the lack of proper appreciation of context-based methodologies. The context of the various CCA covered in this book are described and included in the summary discussions (Appendix Table 1 will be appended in Part 3: Synthesis).

Overall, this framework also hinges on the theory of change, in which selected key factors bring about desired changes for a target audience when implemented under a clear context.

REFERENCES

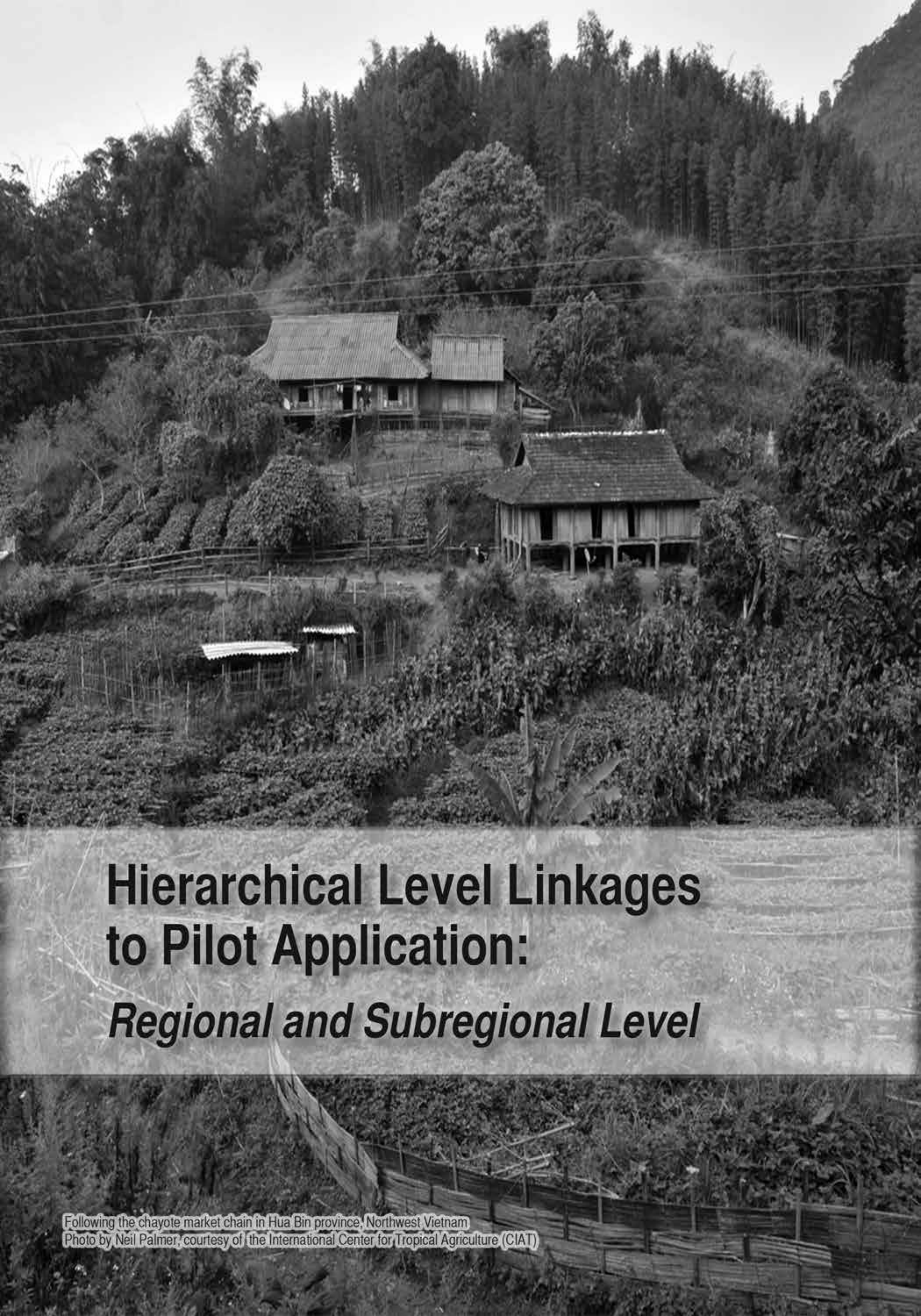
Agriculture for Impact. 2015. *The Farms of Change: African Smallholders Responding to an Uncertain Climate Future*. Imperial College, London, UK: Agriculture for Impact.

Center for Sustainable Development. 2015. “What is Sustainable Rural Development?” Accessed 2 December 2015. http://www.csd-i.org/sustainable-rural-development

VCCAR (Victorian Centre for Climate Change Adaptation Research). 2016. “Climate Change Adaptation Definitions.” Accessed 2 December 2015. http://www.vcccar.org.au/climate-change-adaptation-definitions

A vegetable farmer tending to his nursery in Benguet, Philippines
Photo by Robert Anton Aparente

2 Case Stories of Climate Change Adaptation in ISARD



Hierarchical Level Linkages to Pilot Application:

Regional and Subregional Level

Following the chayote market chain in Hua Bin province, Northwest Vietnam
Photo by Neil Palmer, courtesy of the International Center for Tropical Agriculture (CIAT)

CASE STORY 1

Battle of the Crops

Who Will Win and Who Will Lose in the Coliseum of Climate Change?

Anton Eitzinger[1], Peter Läderach[1], Linh Giang Tuan[1], Ammapet Ramaraj[1], Kennedy Ng'ang'a[2], and Louis Parker[1]

ABSTRACT

There is a need to understand how climate change can affect agriculture in the Greater Mekong Subregion (GMS). Determining which crops are the most vulnerable, where new opportunities can emerge, and where these crops are located are pressing issues that need to be immediately addressed. The scientists at the International Center for Tropical Agriculture (CIAT) have assessed the impact of climate change by 2050 on 28 crops that are vital to the food security in the GMS. The selected crops include rice, which is the major staple in the region, and other subregionally important cash crops such as rubber and coffee.

Certain crops have been identified as "winners" under the projected climate change scenario. Cassava, pigeon pea, groundnut, and coconut are notable examples, as they would respond well to the projected changes in climate; the areas suitable for production of these crops are projected to increase.

A number of "loser" crops have also been identified, notably, maize, coffee, common bean, and potato; the suitable area for the production of these crops are projected to decrease.

This study does not attempt to make recommendations on the future production of rice. The crop model used in this study focuses on rainfed agriculture; therefore, it is limited in its capacity to project changes in the suitable areas of rice, which is a crop often irrigated in Southeast Asia (Mutert and Fairhurst 2002). For example, in Vietnam, 54 percent of total rice area is irrigated, whereas 23 percent of total rice area in Thailand is irrigated (Mutert and Fairhurst 2002). Nonetheless, previous studies have found that rice would likely be negatively affected by climate change, with irrigated rice particularly hard hit (Nelson et al. 2009).

---

1 International Center for Tropical Agriculture
2 Agro Climate Research Centre, Tamil Nadu Agricultural University, Coimbatore, India

In this study, the results of the analysis of the normalized difference vegetation index of the moderate resolution imaging spectroradiometer (MODIS NDVI) images for 2001 and 2012 were integrated into the broader context of land-use change in the region. This approach enabled a holistic and inclusive understanding of the challenges facing the GMS.

The results of the study provide an insight into which crops are particularly vulnerable to and which crops will benefit from climate change. The findings provide a means for policy makers, researchers, farmers, and the private sector to identify and prioritize the relevant climate change adaptation (CCA) measures to help ensure inclusive and sustainable agriculture and rural development (ISARD) in the GMS. The results are spatially explicit and provide insights into which crops may be most affected, and where these crops are located. The development of the suitability maps should be taken as an important first step in assessing what events are likely to occur in the future.

The impact of pests and diseases on crop production needs to be further studied. Likewise, further research needs to be conducted on how these changes in the areas of production will affect people's livelihoods and the economies in the region. To ensure that farming systems in the GMS remain competitive, sustainable, and productive under progressive climate change, initiatives toward this end need collaboration among governments, the private sector, farmers and farmer cooperatives, research organizations, and climate finance actors.

This study, conducted at the subcontinental scale, provides an opportunity for different actors to come together and identify which crops are most vulnerable to climate change and where the impacts of climate change may be most severe. Accordingly, the most at-risk communities could also be identified. Response mechanisms could thus be established, and CCA measures could be implemented to ensure that communities have the capacity to respond to the threats that climate change imposes.

THE GREATER MEKONG SUBREGION

Climate Change in the Greater Mekong Subregion

The Greater Mekong Subregion (GMS) is an area of vast ecological, economic, and cultural importance. The impacts of climate change (e.g., higher temperatures, increases in the frequency and intensity of drought events, and altering precipitation patterns) pose a serious threat to the region. The agriculture sector is of utmost concern primarily because the sector is highly sensitive to climatic changes. The effects of climate change are not limited to the future; they are a present concern such that its impacts are already being felt in the GMS, and small-scale farmers are feeling the brunt of this pressure.

The climate is already changing. As noted by the Intergovernmental Panel on Climate Change (IPCC), mean temperature in the GMS has increased by 0.5–1.5 °C since 1950 (Solomon et al. 2007). The continued impacts of climate change are likely to be most challenging for the poorest communities of the GMS, who rely on agriculture to sustain their livelihoods, and who have limited economic capacity to respond to reductions in productivity.

The GMS is an area that possesses vast natural wealth. It encapsulates a diverse array of ecological zones, including highland and dryland ecosystems, rainforest, and wetlands. The Mekong River heavily influences the physical characteristics of the GMS, as well as the socioeconomic, cultural, and political fabric of the region. From its source, which is located in the Tibetan highlands of Southeast China, the river passes through Myanmar, Lao People's Democratic Republic (PDR), Thailand, and Cambodia before it reaches its final destination in Vietnam. The Mekong River has a length of approximately 4,889 kilometers (km). For the riparian nations, the river acts as a geographical border; for roughly 73 million inhabitants, it is a primary source of livelihood (CICP 2010).

Forest habitats are found throughout the GMS. However, several studies have noted widespread deforestation, primarily due to the intense pressure from agricultural expansion, population growth, and encroachment from urbanization. Nonetheless, large forest areas remain, with Lao PDR, in particular, possessing some of the most abundant primary forest. Furthermore, efforts are underway in Vietnam to reforest those previously degraded and deforested areas.

One focus of this study is to assess the changes in land use in the region from 2000 to 2012. This is an important step in understanding what land-use changes have occurred, and which areas have been most affected.

The GMS is also a melting pot of different ethnic groups, languages, and cultural practices; the culture between and within each country are widely diverse. In Vietnam alone, there are 54 different ethnic groups. A recent census in Lao PDR calculated a total of 49 different ethnic groups and more than 160 subgroups, whereas there are 70 ethnic groups in Thailand. The same diversity of people and cultures can be found across the GMS (ADB 2012).

The GMS is a dynamic region characterized by high levels of economic growth. Over the past five years, Cambodia, Lao PDR, and Vietnam have recorded annual GDP growth rates exceeding 5 percent per year (Trading Economics 2016a). The population of the GMS also continues to increase, with Vietnam recently passing the 90 million mark, thus placing it as the world's 14th most populous country (Trading Economics 2016c).

Despite rapid developmental changes in the region, agriculture remains an important sector of the economy and for the maintenance of livelihoods. In Lao PDR, over 70 percent of the population is employed in agriculture, whereas agricultural population in Thailand still occupies over 30 percent of the workforce. Agriculture in the region is important economically, socially, and culturally. Vietnam, for example, has established itself as an emerging agricultural powerhouse (Trading Economics 2016b). The country now sits as the second largest global producer of coffee behind Brazil. It also produces large amounts of cashew, rice, tea, and rubber (FAOStat 2014). Climate change, therefore, would have severe repercussions to the communities in the GMS who rely on agriculture to sustain their diets and incomes.

THE CLIMATE CHANGE ADAPTATION STRATEGY

Understanding how climate change can impact agricultural systems is essential in designing and developing regionally specific and long-term adaptation and mitigation strategies that will enhance farmers' resilience and secure livelihoods. It is an issue that requires immediate attention—one that is complex and is determined by the interaction of environmental, economic, social, and cultural forces.

One way by which the impacts can be assessed is through the application of crop modeling and land-use change analysis via a geospatial lens. Using geographical information systems (GIS) provides a powerful means to compile, assess, model, and analyze large sets of data in order to answer spatial and temporal questions. Furthermore, the software, packages, and data are increasingly open source and are easily accessible.

This report provides a means for stakeholders, policy makers, and researchers to better understand how the impacts of climate change can be assessed through some of the available tools that are capable of evaluating such phenomenon before the projected impacts of climate change on the key crops in the GMS are presented. This study is related to a number of modeling exercises that have been conducted by the International Center for Tropical Agriculture (CIAT) in Africa (AGRA 2014), in which the impacts of climate change on cassava and beans were analyzed. Further studies have been conducted in Latin America at varying scales, with focus on which crops are the most vulnerable to climate change, and how this may affect farmers' capacity to continue with their current cropping systems.

Description of the Adaptation/Tools Used

Historic Climate Analysis. The TS 3.10.01 (CGIAR 2015) climate data set was downloaded from the Climate Research Unit (University of East Anglia) with a resolution of roughly 55 km × 55 km per grid cell.

Crop Modeling. EcoCrop, a simple climatic niche model, was used in this study to assess the climatic suitability of 28 key crops in the GMS.

Land-Use Change Analysis. Satellite data from the normalized difference vegetation index of the moderate resolution imaging spectroradiometer (MODIS NDVI) was used to identify the land-use change in the region.

This section outlines the tools and data sets that were used in the analysis. It provides the reader with a general understanding of the types of available resources, with reference to where they can be acquired and the associated costs.

Humanity currently stands in a unique point in history such that available technology can provide new means of analyzing data and understanding our environment. This study utilizes some of these new and innovative technical capacities that would not have been possible 10 years ago.

How has the climate in the GMS changed over the last century?

This was the first question that was asked as part of the study. In order to shed light to this question, past climate trends and climate variability were analyzed. Due to the improvements in data storage and analysis resulting from the ubiquitous influence of digital technology and the profound capacity of scientists to explore huge data sets, past changes in climate can now be modeled. Accordingly, the TS 3.10.01 (CGIAR 2015) climate data set was downloaded from the Climate Research Unit with a resolution of 0.5 × 0.5 degrees (roughly 55 km × 55 km per grid cell). There was no monetary charge for collecting this data set, and it can be downloaded in various formats suitable for analysis in Microsoft Excel or GIS.

EcoCrop, a simple climatic niche model (Ramirez, Jarvis, and Laderach 2013), was used to assess the current and future suitability of 28 key crops in the GMS. The model is operated through the freely available R-software (R-Project 2015), which is available in a script format. The strength of EcoCrop is that it has modest data requirements, and thus can be used at the local, regional, national, continental, and global scales.

The climate data for current (i.e., 1950–2000) and future conditions (Hijmans et al. 2005) was downloaded from WorldClim (WC) at a resolution of 5 km × 5 km. WC provides interpolated global climate surfaces using latitude, longitude, and elevation as independent variables; it presents long-term (i.e., 1950–2000) monthly means of maximum, minimum, and mean temperatures as well as total rainfall. Input data for the WC database was sourced from global weather stations, including approximately 47,000 weather stations with monthly information on precipitation; about 23,000 stations with mean temperature data; and 13,000 locations. The future climate data was derived from the *IPCC 5th Assessment Report* through the Coupled Model Intercomparison Project Phase 5 and the Representative Concentration Pathway 8.5. This is often referred to as the “business-as-usual” projection. The data is downscaled and processed to the same extent as the current climate data, and therefore enables model integration.

The increased accessibility and reduced costs of satellite data provide researchers with a huge archive of images by which the environment can be assessed. The researchers took this opportunity at CIAT, thus enabling them to conduct a land-use change analysis for the GMS.

Using MODIS NDVI images for the period 2001–2012, which were analyzed through the environment for visualizing images (ENVI) and ArcGIS tools, the researchers were able to quantify the changes in the forest cover, agricultural area, plantations, and savannah habitats of the GMS. In total, 300 NDVI files (at a resolution of 250 meters and corresponding to an image taken every 16 days) placed the crop suitability findings within a wider landscape approach.

OUTCOMES OF THE INTERVENTION

Based on the results, cassava, pigeon pea, groundnut, and coconut have been identified as the "winner" crops. These crops are projected to be resilient to climate change. In particular, cassava—which is hardy, resilient to temperature increases, and highly tolerant to drought—displays many characteristics that would ensure it to be a winner under climate change.

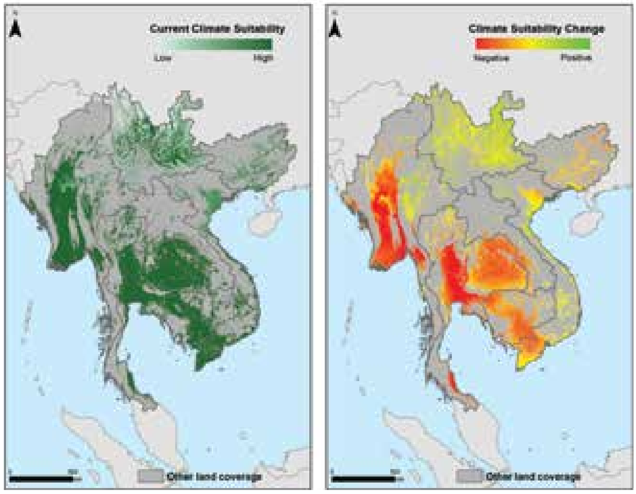
The "loser" crops identified were maize, coffee, common bean, and potato, which are susceptible to temperature increases. These crops may no longer be suitable in certain areas of the GMS if adaptation measures are not integrated into the current farming practices.

Temperatures have increased in the GMS over the last century, and this notion is supported by the findings of IPCC (Solomon et al. 2007). Likewise, land-use change is occurring in the GMS. From 2000 to 2012 alone, there have been some marked changes in how the land is being used in the region. Notably, the total area dedicated to agriculture has increased by roughly 8 million hectares (ha). Moreover, forest/tree plantations have expanded by roughly 15 million ha.

In this study, a total of 28 crops integral to the food security in the GMS were modeled and analyzed. Certain crops (i.e., cassava, pigeon pea, ground nut, and coconut) are projected to be highly resilient to climate change, with minimal reductions in suitability and distribution against the current conditions. Meanwhile, a number of crops (i.e., maize, coffee, common bean, and potato) would suffer substantial reductions in suitability under climate change.

Maize is projected to be one of the main "loser" crops in the GMS under the climate change scenario (Figure 1.1). Currently, it is grown on roughly 3 million ha in the GMS, and is an important crop for human consumption and for export.

Figure 1.1. Maize: Projected change in climatic suitability



Current Climate Suitability
and Potential Maize Distribution

Predicted Climate-Suitability
Change for Maize by 2050
(ave. of 32 GCMs from RCP 8.5)

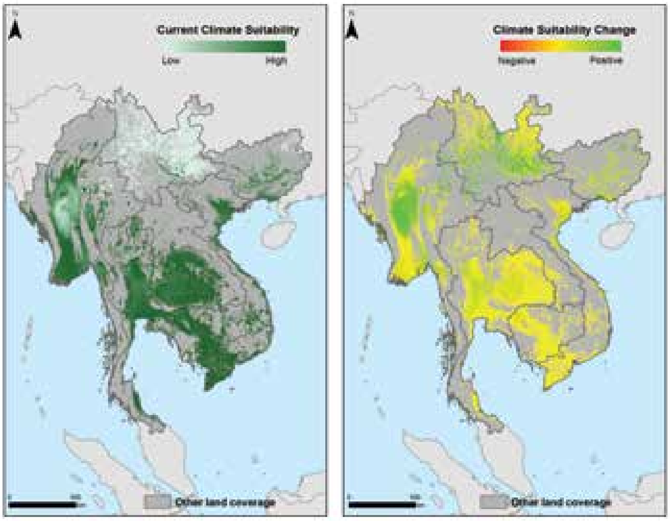
Note: GCM = general circulation model; RCP = representative concetration pahtways

In 2011, maize was one of the top ten commodity crops in terms of export quantity (FAOStat 2013) in Cambodia, Lao PDR, and Myanmar (29,945 metric tonnes; 202,947 metric tonnes, and 123,700 metric tonnes, respectively). The projected reductions in maize suitability are widespread across the GMS. Consequently, the impacts of climate change on maize production are projected to be severe and geographically widespread across the GMS. Many farmers may be affected, and this could have severe impacts on the incomes and livelihoods of GMS farmers.

Coffee is another important crop in the GMS as it provides significant economic contributions to farming communities in the Central Highlands of Vietnam and in the southwestern regions of Lao PDR. The projected climate change impacts will be detrimental to farmers, and will require adaptation measures to ensure that coffee yields in the region will not decrease. The climatic suitability of coffee is projected to decline in the Central Highlands of Vietnam; this region accounts for 95% of the coffee growing area of the country (ISLA 2015).

Nevertheless, not all crops are expected to suffer under progressive climate change. Cassava (Figure 1.2) is one crop that is projected to be the leading “winner.” This hardy crop responds well to higher temperatures, and is projected to benefit from the changes in climate, particularly in the cooler regions where temperatures are expected to rise. This is noticeable in the northern areas of the GMS, particularly the Yunnan province, where the current climatic conditions are not conducive for cassava production. Under the projected climate change and the increase in temperature, cassava production would likely expand.

Figure 1.2. Cassava: Projected change in climatic suitability



Current Climate Suitability and Potential Cassava Distribution

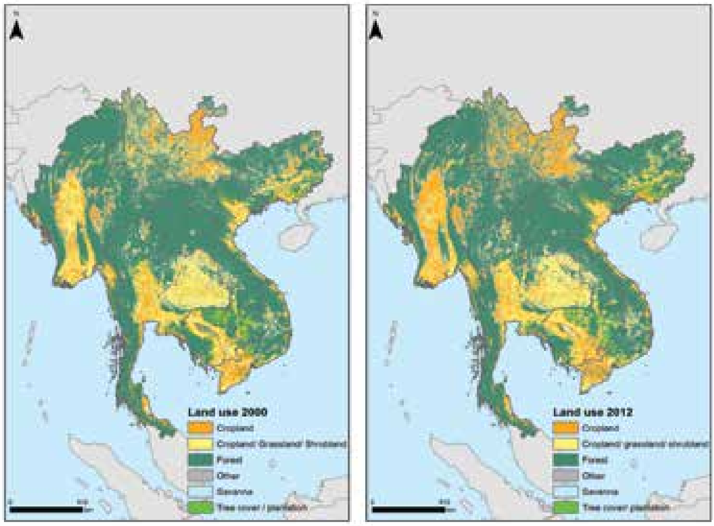
Predicted Climate-Suitability Change for Cassava by 2050 (ave. of 32 GCMs from RCP 8.5)

Cassava is an important cash crop as it is used for feed, industrial purposes, biofuel, and human consumption (in some regions). It is currently grown on about 2 million ha across the GMS. From 2000 to 2011, the area of cassava production increased by more than 580,000 ha. In 2013, dried cassava (FAOStat 2014) was one of the top ten export commodities of Cambodia, Thailand, and Vietnam in terms of quantity (59,952 metric tonnes, 5.8 million metric tonnes, and 1.7 million metric tonnes, respectively) and in terms of value (USD 13.6 million, USD 1.3 billion, and USD 363 million, respectively).

The analysis of historic climatic trends done in this study revealed that the temperature in the GMS had risen between 1.8°C and 20°C from 1901 to 2009, which supports the findings of the IPCC report (IPCC 2007). Furthermore, in the last decade, the mean, maximum, and minimum temperatures have been higher than those in the past decades. The annual precipitation data for the period 1901–2009 show enormous variability between years and between decades. The maps reveal the high trend for inter-decadal variability.

Land-use changes are occurring across the GMS (Figure 1.3). Over the years, the area for agricultural production has expanded to approximately 8 million ha, and the areas of homogeneous tree cover/plantations have likewise increased to about 15 million ha. Lands in the region have been converted into plantations partly due to the increasing rubber plantations in Lao PDR. However, this conjecture requires more detailed analysis of remote sensing data, supported by on-the-ground truth checking. Such analysis will show how a landscape analysis can provide means for further research gateways.

Figure 1.3. Land-use change, 2000 and 2012



POLICY RECOMMENDATIONS FOR FUTURE CLIMATE CHANGE ADAPTATION

The following points are the recommended courses of action for the development of future CCA strategies:

1. The development of suitability maps can be the first step in assessing the possible scenarios of climate change. Likewise, the specific impacts of such changes on the livelihoods of people, economies, and occurrence of pests and disease need to be further studied.
2. The costs, benefits, and trade-offs of possible climate change adaptation strategies have to be assessed carefully.
3. Climate change adaptation has to involve the entire sector, including governments (policies and strategies), private sector (market information and adaptation support), farmers and cooperatives (adaptation in the field), research institutions (guiding adaptation), climate finance funds (support adaption), etc.
4. The list of crop "winners" and "losers" could be used to inform decision making at various institutional levels. For the benefit of the Mekong River Commission, the results of the study can help policy makers across the GMS. As such, stakeholders need to collaborate and determine which regions and crops are most vulnerable to climate change, and to prioritize their targets accordingly. Such information can then help influence CCA formulation at the local scale.

SUMMARY OF LESSONS AND THE WAY FORWARD

The "winner" crops (i.e., cassava, groundnut, coconut, pigeon pea) are those crops that would remain suitable under future climate conditions. In particular, cassava provides a "go-to" crop when high temperatures, poor soil quality, and adverse conditions characterize an area. CIAT has undertaken substantial work into its capacity to succeed under climate change, and this study further supports the potential benefits that the crop can provide for the GMS. A number of crops have been found to be less favorable under climate change projections; these crops have been identified as potential "losers" (i.e., maize, coffee, common bean, and potato).

Coffee is a crop that generally responds poorly to temperature increases. As such, coffee production would likely move to areas with higher elevation in response to the need to maintain cooler climatic conditions for its production. A recent study by CIAT in Central America has identified that coffee production would have to move to higher elevations in order to maintain the current level of production. As such, conducting a similar study in the GMS would provide important insights into the potential elevational changes in coffee production, and if such changes are possible in the region.

Note that this study was conducted at the subcontinental scale because the general patterns and trends in the GMS need to be identified. Nonetheless, the tools and models used in this study can still be employed at the local, regional, and national scales as highlighted in previous studies.

Furthermore, there is the potential to integrate additional data. At present, the analysis conducted in this study has focused on the climatic niches of the 28 key crops and on how these niches would change under progressive climate change. However, climate does not solely determine where and which crops are grown; such decisions are also based on economic, political, and cultural decisions. Although modeling such factors is complex, it is still feasible to study the integration of social preferences. For example, understanding which crops are grown based on the social preferences of the local people will be important in planning for climate change. It can also help researchers and breeders in identifying potential new gateways to ensure that these crops remain viable in the future.

It is also feasible to gather additional biophysical data in order to increase the robustness of the study, such as integrating soil data into the analysis.

Finally, integrating spatial data on pests and diseases is another avenue that could be incorporated into the analysis. In particular, research on the impacts of mealybug on cassava production and how this could reduce the viability of the crop under future climate conditions (CIAT 2013) would be an interesting and useful addition to the current study.

The results of this study can be shared with partners and researchers who work at the field and farm levels. Local-level practitioners and farmers, who are trying out new seeds, techniques, and methods, will also benefit from this study as the results will help them to understand how their work is placed within a broader landscape.

This study can also benefit ongoing research on maize and intercropping, particularly those studies that focus on the integration of maize and cassava systems; this study will help increase farmers' resilience to climate changes. Planting cassava with maize can enable farmers to have an alternative if the temperature changes result in reduction in maize yields.

Furthermore, the successes of other crops, such as groundnut and coconut, could provide agronomists with new pathways for determining which crops can be integrated into the current maize systems, provide increased resilience to climate change, identify a more diversified diet, and identify potential ways to increase farmers' income.

The results of this study infer that farmers need to adapt to climate change. However, the types of adaptation measures will be spatially heterogeneous and will be determined by the different challenges and the pressures incurred. The impacts of climate change will vary spatially, and the changes in cropping systems will be heterogeneous. They will be determined by the climatic, biophysical, and socioeconomic phenomena, with regional variations both within and between the countries of the GMS.

Stakeholders and policy makers need to be flexible in responding to the impacts of climate change. They need to adapt their current practices and decision-making processes, as well as ensure that climate change will be integrated into the development agenda.

Humanity currently stands at a pivotal moment, whereby changes in the climate threaten some of the region's key crops. Ensuring that the production systems of maize and coffee will remain productive will require a collaborative effort from scientists, crop breeders, farmers, government organizations, policy makers, and stakeholders.

There is a wealth of information available and a vast store of knowledge held by—but not exclusively contained within—networks of farmers and scientists that can enable current cropping systems to flourish under climate change. However, this may require information sharing not just horizontally between the same groups, but vertically between all the different actors and players in the agriculture sector.

ACKNOWLEDGMENT

This study was supported by the CGIAR Program on Climate Change on Agriculture and Food Security (CCAFS) and was undertaken to help understand the likely impacts of climate change in the Greater Mekong Subregion.

REFERENCES

ADB (Asian Development Bank). 2012. *Greater Mekong Subregion Atlas of the Environment, 2nd edition*. Manila, Philippines: ADB.

AGRA (Alliance for a Green Revolution in Africa). 2014. *Africa Agriculture Status Report: Climate Change and Smallholder Agriculture in Sub-Saharan Africa*. Nairobi, Kenya: AGRA.

CGIAR (Consultative Group for International Agricultural Research). 2015. "Historic Climate Database for GIS." Accessed 16 April 2015. http://www.cgiar-csi.org/data/uea-cru-ts-v3-10-01-historic-climate-database

CIAT (International Center for Tropical Agriculture). 2013. "Clamp-Down Launched on Devastating Threats to Starch Crop." Accessed 17 April 2015. http://ciatblogs.cgiar.org/support/mealybugs-pose-threat-to-cassava/

CICP (Cambodian Institute of Cooperation and Peace). 2010. "An Introduction to Greater Mekong Subregional Cooperation." *CICP Working Paper* No. 34. Phnom Penh, Cambodia: CICP.

FAOStat. 2013. "Export Quantity of Maize in 2011, Cambodia, Lao PDR, and Myanmar." Accessed 22 February 2016. http://faostat.fao.org/site/535/DesktopDefault.aspx?PageID=535#ancor

——. 2014. "Food and Agricultural Commodities Production." Accessed 16 April 2015. http://faostat.fao.org/site/339/default.aspx

Hijmans, R.J., S.E. Cameron, J.L. Parra, P.G. Jones, and A. Jarvis. 2005. "Very High Resolution Interpolated Climate Surfaces for Global Land Areas." *International Journal of Climatology* 25(15): 1965–1978.

IPCC (Intergovernmental Panel on Climate Change). 2007. *Climate Change 2007: Synthesis Report*. Cambridge, UK: Cambridge University Press.

ISLA (Initiatives for Sustainable Landscapes). 2015. "Central Highlands – Vietnam." Accessed 22 February 2016. http://www.landscapesinitiative.com/en/highlands---vietnam

Mutert, E., and H.T. Fairhurst. 2002. "Development in Rice Production in Southeast Asia." *Better Crops International* 15: 12–17.

Nelson, G.C., M.W. Rosegrant, J. Koo, R. Robertson, T. Sulser, T. Zhu, C. Ringler, S. Msangi, A. Palazzo, M. Batka, M. Magalhaes, R. Valmonte-Santos, M. Ewing, and D. Lee. 2009. *Climate Change: Impact on Agriculture and Costs of Adaptation*. Washington, D.C., VA: International Food Policy Research Institute.

R-Project. 2015. "The R-Project for Statistical Computing." Accessed 16 April 2015. http://www.r-project.org/

Ramirez-Villegas, J., A. Jarvis, and P. Laderach. 2013. "Empirical Approaches for Assessing Impacts of Climate Change on Agriculture: The EcoCrop Model and a Case Study with the Grain Sorghum." *Agriculture and Forest Meteorology* 170: 67–78.

Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller, eds. 2007. *Climate Change 2007: The Physical Science Basis*. Working Group I Contribution to the Fourth Assessment Report of the IPCC, Vol. 4. Cambridge, UK/New York, NY: Cambridge University Press.

Trading Economics. 2016a. "GDP Annual Growth Rate, Asia." Accessed 18 February 2016. http://www.tradingeconomics.com/country-list/gdp-annual-growth-rate

——. 2016b. "Population, Asia." Accessed 18 February 2016. http://www.tradingeconomics.com/country-list/population

——. 2016c. "Vietnam GDP Growth Rate, 2000–2016." Accessed 18 February 2016. http://www.tradingeconomics.com/vietnam/gdp-growth

World Bank. 2015. "GDP Growth (Annual %)." Accessed 16 April 2015. http://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG

World Bank, CIAT, and CATIE (The Tropical Agricultural Research and Higher Education Center). 2014. "Climate-Smart Agriculture in Argentina." *CSA Country Profiles for Latin America Series*. Washington, D.C.: The World Bank.

You, L., U. Wood-Sichra, S. Fritz, Z. Guo, L. See, and J. Koo. 2014. "Spatial Production Allocation Model (SPAM) 2005 v2.0." Accessed 16 April 2015. http://mapspam.info

Agriculture in Mekong River bank
Photo by Chhut Chheana

CASE STORY 2

Ensuring Food Security in the Lower Mekong Basin

Nguyen Dinh Cong[1]

ABSTRACT

The population of the Lower Mekong River Basin (LMB) is estimated to be over 60 million, a large proportion of which have livelihoods that depend on the river system. Over 60 percent of the economically active population in the LMB has occupations that are vulnerable to water-related shocks and degradation due to climate change, thereby threatening the food security in the region. Currently, the Mekong River Commission (MRC) is developing climate change adaptation (CCA) strategies for the whole basin. As part of the development process, three CCA options have been evaluated through the successful pilot implementation of the options. The implementation results show that the proposed CCA framework is feasible and can be effective in addressing the threats to food security that climate change poses in the LMB. Based on the evaluation results, project implementers need to work with local farmers to develop local and evidence-based adaptation strategies that will integrate the villagers' actual practices in response to the impacts of climate change. There is a huge probability that local farmers would adopt and continue the proposed strategies when they themselves develop their own CCA measures. In this case story, a number of recommendations are also made toward this end.

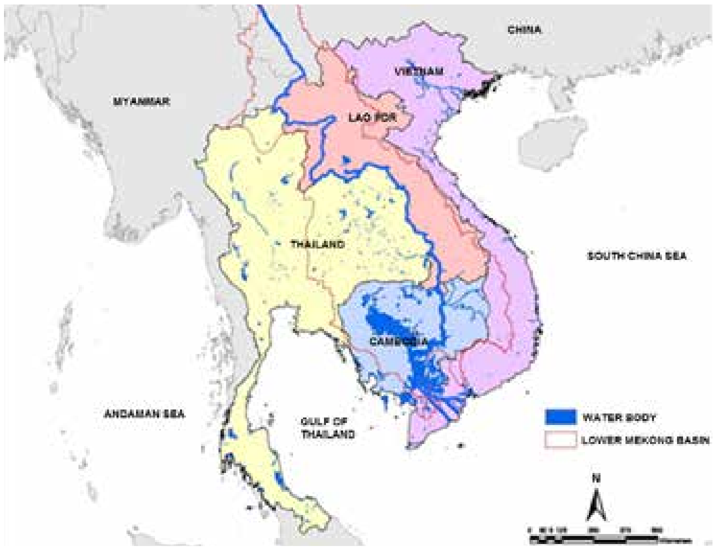
INTRODUCTION

Mekong River is one of longest rivers in the world, with length of approximately 4,800 kilometers. It starts from the Himalayas of China, and then flows from the north to south direction before it reaches its final destination into the sea in Vietnam. The Lower Mekong Basin (LMB) (Figure 2.1) is approximately 795,000 square kilometers; it covers majority of the land area of Lao People's Democratic Republic (PDR) and Cambodia, the Northern and Northeast regions of Thailand, and the Mekong Delta and Central Highland regions of Vietnam (MRC 2011b).

---

1 Agriculture and Irrigation Program, Mekong River Commission

Figure 2.1. The Lower Mekong Basin



The Mekong River Commission (MRC) is an intergovernmental body responsible for the coordination of the development efforts and sustainable management of the Mekong Basin. It was established in 1995 through an agreement signed by its four member countries, namely, Cambodia, Lao PDR, Thailand, and Vietnam. The MRC has two dialogue partners: China and Myanmar.

The Commission looks at all the sectors within the basin, such as fisheries sustainability, agricultural opportunities, navigation, flood management, environment preservation, etc. In order to fulfill its mandates, the MRC facilitates a broad range of dialogues among governments, the private sector, and civil society groups.

According to Yusuf and Francisco (2009), the Mekong River Basin is one of the areas in the world that is most vulnerable to climate change. It is highly vulnerable to the damages that severe drought and flooding, sea level rise, and temperature increases can cause. Consequently, each Mekong country has issued relevant national policies and action plans in response to the threats imposed by climate change. A number of adaptation activities have been initiated and several others are currently being implemented.

However, the question that needs to be answered is *"What can be done in the LMB at the regional level in terms of climate change adaptation?"* The *State of Mekong Basin Report* presented a recent study that used the climate general circulation model to develop future climate scenarios for 2030. The result showed the following:

1. Temperature will increase by 0.79°C in the whole Mekong Basin by 2030, with greater increases (from 0.68°C to 0.81°C) in the colder catchments located in the north of the basin.

2. Annual precipitation will increase by 200 millimeters (mm) or by 13.5 percent by 2030. This increase will predominantly manifest during the wet season, ranging from 3 mm to 360 mm.
3. Flood incidents in all parts of the basin will increase by 2030. The downstream catchments within the mainstream of the Mekong River will be the most affected (MRC 2010).

Overview of the Lower Mekong Basin

In 2007, the population of the Lower Mekong River Basin was estimated to be 60 million. This figure indicates that the overall population in the region has increased by about 12 percent since 2003 at 55 million, although the trends vary between countries. The LMB population has increased by 25 percent in Cambodia, by about 6 percent in Lao PDR, remained the same in Thailand, and increased by about 10 percent in Vietnam. The percentage of population and territory within the basin vary between countries. Cambodia and Lao PDR lie largely within the basin, but together comprise only 30 percent of the basin population. The basin territory in Thailand is only 37 percent of the country, and comprises about 39 percent of the basin's population. In Vietnam, the Mekong Delta and Central Highlands comprise only 20 percent of the country but contain 31 percent of the basin's population (MRC 2010).

The LMB is as mixed culturally, socially, economically as it is geographically. Across the region, there are numerous ethnic groups, languages, and dialects; different histories, cultures, and customs; and people live under different political and economic systems. Nevertheless, they also have much in common—most of the population in the basin lives in the rural areas. Poverty is still rampant across the basin (although Thailand has already reached its national goal for poverty reduction). Majority of the population is composed of subsistence farmers who supplement what they grow with the fish they catch and the food and other materials they gather from forests and wetlands.

Most of the people's livelihoods in the basin are closely linked to the river system, with over 60 percent of the economically active population having water-related occupations that are vulnerable to water-related shocks and degradation (MRC BDP 2011). With more than 20 percent of the population living below the poverty line—and approximately 15 percent undernourished—the agriculture and fishery sectors are therefore vital to the food security of the region.

Agriculture is the single most important economic activity in the LMB. The sector provides livelihood to approximately 60 percent of the basin population. Mekong fishery is among the largest inland fisheries in the world and provides most of the protein for the basin population.

Agriculture is the most sensitive sector to climate conditions, particularly to climate variability and climate change. Air temperature, precipitation intensity and distribution pattern, air humidity, solar radiation, and wind velocities are the climatic factors that significantly affect agricultural production. In recent years, agricultural productivity in Asia has slightly decreased due to weather and environmental factors such as high temperatures, drought, flood, and soil degradation. Similarly, crop productivity in many Asian countries has declined in the past decade, mainly due to increasing temperature and incidence of weather-related disaster events (Cruz et al. 2007). In particular, rice production is the main agricultural commodity and the staple food in Southeast Asia, and it depends highly on climate conditions, water availability, soil quality, and other environmental factors.

In recent years, the effects of climate change have been manifesting in the region. According to the baseline period in the last 30–50 years, the temperature has increased, rainfall pattern has changed, flood and drought have intensified, and sea level has risen (MRC 2010). Consequently, agricultural output and yields have also decreased. Since flood- and drought-affected areas are more vulnerable to food insecurity, researchers have given particular focus on the relationship between flood, drought, and food security.

The effects of climate change also exacerbate the problems associated with food supply to meet the increased demand in the region. The impacts of climate change are likely to be severe on the LMB communities given their strong reliance on natural resources for their livelihoods. Therefore, food security needs to be assessed at a basin-wide level in order to identify the magnitude of climate change impacts on the region and to determine the vulnerable areas such that these threats can be addressed.

The MRC has conducted a food security assessment in the LMB in order to identify the impacts of climate change on the food and nutrient security of the region. The AquaCrop model was used in the analysis to predict the change in crop yield under projected climate scenarios. The initial results of the study indicate that on the average, the yields of rice (wet and dry season combined) and maize would be negatively affected by climate change (Hunink, Droogers, and Kien 2014). The results further indicate that climate change would seriously impact food security in the LMB.

THE CLIMATE CHANGE ADAPTATION STRATEGY

The MRC has a crucial role in initiating and implementing CCA strategies in the basin. It provides regional coordination and harmonization of efforts, including ensuring the commitment of government and involvement of line agencies. At present, the MRC is embarking on the development of the Mekong Adaptation Strategy and Action Plan (MASAP) to climate change. This document shows the CCA strategies that LMB countries will adopt to address the possible impacts of current and future climate changes. The MASAP is being developed based on the assessment of a range of future climate change scenarios in the different sectors of the basin. In the Plan, a number of strategic priorities and actions are laid out. In the future, the

MASAP will have to be reviewed, improved, and updated with new information about the impacts of climate change and on strategies for adaptation.

Studies for MASAP Development

To develop the MASAP, a number of studies have been designed at each stage of the development process in order to assess the impact of climate change on the region. These studies aim to identify the impact of and vulnerability to climate change of the whole LMB. The components of the studies include hydrology, flood risk and vulnerability, drought risk and vulnerability, ecosystem and biodiversity, food security, and sustainable hydropower.

The planning process consists of the following stages (Phan 2014):

1. Scoping adaptation strategy,
2. Vulnerability assessment (potential impacts and adaptive capacity),
3. Identification of adaptation options and development of adaptation strategy,
4. Implementation of adaptation options, and
5. Monitoring and evaluation of adaptation implementation.

At each stage of the process, all stakeholders need to be involved in the discussions and consultations. The decision making intends to follow the participatory approach.

Climate Change Adaptation Strategy Options and Village-Level Piloting

Agricultural adaptation

The results of the literature review showed a number of potential agricultural adaptation measures for the LMB:

1. Strengthening the resilience of rainfed and irrigated rice-based systems through using new and improved rice varieties, better management practices, and using protective measures against extreme climate events;
2. Adjusting the traditional cropping calendar;
3. Improving water efficiency and water management techniques in drought-prone areas to alleviate water shortages;
4. Improving soil fertility and soil management;
5. Promoting agriculture diversification to reduce reliance on monoculture; and
6. Shifting cropping systems.

Improving water efficiency and water management

According to the MRC (2014), the pilot implementation of the adaptation measure to improve water efficiency and management has already been completed in Kangkoknuea village, Champhone district, Savannakhet province, Lao PDR.

Kangkoknuea village has a population of 1,879 people, with 327 households. About 70 percent of the population is composed of farm households who grow rice during the wet and dry seasons. Every year, an average of 151 families and 143 households are affected by floods and droughts, respectively.

The project was implemented by the Natural Resources and Environment Institute, Lao PDR under the MRC framework. The project implementers had previously determined that extending the crop irrigation to farmers during the dry and rainy seasons for lowland rice cultivation would be the priority adaptation activity for the targeted villages. Project implementation started in November 2011 in order to meet the seasonal requirements for rice cultivation (as requested by the community).

First, the project team, in collaboration with the local team and villagers, conducted a meeting at the Natural Resources and Environment district office to prepare a detailed work plan, which includes designing soil irrigation canal, task allocation, selection of community volunteers, and budget. The construction phase of the canal was built from 5 to 15 December 2011. The activities included building a pumping station and testing the operating system of the canal.

Accordingly, the irrigation canal was extended by about 1,000 meters, with 65 farm households benefitting from the project (MRC 2014). The project was able to irrigate approximately 76 hectares of farmland. Farmers who cultivate rice during the dry season using water from the upgraded and extended irrigation canal were able to increase their rice harvest, with yields reaching up to 4 metric tons per hectare with the application of inorganic fertilizers. Harvesting this kind of yield had only been possible when farmers cultivated in other fields during the wet season.

Strengthening resilience in rainfed and irrigated rice-based systems

In Taleow village, Champhone district, Savannakhet province, 98 farm households occupying a 345-hectare area of the village are normally affected by flooding. To help improve their adaptive capacities to the impacts of climate change, new rice varieties have been introduced to the local farmers (MRC 2014). The MRC collaborated with the National Agriculture and Forest Research Institute (NAFRI) of Lao PDR to implement this project.

Flood-tolerant rice varieties were then introduced and field tested in the village. In the field test, the rice varieties TDK-Sub1 and IR64 were planted in a 1-hectare field under the supervision of the NAFRI. The initiative aimed to test and demonstrate to the intended farmer-beneficiaries the capacity of the flood-tolerant rice varieties.

Based on the results of the field test, the farmers were satisfied with the quality of and the yield obtained from the new rice varieties. They consequently adopted the technology and have continued to plant the crop for their own consumption and to share the grains with other farmers.

Capacity building to enhance farmer's resilience to climate change

Capacity-building activities in three villages in Champhone district, Savannakhet province have been initiated in order to enhance farmers' resilience to climate change. The Environment Research Center of the National Economic Research Institute under the Ministry of Natural Resources and Environment (MoNRE) served as the main implementing agency of the initiative. The project team consisted of representatives from MoNRE, the provincial and district authorities, and the villages. Specifically, the study villages were the following (MRC 2014):

1. *Kangkoknuea village*. About 175 households that occupy a 118-hectare area of the village are affected by flooding, whereas 115 households within the 76-hectare area of the village are affected by drought.
2. *Nakathang village*. About 130 households that live within a 50-hectare area of the village are affected by flooding.
3. *Taleow village*. About 98 households occupying a 345-hectare area of the village are affected by flooding.

Training workshops that focused on strengthening the local communities' resilience to climate change were conducted, which were attended by the local villagers from Kongkoknuea, Nakathan, and Taleow. Specifically, the training workshop focused on topics that would improve yields and diversify food production. The participants were also trained to conduct vulnerability assessment and adaptation planning.

In summary, the target beneficiaries were trained in the following areas (MRC 2014):

1. Climate change risk assessment, modeling, and data inputs;
2. Climate change and gender mainstreaming in climate change;
3. Basic scientific knowledge on climate change (climate change awareness); and
4. Adaptation identification and planning through exercise and practices.

OUTCOMES OF THE ADAPTATION STRATEGIES

At the basin level, the MRC has already established a framework of collaboration among the four member countries that will enable them to develop a main strategy at the regional level. A number of CCA options had been proposed, and subsequently pilot tested at the local level.

Three CCA activities have been successfully implemented in the basin in order to improve local livelihood. These activities included (1) improving irrigation system, (2) introducing flood-tolerant rice varieties, and (3) enhancing the local communities' resilience to climate change. The outcome of the pilot implementation of the three initiatives showed high community acceptability. Thus, the MRC was able to develop the guidelines for mainstreaming CCA strategies.

The implementation results of the adaptation options at the pilot sites showed that local farmers and authorities had gained significant working knowledge on how to conduct risk assessment, identify appropriate CCA strategies, and accordingly implement such strategies.

LESSONS LEARNED AND RECOMMENDATIONS

A number of lessons can be learned from the pilot implementation of the CCA strategies in the LMB:

1. The proposed framework for the development of the MASAP is feasible and effective for mainstreaming the proposed CCA measures in order to improve food security in the LMB.
2. It is possible that local farmers were able to gain basic knowledge and information on climate change, its impacts, vulnerability assessment, prioritization of adaptation activities, and project implementation.
3. Project implementers need to work with the local farmers to be able to develop the appropriate local and science-based adaptation strategies that would integrate the local communities' actual practices into the CCA measure.
4. Local farmers are morely likely to adopt and continue the proposed measures if they develop (or when they are part of the development process) their own CCA strategies.

The plans laid out in the development of the MASAP need to be accomplished in order to assess the proposed strategies through using scientific evidence that are based on the results of the pilot implementation. Only then can the action plan be finalized and then introduced in the LMB. Thereafter, the next important step is to mainstream CCA planning into the development agenda of the region.

Likewise, climate change in the LMB needs to be further studied to provide the local people with sound, science-based information about its impacts. Financial support should also be extended to the local people to enable them to implement their own CCA activities. A community fund could be also established to enable the communities to hold a prioritization workshop that would identify CCA options, where to purchase seeds of the new crop varieties, and where and how to avail of technical assistance.

ACKNOWLEDGMENT

The author gratefully acknowledges the Southeast Asian Regional Center for Graduate Study and Research in Agriculture and the Oscar M. Lopez Center for Climate Change Adaptation and Disaster Risk Management Foundation Inc., for organizing the writeshop that facilitated the story writing. Special thanks goes to the author's colleagues at the MRC Secretariat for the information sharing and discussions pertaining to the subject written in this chapter.

REFERENCES

Cruz, R.V., H. Harasawa, M. Lal, S. Wu, Y. Anokhin, B. Punsalmaa, Y. Honda, M. Jafari, C. Li, and N. Huu Ninh. 2007. "Chapter 10: Asia." In *Climate Change 2007: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, edited by M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson, 469–506. Cambridge, UK: Cambridge University Press.

Hunink, J., P. Droogers, and T.M. Kien. 2014. *Past and Future Trends in Crop Production and Food Demand and Supply in the Lower Mekong Basin*. Vientiane, Lao PDR: MRC.

MRC (Mekong River Commission). 2010. *State of the Basin Report 2010*. Vientiane, Lao PDR: MRC.

——. 2011a. *Mekong River Commission Basin Development Plan 2011: Assessment of Basin-Wide Development Scenarios*. Vientiane, Lao PDR: MRC.

——. 2011b. *Planning Atlas of the Lower Mekong River Basin*. Vientiane, Lao PDR: MRC.

——. 2014. "Local Demonstration Projects on Climate Change Adaptation: Final Report of the First Batch Project in Lao PDR." *Demonstration Project Series* No. 1. Vientiane, Lao PDR: MRC.

Phan, N.H.T. 2014. "Climate Change and Adaptation in a Transboundary Context: Requirements for the Lower Mekong Basin (LMB)." Paper presented at the Pre-summit International Conference: Water, Energy, and Food Security in Transboundary Basins under Changing Climate, Ho Chi Minh City, Vietnam, 2-3 April 2014.

Yusuf, A.A., and H.A. Francisco. 2009. *Climate Change Vulnerability Mapping for Southeast Asia*. Singapore: Economy and Environment Program for Southeast Asia.

Hierarchical Level Linkages to Pilot Application:

Country Level

First planting activity by CFS farmer-participants in Bali province, Indonesia (2013)
Photo courtesy of Badan Meteorologi, Klimatologi dan Geofisika

CASE STORY 3

Bringing Down Climate Knowledge to Enhance Farmers' Adaptation

Andi Eka Sakya[1], Nurhayati[1],
Nelly Florida Riama[1], and Novana Sari[1]

ABSTRACT

In the past, using good seeds and applying proper fertilizer, land preparation, irrigation, and cultivation were sufficient to enable farmers to maximize their profits from crop farming. Nowadays, these practices are no longer enough. Farmers also need to know how to deal with climate variability in order to minimize losses due to poor crop productivity.

One strategy that can help address the threats imposed by climate change and variability on agriculture is through implementing a Climate Field School (CFS) program. CFS aims to help increase farmers' climate knowledge in relation to crop production, such that they can apply this knowledge to their farming practices and consequently reduce crop losses.

Based on the implementation results of the CFS program in Indonesia, the level of climate knowledge of CFS farmer-participant increased by 70%–75%. The farmer-participants also testified that their crop yield increased as a result of their participation in the program. Using method calculation to assess the effect of the CFS program on farmers' crop yield, it was determined that the program significantly increased farmers' harvests in 2013 and 2014.

---

1 Agency for Meteorology, Climatology, and Geophysics, Indonesia

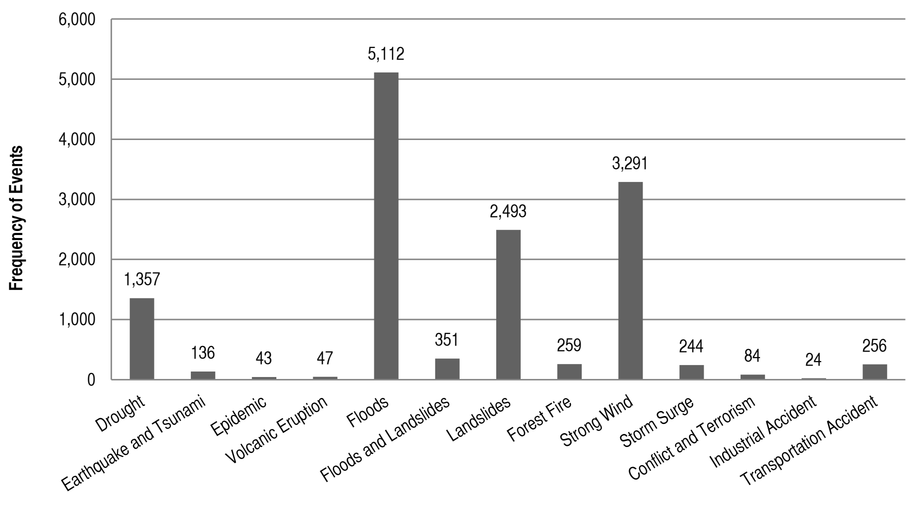
INTRODUCTION

The *IPCC Fifth Assessment Report* reported that the temperature of the Earth's surface has already increased by 2°C (IPCC 2014). The Working Group of the Intergovernmental Panel on Climate Change (IPCC) further explained the potential repercussions of such temperature increase on various climate-sensitive sectors such as agriculture, fishery, health, transportation, tourism, and many others.

Agriculture is one of the highly vulnerable sectors to climate variability and extreme climate events. In Indonesia, these extreme climate events are known as the "Big Four" of the largest natural disasters (Figure 3.1). In the last 10 years, more than 1.4 million hectares (ha) of Indonesia's land area have been affected by flooding, and more than 1.6 million ha have been affected by drought (BNPB 2014).

Indonesia is an archipelago that lies in the tropic line. It is within the mountainous ring-of-fire and is prone to extreme weather and climate. In the past 10 years, the average annual temperature in Jakarta has increased. In 1976, the annual temperature in the capital was only 27.3°C; in 2003, the temperature reached 29.2°C, which indicates a 1.9°C increase in temperature in the span of 27 years. Such phenomenon is not unique in Jakarta, but also in other cities throughout Indonesia. In Banten province, the annual average temperature has increased by 1.3°C in the last 30 years. These alarming temperature changes have consequently led the National Agronomist Association to state in 2014 that Indonesia needs to have a concrete climate change adaptation (CCA) plan, considering that an increase in temperature of 1°C will reduce seed growth by up to 50 percent.

Figure 3.1. Frequency of disasters in Indonesia (2005–2014)



Source: BNPB

The changing rainfall pattern also gives an interesting insight. If the average rainfall amount from 1970 to 2000 will be compared with that from 1980 to 2010, it will show that the rainfall pattern has changed over the years, which has affected the onset of seasons. Likewise, the amount of rainfall has also changed in recent years.

When the current climate variability and change is analyzed from the angle of the agriculture sector, the analysis would be more complicated. For example, small-scale farmers rely heavily on natural resources (resource-based) and traditional indigenous knowledge (local wisdom) in crop production, and not on observation (observation-based). Also, local farmers have no scientific data or access to them, more so the capability to interpret such data so they can be guided accordingly in their agricultural decision making (e.g., correlation between the amount of rainfall and type of crops that can be produced given the changing climate).

In the past, using good seeds and following the proper application of fertilizers, land preparation, irrigation, and cultivation were sufficient to enable farmers to maximize their profits from crop production. Today, these are no longer enough to sustain farmers. They also need to know how to deal with climate variability in order to reduce crop losses due to poor crop productivity.

The total agricultural area in Indonesia is about 13 million ha. However, these agricultural lands are spread all over the archipelago. The ratio of land area per farmer is estimated to be about 0.5 ha or less per farmer. This shows that most Indonesian farmers are considered small-scale, and small-scale farmers are usually those traditional farmers whose farming practices are based on indigenous knowledge. Thus, how they read climate patterns, and subsequently strategize their crop production, are based on traditional know-how.

In South Sulawesi province, especially in Sidrap regency, local indigenous knowledge is passed on from one generation to the next. Before planting, farmers and relevant agencies (BMKG, Ministry of Agriculture, etc.) always hold an event called *Tudang Sipulung* (the Great Assembly), which gathers local farmers together in a meeting so that the farming community can deliberate on the farming guidelines for the season. This guidelines involve the measures to be used for onset planting, identifying the crop varieties to be used, determining the amount and type of fertilizers to be applied, and establishing sanctions for those who will fail to uphold these guidelines. The *pallontara*[1] also presents his readings during Tudang Sipulung to enable the community to determine whether the planting season would be rainy or dry.

The beginning of the rice-planting period is established based on natural indicators—how the animals and plants are responding to the environmental changes due to

1 A *pallontora* is an individual who reads and predicts natural phenomena such as weather, local climate, pests, plant growth, etc. for a given season.

seasonal change. Some examples of these indicators include when ants start to come out of the nest and move from lowlands to highlands, when banana fronds begin to face upward, and when cool wind blows during hot days (Damis 2015).

The challenge then lies on how to integrate climate science knowledge into traditional farming practices that stem from indigenous knowledge.

It is now widely recognized that farmers' income is decreasing due to the direct and indirect vulnerability of the agriculture sector to natural disasters. Moreover, traditional farmers are generally unaware of the importance of climate information in farm production. According to the Badan Pusat Statistik (BPS) or Central Bureau of Statistics of Indonesia, Indonesian farmers' income in 2013 was only about Indonesian Rupiah (IDR) 26 million, lower than that in 2003 at IDR 31.17 million. This translates to a decline of about IDR 5 million in 10 years, and a contribution of only 0.76 percent to the national state revenue.

Many initiatives are currently in the pipeline in order to reduce the impacts of extreme climate events and climate variability on Indonesia's agriculture. Such initiatives include raising farmers' awareness of climate information and the impacts of climate on crop production, improving weather/climate forecasts, and introducing agricultural cultivation technologies. However, these initiatives are far from being adaptive actions. As such, the Indonesian government issued Presidential Instruction No. 11 in 2011 in order to secure rice production in the face of extreme climate events and climate variability. Specifically, the policy establishes a program that promotes the importance of climate information in agricultural production. This policy aims to enhance the capability of farmers in making the proper adjustments and in adapting to climate variability and climate change. The Meteorology, Climatology, and Geophysics Agency of Indonesia (BMKG) was then tasked to communicate and disseminate relevant climate information and early warning to stakeholder agencies, organizations, and other entities from the national to the local level.

Alongside this, the Climate Field School (CFS) was established as an adaptive response to the threats posed by climate change to Indonesia's agriculture sector. The CFS program aims to increase farmers' knowledge on climate information and improve their farming practices through a training process, thereby reducing crop losses. In particular, the CFS program targets farmers from major crop-producing regions.

According to Boer (2009), the idea of CFS was developed from the concept of the Farmer Field Schools, which is designed for Integrated Pest Management. The CFS program was developed by Bogor Agricultural University in 2003, in partnership with the regency of Indramayu, Ministry of Agriculture (MoA), the Meteorology and Geophysics Agency (BMG, which became BMKG in 2008), with funding support from the Asian Disaster Preparedness Centre and subsequently from the International Research Institute for Climate and Society-University of Columbia.

The CFS was first developed in three subdistricts of Indramayu, namely, Cage Haur (Karang Mulya), Juntinyuat (Village Junti kedokan), and Losarang (Village Tanjeng). The idea of the CFS is to employ a participatory approach by letting farmers experience for themselves how using climate information in their farming practices can reduce farm losses, and thus provide great benefits to farming communities. Accordingly, field demonstrations were conducted in the form of simulation activities and interactive discussion between extension workers (as trainers) and local farmers.

However, the implementation of the CFS program was not met without any challenges. Some of the factors that hindered its continuous implementation at that time are as follows:

1. Field facilitators had limited technical knowledge of the training materials; only a small number of extension workers understood the CFS material well.
2. Not all of the modules in the trainers' manuals were patterned after current local conditions.
3. Not all of the researchers at the CFS implementation sites had actual working knowledge on how to use climate information for agricultural production.
4. The financial support extended by the Asia-Pacific Network Capacity Building for Sustainable Development (APN Capable) was limited.

DESCRIPTION OF THE ADAPTATION

In 2010, the Australian Agency for International Development (AusAID) provided technical support for the establishment of a CFS program in Indonesia. The program was conducted in two districts: West Lombok regency in West Nusa Tenggara (NTB) and Kupang regency in East Nusa Tenggara (NTT). The CFS in NTB and NTT became an example of how extension workers can proactively induce and affect the planting decisions of farmers through the application of climate information to crop production strategies. As of 2015, several CFS have been implemented in 31 provinces nationwide, supported mostly by the Government of Indonesia (Table 3.1).

The BMKG runs the CFS program in close collaboration with the extension workers of MoA and the local farmers in the region. However, most of the climate data are often too technical (especially for farmers) to be understood and to be integrated directly into local farming practices. Hence, the BMKG serves as the climate information provider, whereas the extension workers serve as the intermediaries between the climate experts and farmers. The extension workers help farmers to translate and interpret climate data into an operational language that can be used daily in the field.

Table 3.1. List of CFS activities in Indonesia, 2007–2015

Year	Activity	Locus (Province)	Supporting Institutions
2007	National Climate Field Schools	Indramayu, West Java; Klaten Purworejo, East Java; Maros & South Minahasa, South Sulawesi	GoI
	ASEAN Climate Field School	Indramayu, West Java	GoI
2009	ASEAN Climate Field School	Surabaya, East Java	GoI
2010	National Climate Field Schools	West Lombok, West Nusa Tenggara East Kupang, East Nusa Tenggara	AusAID GoI
2011	National Training of Trainers for Agriculture Extension Workers	Jakarta Sukamandi, West Java	Indonesian Climate Change Trust Fund, UNDP
	National Climate Field Schools	Aceh, South Sumatera, Lampung, Banten, West Java, Central Java, Yogyakarta, East Java, West Nusa Tenggara, South Kalimantan, South Sulawesi (11 provinces)	GoI
2012	National Climate Field Schools	Aceh, North Sumatera, West Sumatera, South Sumatera, Lampung, Banten, West Java, Yogyakarta, Central Java, East Java, West Nusa Tenggara, Bali, West Kalimantan, Central Kalimantan, South Kalimantan, South Sulawesi, Southeast Sulawesi, North Sulawesi (18 provinces)	GoI
2013	National Climate Field Schools	Aceh, North Sumatera, West Sumatera, South Sumatera, Lampung, Banten, West Java, Yogyakarta, Central Java, East Java, West Nusa Tenggara, Bali, West Kalimantan, Central Kalimantan, South Kalimantan, South Sulawesi, Gorontalo, Southeast Sulawesi, North Sulawesi, Jambi, Riau, Bengkulu, East Kalimantan, Central Sulawesi, East Nusa Tenggara (25 provinces)	GoI

Table 3.1. (continued)

Year	Activity	Locus (Province)	Supporting Institutions
2014	National Climate Field Schools	Aceh, North Sumatera, West Sumatera, South Sumatera, Lampung, Banten, West Java, Yogyakarta, Central Java, East Java, West Nusa Tenggara, Bali, West Kalimantan, Central Kalimantan, South Kalimantan, South Sulawesi, Gorontalo, Southeast Sulawesi, North Sulawesi, Jambi, Riau, Bengkulu, East Kalimantan, Central Sulawesi, East Nusa Tenggara (25 provinces)	GoI
2015	National Climate Field Schools	Aceh, North Sumatera, West Sumatera, South Sumatera, Lampung, Banten, West Java, Yogyakarta, Central Java, East Java, West Nusa Tenggara, Bali, West Kalimantan, Central Kalimantan, South Kalimantan, South Sulawesi, Gorontalo, North Sulawesi, Jambi, Riau, Bengkulu, The Islands of Riau, Bangka Belitung, North Kalimantan, Central Sulawesi, West Sulawesi, East Nusa Tenggara, Maluku, North Maluku, Papua, and West Papua (31 provinces)	GoI

Note: AusAID = Australian Agency for International Development; CFS = Climate Field School; GoI = Government of Indonesia; UNDP = United Nations Development Programme

The CFS activities have the following objectives:

1. To increase farmers' knowledge on climate, and thus improve their ability to anticipate and respond appropriately to extreme climate events and climate variability in their agricultural production;
2. To assist farmers on how to observe climatic parameters and accordingly use such information in their farming activities and strategies; and
3. To assist farmers in interpreting and translating climate (forecast) data in a language that can be easily understood such that the information can be used to support farming activities, especially in farm decision making and in developing cropping strategies.

For a CFS to function effectively, its implementation needs to have strong collaboration between partners. At the national level, the BMKG collaborates with the Indonesia Agriculture Research and Development Centre of the MoA in developing strategies that would accelerate the delivery of climate information to end users. Likewise, the BMKG has partnered with the Agriculture Research and Development Division (BPTP) to implement initiatives that would enable experts from BPTP to coach the participants on how to use the crop calendar, which is accordingly based on the climate data provided by the BMKG. The BMKG also collaborates with universities, whose role has been important in the development of the CFS program and in identifying the indigenous knowledge of farmers. On the other hand, funding support from the national budget and other donor sources (i.e., AusAid, UNDP) ensures the continued implementation of the CFS activities.

In identifying the CFS participants, the BMKG requests local governments at the provincial and regency levels to nominate agricultural field officers, plant pest technical officers, extension workers, and local farmers who will participate in the CFS program based on the following criteria:

1. S/he should have no prior participation in any CFS program.
2. S/he should have farming as her/his main livelihood.
3. S/he should be recommended by their respective local agricultural offices.
4. S/he should have previous working experience as agricultural field officers (for CFS Stage 1), extension workers (for CFS Stage 2), or members of farmer group (for CFS Stage 3).
5. S/he should be committed to follow through and continue applying the climate knowledge gained from the CFS program.

The main objective of CFS is to translate technical climate information into a language that farmers can fully understand. The BMKG, as the climate information provider, needs facilitators with whom the target farmer-beneficiaries can easily relate to and understand such that the climate information can be applied appropriately to their farming practices. Accordingly, the extension workers serve this role of facilitator.

First stage: "Trainers' training"

At this stage, the target audience is the staff of the provincial and regency local government, particularly the agricultural field officers and plant pest technical officers of MoA. The participants are then taught how to interpret the climate information provided by the BMKG. The main objectives of this stage are to increase the participants' knowledge on climate data interpretation and on designing information dissemination strategies, and to introduce to the participants in Stages 2 and 3 how to simulate and observe climate variables.

Second stage: Training of local extension workers

The trainers who have been trained during the first stage will play a pivotal role at this stage. The target audience at this stage is the local extension workers who will closely work with the farmers. This stage is also patterned after the Training of Trainers (ToT) principle, complemented with some simulation techniques. The activities lined up at this stage normally take four days, and involve the following:

- introduction to the methods for applying climate information to agricultural production,
- development of planting techniques based on the climate information provided, and
- strategies to motivate farmers to learn the importance of climate information in agriculture.

Third stage: Working with farmers

The third phase of the CFS program is the most crucial stage. This is when the extension workers deliver the information to the farmer-participants, who are the primary target beneficiaries of the CFS. At this final stage, the knowledge obtained by the extension workers from the previous phase is passed on directly to the farmers using field teaching techniques. Specifically, the extension worker teaches the farmers how to apply the climate data to their farming practices.

The objective of this stage is to transfer directly the knowledge gained by the extension workers from the second phase to farm households, thereby capacitating them with the technical know-how of the climate data. This stage consists of the following steps:

1. influencing farmer households to be receptive of science-based climate information,
2. transferring CFS knowledge to other farmers, and
3. farmers' application of CFS knowledge to farming practices.

The training materials used in the CFS activities are based on the collaborative efforts of the BMKG, the MoA, and Bogor Agricultural Institute. They consist of the following modules:

- introduction to the impacts of climate change on agriculture, particularly on plants and livestock;
- climate change adaptation and mitigation strategies;
- understanding weather and climate characteristics;
- simple measurement practices;
- simple water balance approximation for soil moisture;
- use of seasonal forecast for planting strategy and calendar;
- understanding the economic value of seasonal forecast; and
- anticipating the spread of crop diseases and plant pests.

The activities set in the training materials are carried out for 3–4 months. Based on the CFS climate data, farmers are taught which type of crops can be planted, how they can adjust their planting calendar, and how they can evaluate and decide which types of inputs should be used.

The trainers of the CFS Stage 3 are selected from the participants of Stage 2. During the three- to four-month implementation period of Stage 3, a total of 12 meetings are conducted (every 7–10 days) at the field; this is concluded with the event called the "Farm Field Day." During the Farm Field Day, farmers present the outcome of the crops they planted during the course of the training in terms of productivity and the economic values (loss/benefit) from their harvest.

OUTCOMES OF THE INTERVENTION/ADAPTATION

From 2011 to 2014, more than 3,678 extension workers and 325 farmers in Indonesia were able to participate in the CFS program (Figure 3.2). Moreover, almost 800 women participants have been trained at the CFS in support of women empowerment (Figure 3.3).

In general, the CFS activities implemented from 2011 to 2014 were successful. The participants attended the full lecture series diligently and actively. At the beginning and at the end of CFS Stages 1 and 2 classes, MoA trainers and extension workers, respectively, performed pretest and posttests to enable the project implementers to measure the program's effectiveness in increasing the participants' knowledge on climate information relative to agricultural practices.

Figure 3.2. CFS activities, 2013–2015

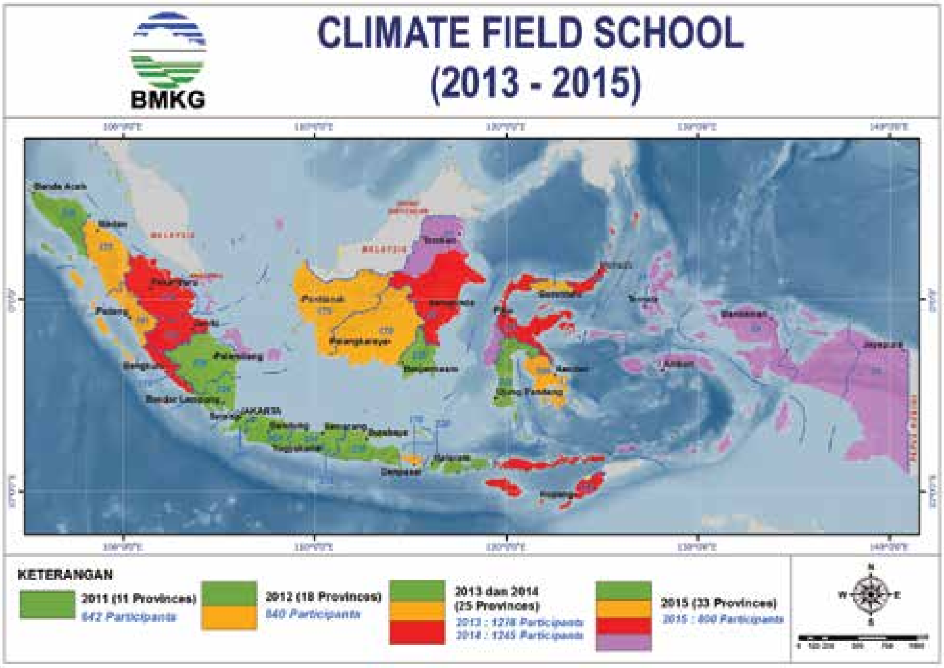
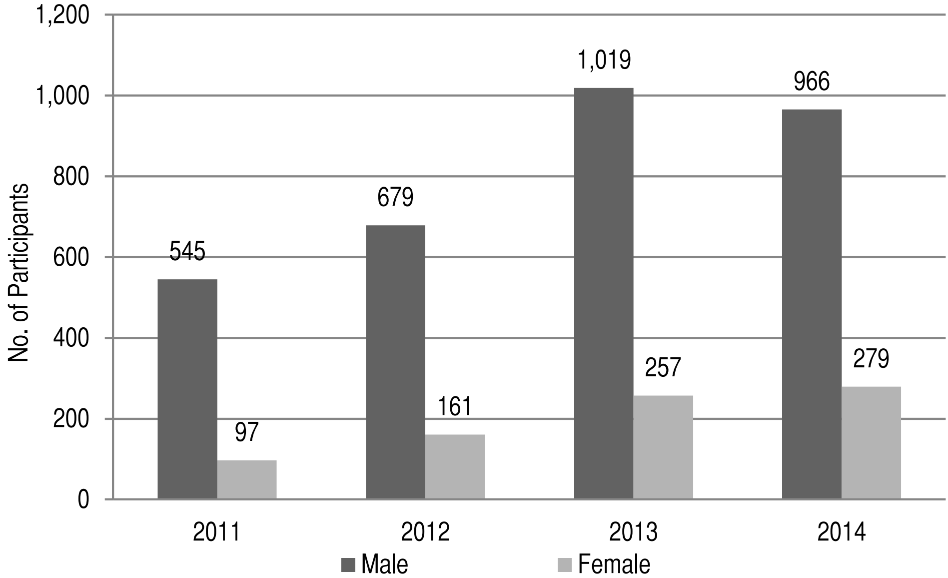


Figure 3.3. CFS participants, by gender

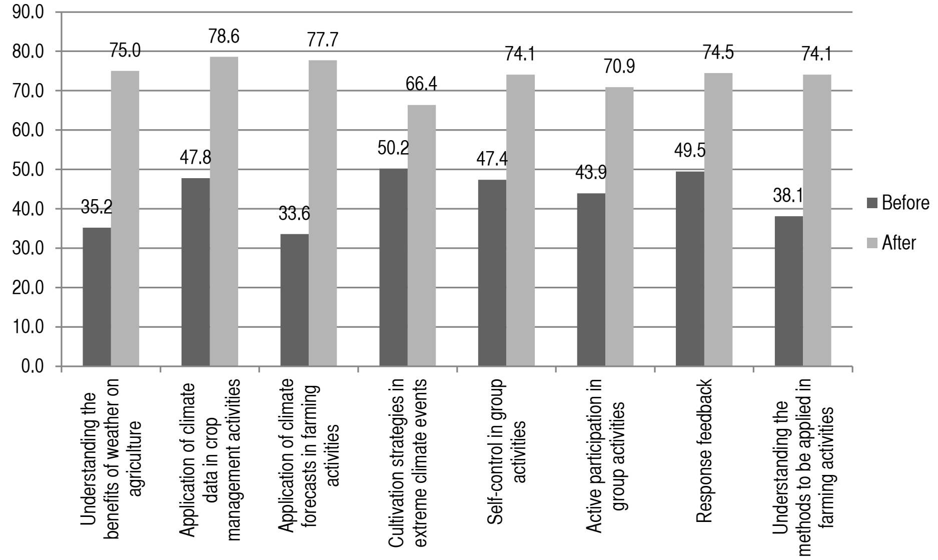


Source: BMKG

One of the results of the CFS Stage 3 evaluation in West Lombok, West Nusa Tenggara in 2011 indicated that, on the average, the knowledge of the CFS farmer-participants on climate data in relation to agriculture increased by 70%–75% (Figure 3.4). It can then be concluded that the objective of CFS had been achieved. With this, the participants of Stage 2 (i.e., the extension workers) were then expected to share their knowledge with their peers. Furthermore, the farmers who participated in CFS Stage 3 can take advantage of climate information services and apply the information in their farming activities.

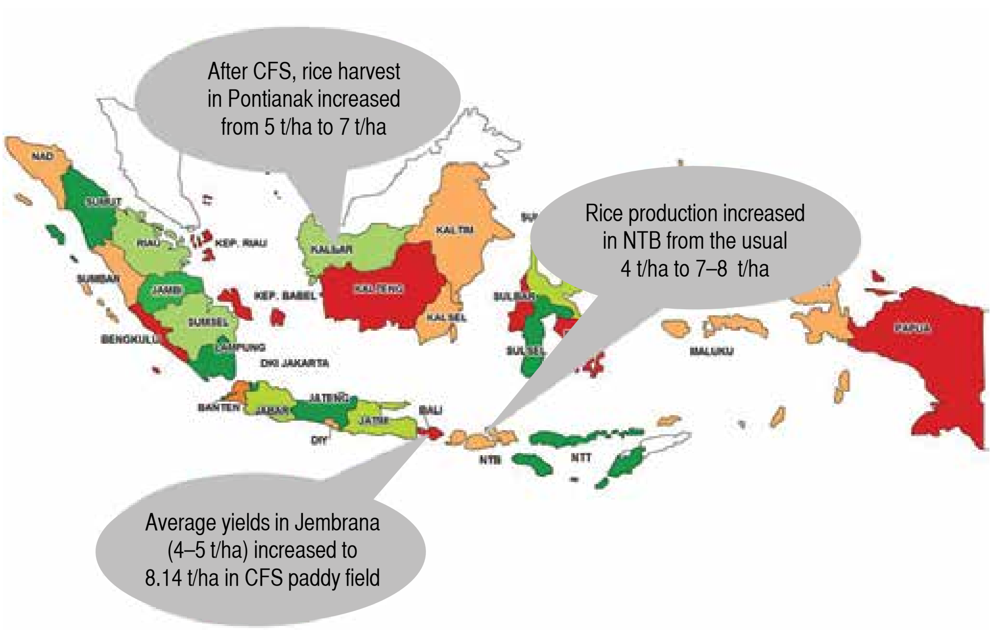
Figure 3.4 shows the performance of the CFS participants in Phase 3. It shows that the participants' knowledge on climate information and its related aspects to agricultural activities improved, as evidenced by the difference in the percentage of the dark gray (pretest results) and the light gray (posttest result). In the third phase, the project implementers also tried to calculate the maximum yield that the CFS farmers could harvest if the area of their plantation would be converted to 1 ha. Accordingly, the farmers testified that their crop yield had increased (Figure 3.5). Using the method calculation, results showed that CFS participation were able to significantly increase farmers' yield in 2013–2015 (Table 3.2).

Figure 3.4. Performance of CFS farmer-participants in West Lombok, West Nusa Tenggara, 2011



Source: BMKG

Figure 3.5. Crop yield gains during CFS program implementation



Source: BMKG

Note: NTB = Nusa Tenggara Barat (West Nusa Tenggara)

Table 3.2. CFS yield, 2013–2015, BMKG

Province	District	Commodity	Harvest Period	Ave Yield (t/ha)	CFS Yield* (t/ha)
2013					
East Java	Malang	Corn	29 Aug	11.1	14.50
Central Java	Pati	Paddy	25 Nov	5.3	7.50
West Kalimantan	Kubu Raya	Paddy	15 Jul	5–6	8.00
South Sulawesi	Maros	Paddy	15 Aug	6	7.40
Bali	Jembrana	Paddy	19 Aug	4–5	8.14
West Nusa Tenggara	Lombok Barat	Corn	23 Oct	5	12.50
North Sumatera	Deli Serdang	Paddy	17 Oct	3.5	3.50
2014					
Banten	Tangerang	Corn	3 Oct	32–33	39.76
Bali	Buleleng	Corn	16 Jul	3–4	6.48
West Kalimantan	Mempawah	Paddy	28 Aug	6–7	10.00
West Nusa Tenggara	Lombok Tengah	Paddy	19 Jun	5.6–5.9	8.46
North Sulawesi	Minahasa Utara	Corn	1 Sept	3	3.45
2015					
Banten	Serang Barat	Paddy	7 Sept	7.2	6.90** 7.90***
West Java	Cirebon	Paddy	11 Jul	5.4	7.50

Notes: (1) *crop productivity results were obtained through measuring crop yield from 2.5 x 2.5 m sample plots (2) ** organic (3) *** inorganic

The CFS participants also learned from actual field experiences that not only do weather and climate conditions affect plant growth, but these factors also influence the rate by which pests and plant diseases spread in an area.

In Bali, farmers plant soybeans in the middle of the year because this period is normally characterized by less rainfall. In 2013, however, the BMKG's climatology station in Bali issued a rainfall forecast stating that there would be more rains in April, May, and June 2013 due to climate anomalies. This information was then used as a guide in developing the initial planting schedule of the CFS farmers and in identifying the types of commodities that can be planted during the conduct of the CFS Stage 3 in Jembrana region. The CFS farmers, together with the BMKG and the CFS agricultural and plant pest extension workers, decided to plant rice based on this issued data. This decision was also followed by the farmers in Tabanan region. The results during CFS Stage 3 in Jembrana showed that farmers' rice yield had increased by 200 percent. Unfortunately, the other districts in Bali did not follow the BMKG's climate information; they suffered crop failures since they had planted the usual soybeans. This experience showed the importance of equipping farmers with climate information. Integrating climate information into farmers' agricultural practices can help them to plan their planting schedule appropriately, identify the suitable crop variety to be planted, and anticipate the possible spread of crop diseases.

Several lessons can be learned from Indonesia's five-year implementation of the CFS program:

1. It is crucial to involve intermediaries who understand both the climate information and farmers' needs.
2. Farmers can easily learn how to use climate information appropriately when it is communicated through an understandable language and through using simple and readily available tools (e.g., using milk containers as rain gauges).
3. Farmers should be encouraged to share their opinions and to develop their own action plan as these can lead to new and innovative ways of using climate information, especially in pest and disease control.
4. Trained CFS farmers can be multipliers of CFS knowledge when they disseminate what they have learned to other farmers.

Although the CFS has been proven to have direct and significant positive influence on farmers' ability to adapt to climate change and variability, the expansion of the program remains challenging. The following are some of the foreseen challenges in the continued implementation of the CFS program:

1. The lack of coordination between government agencies at the regional level, caused by the changes of government system (decentralization), is a challenge in the successful implementation of the CFS program.
2. There is no effective method for expanding and developing the CFS program into a national program that would combat the impacts of climate change.
3. It is difficult to integrate scientific climate data into local farmers' traditional agricultural practices in order to adjust their farming practices. Their traditional farming knowledge and practices have been passed from generation to generation; thus they are deeply ingrained in their way of life. Asking the farmers to abandon such practices will be met with high resistance.
4. The success of the CFS activities is based on the collaboration of and cooperation among climate information providers, extension workers, and researchers. Each party must contribute in accordance with their capabilities and function. Thus, should one of these actors fail in their functions, accomplishing the objectives of the CFS program would be difficult.

Climate anomaly, either in the form of extreme high temperature or high amount of rainfall, can cause a hazardous dry or rainy season. Forest fires are more likely to occur in an extremely dry season; massive flooding and landslides often result from extreme heavy rains. It has been recently determined that the transition from dry to rainy season sporadically produces local depression. The change also generates local storm that can cause massive damages to many houses and infrastructure, crop losses, and even loss of human lives.

Considering that Indonesia has 33 provinces, each having their own respective climate characteristics, it is not possible to implement the CFS program for all provinces simultaneously. Therefore, those crop-producing provinces that are most vulnerable to climate change need to be prioritized.

The BMKG coordinates and regularly meets with the MoA in order to transform BMKG's climate information into a more understandable language such that extension workers can communicate the climate data more effectively to farmers. The main objective is not only to prepare and disseminate the standard CFS material, but also to mainstream climate-based farming education in various locations.

The Indonesian government has also initiated the expansion of the CFS program to cover other countries in the region. In 2014–2015, the CFS program for Asia Pacific was launched through the conduct of the Training of Trainers for Climate Field School Asia Pacific. The training event was attended by representatives from ASEAN and in Pacific region countries, namely, Malaysia, the Philippines, Thailand, Lao People's Democratic Republic, Vanuatu, Myanmar, Vietnam, Timor Leste, and Indonesia. At the training, Indonesian experts delivered lectures and hands-on exercises on cloud and rain formation processes, gave an introductory course on simple meteorological instruments, and provided courses on indigenous farming knowledge and on crop calendars. The participants also conducted a site visit to Banten province, which had an ongoing implementation of CFS Stage 3 at that time, with 25 local farmers in attendance (Figure 3.6).

The Training of Trainers for Climate Field School Asia Pacific was strongly supported by the World Meteorological Organization (WMO). This initiative will become a regular activity of the Indonesia Regional Training Center, which serves as one of the WMO regional training centers.

Figure 3.6. Activities during CFS Training of Trainers-Asia Pacific

Photo courtesy of BMKG

SUMMARY OF LESSONS AND WAY FORWARD

Farmers are vulnerable to and directly impacted by the inevitability of climate change. Increasing their climate literacy is one adaptation step that can strengthen local farming to enable them to integrate science-based climate information into traditional farming methods. The CFS is one adaptation measure that can be adopted to help farmers face the threats imposed by climate change. CFS activities have been done successfully in Indonesia. The program has been successful in bridging the knowledge gap of farmers on climate information and the impacts of climate variability on crop productivity. Based on the CFS experience in Indonesia, the local farmers' improved climate knowledge has led to better crop management and productivity.

In 2016, the implementation of CFS activities is being continued in 33 provinces of the country through direct face-to-face communication with extension workers and farmers throughout the training course. CFS Stage 3 will also be held in 13 provinces with a target of five groups of farmers in each provinces. The *Training of Trainers CFS Asia Pacific* will also run for the third time in Bogor, West Java and will be attended by representatives from more than eight countries.

ACKNOWLEDGMENT

The authors acknowledge the following institutions for the data and documentation of CFS activities and other supporting data used in this chapter: BMKG, especially the BMKG stations, National Statistic Agency, National Disaster Management Agency, Bogor Agricultural University, Extension Work and Food Security Agency (Badan Penyuluhan dan Ketahanan Pangan)–regency of Sidrap, provinces of South Sulawesi and Bali.

REFERENCES

BNPB (Indonesian National Board for Disaster Management). 2014. "Disaster Statistics Indonesia 2005–2014." Accessed 28 March 2014. http://dibi.bnpb.go.id/data-bencana

Boer, R. 2009. "Climate Field School: Adaptation of Climate Change Risk." *Salam Magazine* (26 January 2009).

Damis, A. 2015. *Kearifan Lokal Kabupaten Sidenreng Rappang*. South Sulawesi, Indonesia: Agroclimate Dissemination Program in South Sulawesi, Work and Food Security Agency-Sidrap Region.

IPCC (Intergovernmental Panel on Climate Change). 2014. *Climate Change 2014: Mitigation of Climate Change*. Geneva, Switzerland: IPCC.

Sakya, A.E. 2015. “Indonesia’s Best Practice on Adaptation to Climate Change through Climate Field School.” Paper presented at COP21 – UN Climate Change Conference, 4 December 2015, Paris, France.

Sakya, A.E., S.W. Harijono, W. Sulistya, Nurhayati, N. Florida, and Marjuki. 2012. “Reducing Crop Loss through Climate Field School: The Indonesian Experience.” In *Climate Exchange* edited by J. Griffiths, C. Rowlands, M. Witthaus, 31–34. WMO Climate Exchange. Leicester, UK: Tudor Rose Publishing.

ANNEX

Story behind the Climate Field School: The Story of Filmon Pello

by Dian Estey

The words La Niña and El Niño did not have any meaning for Filmon Pello, a farmer from Baubau regency, the province of East Nusa Tenggara. He felt that the last 10 years of farming have become harder than the previous years due to the extreme weather conditions. Drought has become a common condition.

“I have been a farmer for 20 years and have always planted in the way I was taught by my great grandparents,” said Filmon. “But my farming practices don’t seem to work anymore.”

Traditional knowledge have taught farmers like Filmon to observe the presence of fireflies (which indicates that the rainy season is near) or to observe the presence migratory birds (which indicates an impending drought) to anticipate changes in climatic conditions. However, these signs no longer happen nowadays, thus, making the method unreliable. This forces farmers to guess—and sometimes anticipate incorrectly—the change in climate. This leads to crop failure when they assess the change in climate incorrectly.

“We had thought that when the rains started last season, it was already the time to plant rice. But the rains stopped two weeks later,” said Filmon about the previous planting season. “If only I knew that farming would become this difficult, I would have stopped a long time ago.”

Fortunately, his friends encouraged him to persist and invited him to participate in a farmer group. "Finally, some staff members from the BMKG came to encourage us to study the relationship between weather and agriculture," said Filmon. Together with 16 other farmers, Filmon began to learn about the patterns of La Niña and El Niño. The farmers were shown how to interpret weather forecasts and information related to agriculture.

"I believe that rain and drought is God's grace, but by knowing when it will rain and when there will be a dry spell will be very helpful in determining our planting period," said Filmon. The Climate Field Schools that Filmon and his peers participated in was the result of the collaboration between the BMKG, the Department of Agriculture, and the Australian government (AusAID). "Before, I did not realize that what we have done to the environment will affect the weather. Thanks to the CFS, I now understand that our activities significantly affect the climate," he said.

Filimon lives in Baubau regency, in East Nusa Tenggara province. Due to its geographic position, the regency is highly vulnerable to the effects of drought and heavy rains caused by the El Niño and La Niña phenomena, respectively. "The terms 'La Niña' and 'El Niño' are no longer just a bunch of words that I often hear on television," said Filmon with great pride. "Now, I understand that El Niño brings drought and La Niña causes heavy rains. Anticipating correctly their occurrence would determine the success of a planting season," added Filmon.

Currently, Filmon and his fellow farmers are preparing their first harvest for this year. With muddy hands and the peanuts that he had just pulled out from the land, Filmon and his fellow farmers no longer see the gloom. "I am very pleased, and I believe my life will be better now," said Filmon with half a shout and confidence.

The Australian government strongly supports the efforts of the BMKG in organizing activities in two places, namely, in Lombok, West Nusa Tenggara and in East Nusa Tenggara, Kupang. So far, this activity has succeeded in increasing the knowledge of 26 farmers and in deepening their understanding of the effects of unpredicted climate conditions on their crops.

On-farm experimentation and demonstration site of DMC-based annual cropping system
Photo by Rada Kong

CASE STORY 4

Conservation Agriculture for Climate-Resilient Rainfed Uplands in the Western Regions of Cambodia

Challenges, Opportunities, and Lessons from a 10-Year R&D Program

***Kong Rada*[1], *Sar Veng*[1], *Leng Vira*[1], *Trang Sopheak*[1], *Stephane Boulakia*[2], *Florent Tivent*[1], *and Lucien Seguy*[3]**

ABSTRACT

The political and territorial reintegration strategy that had been implemented in Cambodia to establish peace and order in the late 1990s caused the degraded evergreen forestlands to be allocated to the demobilized Khmer Rouge families in the western regions of the country. The increasing regional demand for cereals and tubers and the highland saturation in central rice areas have driven massive immigration of smallholder farmers. Almost half a million hectares of those forestlands were thus converted in less than 15 years for annual upland cash crops development. This dramatic expansion in agricultural area, without any plan for sustainability, has exerted tremendous pressure on the natural forest resources and on biodiversity. Its effects rapidly spread to the water and soil resources of Cambodia.

With conventional practices and more frequent flooding and incidents of drought, smallholder farmers could hardly sustain their livelihoods, which are mainly based on annual upland farming. Farmers with investment capacity have shifted to planting tree crops and/or to animal production in order to cope with the hazardous phenomena.

This case story presents the collaborative R&D program between farmers and researchers in Battambang and Kampong Cham provinces in Cambodia. The program aimed to restore soil fertility and build the resilience of smallholder farmers to the effects of climate change while improving crop productivity and profitability of the smallholder farmers.

---

1 Conservation Agriculture Service Center, Ministry of Agriculture Forestry and Fishery, Cambodia
2 Centre de Cooperation Internationale en Recherche Agronomique pour le Developpement, CIRAD-Persyst, UR Aida
3 Agroecoriz

Using the Diagnosis, Design, Assessment, Training, and Extension (DATE) methodology, the project implementers designed, tested, and evaluated crop production systems that are grounded on the principles of conservation agriculture (CA). DATE is a multi-scale, multi-stakeholder participatory approach. It integrates scientific and tacit knowledge, and is composed of four components: agrarian systems diagnosis, field experiment, on-farm assessment, and pre-extension.

A number of CA-based cropping systems have been designed and validated in the program: (1) monocropping of maize in association with pigeon pea or mungbean as relay crops, (2) biannual rotation cropping of maize with soybean or cassava, and (3) intensified cropping of maize and cassava. Synergizing this with the benefits of CA, each system has the capacity for climate change adaptation (CCA) and mitigation, to retain soil fertility, and to increase smallholder farmers' profitability. Based on the results, pigeon pea is the most suitable crop for mollisols used with maize since it can improve the water retention capacity of the soil, reduce soil evaporation, and reduce mineral nitrogen inputs. Moreover, its grain can be sold or used as animal feed to augment farmers' income, a characteristic that smallholders look for in an agricultural production system. Likewise, shifting to mungbean to be sown by hand broadcast after harvesting early maize significantly reduces farmers' risks and costs, thereby improving their productivity. Shifting to CA-based cassava production (a key annual crop) using chisel to operate strip tillage on planting rows after the early maize harvest also enables farmers to significantly minimize risks and costs. These risks and costs are estimated to be about United States Dollar (USD) 300–400 per hectare and USD 200 per hectare, respectively.

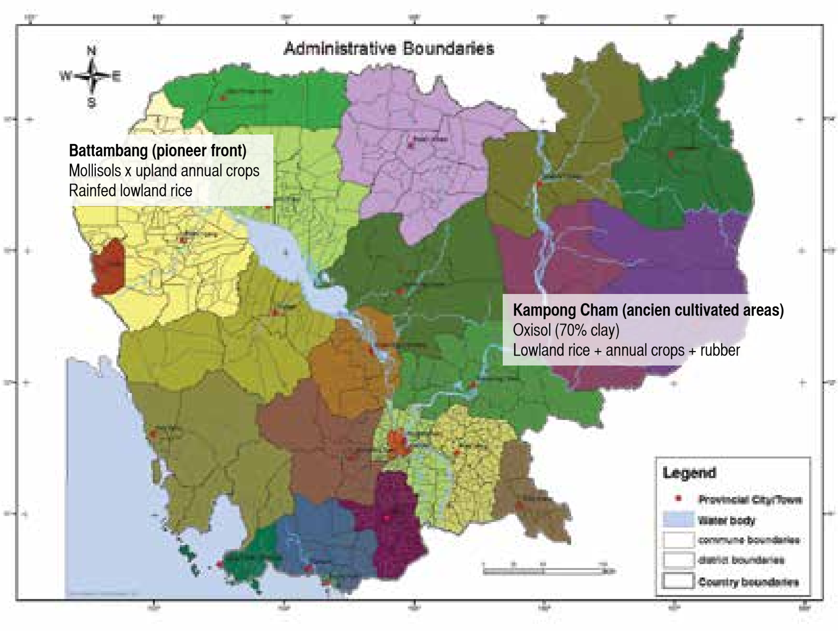
Designing CA-based cropping systems based on the DATE methodology presents clear benefits. DATE is a holistic approach for identifying technical, socioeconomic, and institutional elements for a sustainable and more inclusive intensification of smallholder farmers' agricultural production systems. However, designing such innovative techniques is a combination of context-specific and context-generic features. These issues need to be taken into account should such innovation be replicated in other regions. In addition, this action-research program should be a continuous process; the agro-technical performances of the introduced cropping systems should be continuously validated in multiple locations and for several years. The outcomes of the cropping systems should also be continuously monitored such that their impacts on natural resources (e.g., soil organic carbon, nutrient cycles, xenobiotic dynamic, etc.) can be determined and measured accurately.

INTRODUCTION

The Challenging Context of the Pioneer Front in the Western Uplands of Cambodia

Most of the Cambodian peripheral regions have experienced dramatic changes in their land cover and land use in the past two decades. The pioneer front dynamics of smallholder farmers and the allocation of public state lands to companies through long-term economic concessions have led to forest degradation and deforestations. The peace settlement in the 1990s was followed by the allocation of degraded evergreen forestlands to demobilized soldiers in the western regions, namely, Battambang and Pailin provinces (Figure 4.1), which are mostly former Khmer Rouge stronghold areas (Diepart and Dupuis 2014). The highland saturation in the central areas of dominant rice-based farming systems and the increasing regional demand for cereals and tubers have driven massive flow of migrant smallholder farmers to these two provinces in the hope that they can possess a secured plot of farmland (Pilgrim, Ngin, and Diepart 2012). Accordingly, more than 400,000 hectares (ha) have been reclaimed between 1996 and 2010 for annual upland cash crops development.

Figure 4.1. Map of the two main regions in Cambodia with ongoing R&D operations on cropping systems for smallholder farmers in upland agro-ecosystems



Note: This map shows Kampong Cham province on ancien agricultural regions (forest reclaiming ended in the 1950s) and Battambang province, which is an area where the pioneer process ended in the early 2000s.

At the national scale, official figures report that rainfed annual upland crops (with maize, soybean, and cassava as principal key crops) soared from 120,000 ha in 2002 to more than 800,000 ha in 2013. These evolutions gave birth to a new agriculture sector alongside strong regional demands, which stimulated the development of local agro-industrial processing capacities.

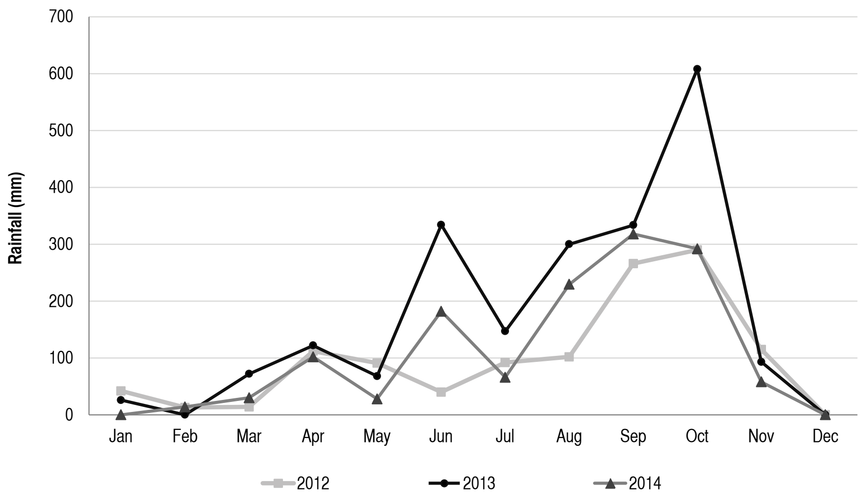
Rapid expansion of agricultural areas exerts tremendous pressure on natural resources. Environmental pressures are exerted on forest resources and biodiversity due to the people's desire to use land for agricultural purposes but without adopting any conservation plan. Soil and water resources are being degraded due to techniques that are based on intensive tillage and herbicide use. In Battambang, maize yields dropped from more than 8 tons per hectare (t/ha) without any fertilizer application after forestlands had been converted to less than 4 t/ha after 10 years of continuous cropping (Boulakia, Kong, and Eberle 2013). Soil fertility decreased due to organic matter mineralization and erosion, which adversely affects the technical performance of agricultural production and limits the possible choices of key annual crops that farmers can produce. Consequently, farmers are gradually forced to apply mineral fertilizers in an attempt to stabilize their yields; they also have to increasingly rely on herbicides to control the weeds (Boulakia et al. 2013).

In addition, cropping systems evolve based on climatic conditions. The changes in Cambodia's climate are influenced by the El Niño and La Niña phenomena, which cause frequent extreme weather events such as drought and flooding. It is projected that changes in climatic conditions would include late onset of seasons, wetter rain season, and longer and drier dry season (IFAD 2013).

These changes have already been observed in Battambang and Kampong Cham (Figure 4.2). In the past, the tropical monsoon climate gives farmers enough time to cultivate two crops per year, with the main season starting in June-July, whereas the secondary season is in February-March. However, the onset of the secondary season has become more uncertain due to the unpredictability of rainfall patterns. As a result, more and more farmers have stopped taking risks and have given up planting secondary crops such as mungbean and sesame regardless of the inherent soil fertility. Likewise, such extreme climatic phenomena, such as the flood events in 2013 and drought in 2014 in Cambodia, have affected the production of main crops like maize and cassava.

The combined consequences of depleting soil fertility and the increased incidence of pests and diseases associated with climate change are causing irregular and worsening yield performances of the short-cycle annual crops. Cassava, due to its high adaptive capacity to low soil fertility and to erratic climate conditions (due to its notably longer cycle), then became more economically attractive to farmers. Thus, most farmers adopted this crop for production, with most regions converting from maize monocropping to cassava monocropping. Eventually, a threshold was reached in 2014 when almost all of the farmers switched to cassava production. This fast conversion to cassava monocropping in the recent Western pioneer front region is similar to what happened in the "old" upland agro-ecosystems of Kampong Cham province (Central East region) in the early 2000s.

Figure 4.2. Monthly rainfall (mm) recorded at the experiment sites, 2012–2014



This case story intends to illustrate some insights on the Diagnosis, Design, Assessment, Training and Extension (DATE) methodology that was used in the uplands of Rattanak Mondul district, Battambang province in designing CA-based cropping systems. These systems helped reverse the soil resource degradation and improve and secure the rainfed production systems in those regimes with increasing irregular rains. This case shows how DATE enables farmers and researchers to (1) monitor and analyze, in real time, the rural and agricultural contexts engaged in rapid changes; (2) build up alternative cropping systems to address the agronomic and economic constraints faced by farmers; and (3) explore the needed measures to support farmers in future development programs. This chapter also proposes some points for consideration to make the approach more efficient.

DESCRIPTION OF THE ADAPTATION

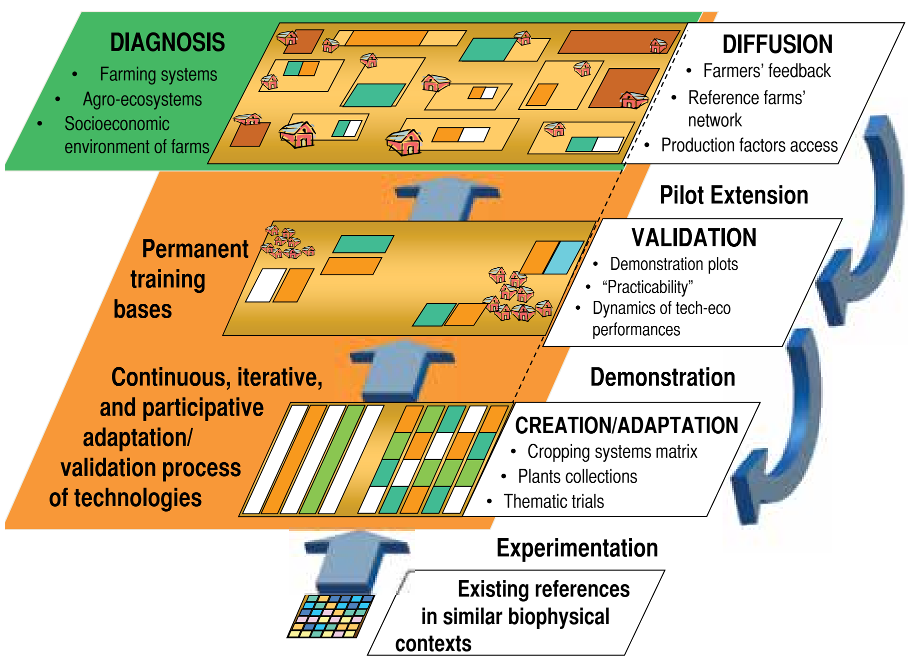
DATE: A Method for Designing CA-Based System "On-Farm, With, and For Farmers"

The DATE methodology involves a multi-stage method that combines expert knowledge source of de Novo proposals with step-by-step and participatory adjustments through practice-and-exchange loops between research experimentation, real-scale demonstration and adaptation sites in farmers' plots, and through a monitored pilot extension network (Husson et al. 2015). DATE is not only for designing innovative systems suitable for farming, it also sets a basis for a permanent training and information-sharing system among stakeholders. The DATE methodology also provides stakeholders with a tool for identifying hierarchized constraints, and for developing test of propositions or orientations that would help address these constraints.

Figure 4.3 shows how the different stages of the DATE approach are articulated in a continuous process (Husson et al. 2015).

- Stage 1 involves diagnosing (through rapid rural appraisal) the key structural elements of the agrarian context (e.g., biophysical characteristics of the different agro-ecosystems, main agricultural sector and markets, services, land-sharing system, land tenure, etc.) and the farming systems (e.g., crops and livestock systems, size, labor force and organization, off-farm activities opportunity, etc.) that are combined into a partition of farm types. This stage also involves presenting differentiated trajectories of evolution (drivers and anticipation) for the identified farms' types.
- Stage 2 is based on a field experiment that introduces, in comparison with the dominant cropping systems, CA-based alternatives that respond to similar production goals and addresses principal diagnosed agronomic constraints related to soil fertility and weed and pest control.

Figure 4.3. Stages and loops occurring between multi-stakeholders in codesigning cropping systems through DATE approach



- Stage 3 involves applying the "best bet" systems to farmers' fields. This "level" is managed for several consecutive years via research, and is conducted in close coordination with village farmer groups. At this stage, the process allows the farmers and researchers to adjust the cropping systems by working on its technical elements (varieties, tools, weeds control, etc.) and to assess its technical and economic performances in reference to farmers' local practices. This stage also serves as a training ground for farmers and technicians, and demonstrates the farmers' ability to cope with the constraints in their agricultural production under different agro-ecosystems.
- Stage 4 is based on the progressive constitution of a pilot network of farmers who are willing to test innovative technologies in their own respective plots. The activities at this stage can consist, in large part, of the initial proposal that has been introduced and adjusted through research. It can also consist of combinations of activities from traditional practices that have been modified through integrating one or few elements of the developed cropping systems (e.g., planting a new crop variety, no-tillage implementation on the sole crops residues, application of herbicides, etc.). However, this practice of "shopping" among the new technical elements and systems introduced needs to be considered carefully. This reflects the farmers' level of understanding of the introduced innovations and also reveals the kind of problems that farmers want to address and prioritize. At this stage, it may be necessary to provide farmers with incentives, although only limited nonmonetary incentive can be provided during the first two years of the collaboration. This support may involve providing farmers with cover crops seeds or access to specific contract services (e.g., direct seeding, spraying, etc.) for a real-based cost charged.

Every several years, the DATE methodology prescribes conducting a plot-level assessment of the cropping systems across contrasted climatic years. The process contributes to the improvement of the design techniques (i.e., crop management modalities and decision rules for rotation) in order to address the marked climate variability.

The process also allows farmers and researchers to observe, at the regional scale (e.g., production basin, river catchment, administrative unit, etc.), the biophysical changes in the farm and the economic changes in farm production. At the community and farm levels, DATE provides stakeholders with the elements to understand how farming systems evolve, the drivers that affect this evolution, and to what extent these evolutions alter natural resources. The process also enables researchers to collect, observe, and record multi-year data that can reveal how climate variability impacts cropping systems' performances, the condition of farm households' livelihoods, and the different types of adaptation measures that farmers use to respond to the climate variability.

This R&D process also enables the researchers to interact with farmer groups and village communities, as the researchers directly work with the local farmers at their actual farm settings using comparable production means. Through these continuous exchanges about the practical crop and farm management systems, the researchers and farmer groups are able to conceive technical proposals; they subsequently test, evaluate, and redesign these proposals. Alongside this, program implementers can identify the economic constraints that farmers face in the adoption of the cropping systems. Accordingly, the researchers and farmers are able to discuss and evaluate possible measures that can be applied to alleviate these constraints.

The following are some of the barriers that constrain farmers' access to production inputs:

1. Limited labor and mechanization (i.e., calendar of household labor force, high cost and limited supply of hired labor during peak season, limited availability of specific tools to be able to sow in crop residue and cover crop mulch and boom sprayer as an alternative to knapsack application);
2. Limited access to specific inputs (e.g., high-quality crop seeds);
3. Lack of disposable funds to acquire the needed inputs and services. This is notably constraining, particularly when crop production is subject to income flux, trade-off between funding the households' needs vs. farming input, and when the farm inputs are financed through credit (through commercial banks, micro finance institutions, etc.).

The level of investment spent on and the level of intensification adopted for crop production depend on the farmers' perceived risks and expected benefits. However, nowadays, the risks are being conditioned by the increasing climate variability and high interannual volatility of farm gate prices.

These difficulties and limitations in understanding the systemic innovations experienced by farmers are progressively addressed through continuous information dissemination and training activities delivered to individual farmers and farmer groups. Such activities include fields visits to researcher- and farmer-managed sites; documentation (through posters, leaflets, video, and so forth); and regular exchanges between farmers and research group about crop implementation and monitoring. DATE explains multi-scale and multi-stakeholders platforms that can also serve to inform policy makers and sensitize farmers in other regions with similar biophysical and/or socioeconomic features.

Status of the CA Cropping System Design and Support Measures for Extension

The agrarian diagnosis (Stage 1 of the DATE methodology) was conducted in 2009 in two communes of Rattanak Mundol, Battambang province. The results revealed that the farming systems in the area were mainly comprised of production of annual cash crops (i.e., maize), raising livestock, and off- and on-farm activities. On average, each farm household has 6 ha of farmland to work on; this farm size is considered to be medium to large scale. The common farm practices in the area were intensive soil tillage and herbicide use. They practice monocropping of maize during the main season (July to November), and plant mungbean, sesame, and maize during the preceding secondary season (April to June). Crops are grown only on a small portion of the farmland during the secondary season, often on an elevated area adjacent to the house in order to ensure on-time sowing of the main season crop (i.e., maize).

The second stage was implemented based on the data on red oxisols found in the central upland areas of Chamkar Leu district, Kampong Cham province, which the researchers have been gathering since 2004 using the DATE methodology. In 2009, two experimental plots were set up on mollisols, typical of the regional uplands, to design and evaluate alternative CA-based cropping systems for the monocropping of maize, biannual rotation of maize and cassava, and biannual rotation of maize and soybean. In the third stage, which involves applying the best-bet cropping system, the monocropping of maize was selected as the best-bet system and was tested on the plots of the volunteer farmers in the target villages. Then, a pilot extension network was developed (Stage 4) through the participation of about 100 interested farmers.

Table 4.1 sketches the progress in the cropping systems implemented through the DATE methodology in the district of Rattanak Mondul (Battambang province) between 2009 and 2014. At least four CA-based cropping systems have been validated on such mollisols:

1. Monocropping of maize with pigeon pea: maize + pigeon pea[1]
2. Biannual rotation of maize and cassava: maize + pigeon pea // cassava
3. Biannual rotation of maize and soybean: maize + pigeon pea // soybean + sorghum
4. Intensified cropping of maize and cassava: early maize + finger millet + sunhemp[2] / cassava // cassava

The succeeding subsections discuss in detail how the cropping systems can implemented.

---

1 Relayed or associated crop

2 Successive crop within the year

Table 4.1. Progression of the CA-based cropping systems design process

Period	Research		Farmer Practices	
	System	Adjustment	System	Adjustment / Reaction
2009	Application of CA-based maize monocropping	2 cover crop species for association with maize were proposed/tested	Initial diagnosis: maize (one preceded by mungbean for two successive cycles per year) was assessed to be the dominant farming system	
	Application of CA-based biannual rotation (M // S, M // C)		Limited interest of farmers; they prefer to follow the two-crops-a-year system despite the growing climate uncertainty	
2010–2012	M + PP = "best" annual combination		M + CC combination was tested with the hope of getting secondary grain/income from CC	Farmers were reluctant because of the delayed sowing of PP (i.e., 15 days after M) in M interrow
		Simultaneous sowing of M and PP with reduction in M interrow to 40–60 cm (shade and weed control)	Only few farmers reintroduced soybean; however, they faced marketing constraints (no attractive price when production volume is too limited)	CC makes the weed control method more complex, making it necessary to abandon the use of atrazine, which is massively used by farmers
2012–2014	Introduced rotation based on "dry season" cassava test with sunflower as a relay crop in late sowing (September)	M + PP sown simultaneously (bet on only one "weather slot") to achieve all sowing	Growing demand for NT implementation for the 2nd crop (i.e., main cycle) with soil plowing prior to first cycle	
	Pre-assessment of C performance during the "dry season" at 9 and 18 months growing cycles	M sown at 0.40-meter interrow yielded better results than that sown from 0.80-meter interrow after three years of testing	Some farmers started to broadcast NT sowing of mungbean in residue in early maize harvest	

Table 4.1. (continued)

Period	Research		Farmer Practices	
	System	Adjustment	System	Adjustment / Reaction
2014– to present	Test of rotations: Early M + CC / dry season Cassava (9 months) / M + CC => 2 M and 1 C in two years Early M + CC / dry season Cassava (18 mos) => 1 M + C in two years	Minimum till/strip till prior to C planting; "Flat" vs "erected" cuttings planting initiate contact on minimum till planters	Massive conversion to C in all districts (2013 < 20% surface; 2014, 60%; 2015, > 90% according to declaration of intention), complemented by intensive tillage and ridging	
			Most of the remaining M surface is under CA or under reduced tillage	Few farmers test strip tillage in C

Note: C = cassava, CA = conservation agriculture, CC = cover crop, M = maize, NT = no-till, PP = pigeon pea

Monocropping of maize with pigeon pea and biannual rotation of maize and cassava

In this CA-based monocropping of maize, pigeon pea is planted in the middle of the maize interrows. Each interrow has a distance of 0.6 meter. The crops are then fertilized using 70-30-30 nitrogen-phosphate-potassium (NPK) formulation. The P and K are all applied as basal, while about two-thirds of N is applied as a soil top dressing. After the maize is harvested in late November, pigeon pea is continually grown during the course of the dry season. The first harvest of pigeon pea is in February, whereas the second harvest is in April. Pigeon pea rapidly grows with the onset of the first rains. The pigeon pea control could be done 3–4 weeks before maize is sown in the next season.

In conventional farming practices for cassava, farmers usually till and ridge the soil. In the CA-based biannual rotation of maize and cassava, however, chisel (equipped with disc-coulters to open the mulch cover before prongs) is used as a strip tillage (prongs at 0.80-meter distance) to loosen and break up the soil on the cassava planting line. The cassava cuttings are then manually planted in a slanted position along the chiseled furrow, using an interval of 0.8 meter in between plants. The crops are fertilized using a formulation of 70-30-60 NPK. Half of K, one-third of N, and all of P are applied 30 days after planting; the remaining K and N are applied 30 days after the first application. Harvesting cassava is done manually during the dry season after 8–10 months cycle. The maize-pigeon pea association is implemented in cassava residues during the following cropping season.

Biannual rotation of maize and soybean

In this cropping system, soybean is sown at a 40-centimeter row space using a fertilizer formulation of 24-30-30 NPK. Unlike in the other cropping system, all N, P, and K are applied as basal upon sowing. Sorghum (var. pool preto) is sown at the rate of 30 kg/ha using a hand-held broadcast spreader when the leaves of the soybean start to turn yellow and fall in mid-October, which is about 25 days prior to the harvest period. The sorghum grows during the last rains of November and the soil's water reserve and is then harvested in January. The already-harvested sorghum does not completely perish during the dry season, but starts to reshoot when the first rain of the rainy season comes. The maize and pigeon are planted as mentioned above, about one month after desiccation of the sorghum cover.

Intensified cropping of maize and cassava

The early maize (using a short-cycle maize variety) is sown in mid-May using the same row space and fertilization technique as that used in cultivating normal maize. Two cover crops are used to induce macroporosity and soil structure in preparation for the cultivation of cassava. Finger millet is broadcasted a day before maize is sown at an application rate of 5 kg/ha. Sunhemp is then sown in interrow spaces 15 days after the maize crop has been planted. The early maize is harvested in mid-September, right after the remaining crops and weeds are controlled in preparation for cassava planting. Cassava cuttings can be planted horizontally along the lines that have been opened up by chisel. If the soil is too wet, then manual planting using a wooden stick is advised in order to avoid making the soil compact, which happens when a tractor or power tiller is used. The same fertilizer formulation of 70-30-60 NPK is used. However, the first application is delayed until the first rain of the rainy season occurs (usually in April). The cassava could then be harvested in July.

Farmers' Inputs in the DATE Methodology

Table 4.1 also illustrates how the DATE approach remains open to farmers' inputs, particularly in the areas of systems orientations and adjustments. Researchers must take the farmers' inputs as an opportunity to learn about the constraints that farmers face in the adoption of the introduced system, their perceptions of the innovation, and their corresponding adjustments to enable them to continue adopting the introduced innovation process. Such inputs also provide feedbacks that would enable researchers to improve on the following:

- the form of the systems (e.g., number of cycle per year, schedule of succession, variety of catch crop, calendar, crop sowing method, etc.) in order to address production goals and methods (e.g., weeds control, labor allocation and organization, etc.); and
- secondary thematic tunings (e.g., crop variety, level of applied mineral fertilizers, practical management of operations, etc.).

For example, with regard to the timing and row spacing in the pigeon pea-maize cropping system, the local farmers voiced their concerns about the following:

1. The manual sowing of pigeon pea 15 days after maize is sown in the 80-centimeter row space entails high labor cost.
2. Competition might occur between pigeon pea and maize if both crops are sowed at the same time using the planter.
3. The procedures for weed control in the pigeon pea-maize association is more difficult and labor intensive because it is not possible to use some of the active ingredients in herbicides, notably the widely used atrazine.

Thus, the researchers tested different row spaces and time of sowing on the pigeon pea with maize experimental plots. Results showed that the optimal row space and time for sowing pigeon pea is 60 cm and 15 days after sowing maize, respectively. Meanwhile, using a sowing device for planting pigeon pea could save labor cost of up to 8 man-days or USD 40/ha.

The soil of CA-based plots with mulch has significantly higher water storage capacity (than the normal plots), which is useful for storing the first rains of the rainy season. However, the amount of rainfall during the dry season is very low; thus, planting cassava late in the rainy season after maize could ultimately fail. To cope with this, the researchers and farmers tested in the experimental plot a new system that involves moving the planting schedule of cassava to mid-September.

The results of the experiment were highly appreciated by the farmers. The system was effective as strategies for the following:

1. *Climate change mitigation*. The system reduces GHG emissions as it cancels soil tillage and ridging.
2. *Climate change adaptation*. The system significantly reduces the costs of soil preparation and weed control.
3. *Climate change resiliency*. The new system has zero risk and provides the local farmers with the option of growing cassava in succession with different short-cycle crops options.

In this co-construction phase, researchers should be open to farmers' suggestions, and they should also encourage the farmers to participate in the DATE approach. This could be done by discussing with farmers the activities and strategies to be implemented in the DATE approach before the activities are actually implemented; farmers should also be involved in the evaluation process.

For instance, the success of the farmers in coping with the shorter and wetter planting season by using mungbean is quite impressive. Mungbean is a short-cycle crop, drought-tolerant, less costly to produce, and commands high market price. Farmers have stopped growing the crop in the secondary season; they have successfully broadcasted it in mid-October on the already-harvested maize plots. Immediately after harvest, mungbean is broadcasted at an application rate of 30 kg/ha, and then the plot is rolled and sprayed on the same day. The mungbean is then harvested in January of the following year.

Should the researchers assess that the farmers' inputs and practices are unsustainable in the long run, they can only comment and raise their concerns; they cannot prohibit the farmers from still practicing them. However, the interactive process does not end at this transition stage. New alternatives must be developed to integrate farmers' inputs and rationale into the new cropping patterns that, in the meantime, respect the necessary conditions for long-term agronomic sustainability. An example of which is the minimum soil disturbance combined with sufficient fresh organic matter (OM) inputs to induce positive soil organic carbon (SOC) balance.

The quality of the farmers' feedback evolves along the design process owing to their interaction with the researchers during the research and design implementation. Farmers' thought process regarding the whole design process matures—from the initial simple interest in the no-till crop practice (to save labor and cash inputs) to being actively engaged in integrating the cropping system into their practices and in adopting the catch crop, association, residue management, and others. Such attitude and behavior signify a progressive understanding and capacity to adopt and adapt to the innovation within the CA framework. The combined application of the three CA principles brings a “warranty” on the agronomic sustainability of farmers’ practices and strengthens the economic profitability of the annual rainfed crops. However, note that the change in farmers’ perceptions, their attitude toward accepting a new rationale for fertility management, and the eventual adoption of the innovation can be slow.

One of the challenges encountered in this R&D project of designing sustainable innovative cropping systems is that production structure and patterns in the pioneer front under a changing market evolve very fast. This becomes an issue when the modifications in the farms’ environment induce rapid changes in the cropping and production systems, quicker than the minimum required time for evaluating their performances and impacts on natural resources and on the farm’s productivity. This fact strengthens the need to create and maintain plots to assume the role of “technological beacon,” where key codesigned cropping systems are compared with one another for several years, alongside past and present farming practices. This method allows researchers to show and quantify the performances of the designed technologies for the following periods: (1) after a transition period where the condition of the soils progressively improved, and (2) across several successive years under varying climatic conditions.

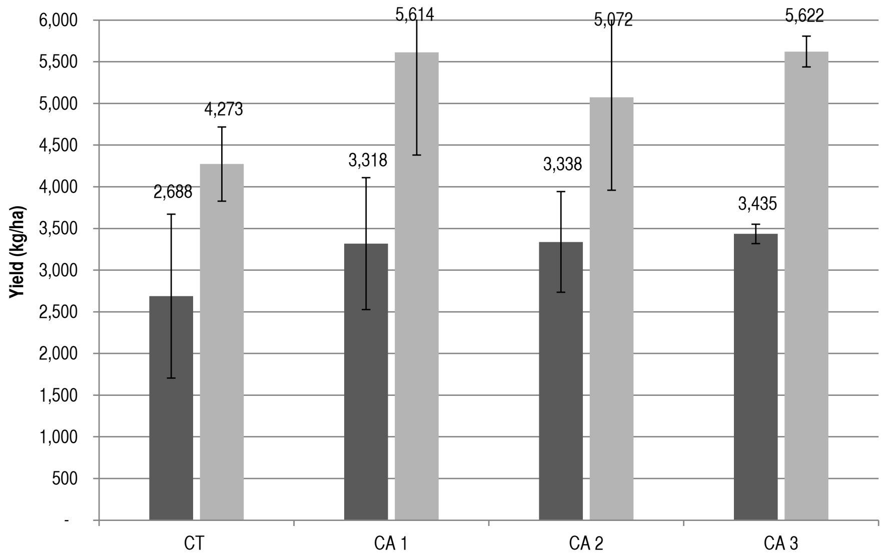
OUTCOMES OF THE ADAPTATION

Adaptation of CA-Based Cropping Systems to Drought and Flooding

Figure 4.4 shows the yield comparison, based on the average of three consecutive years (2012–2014), between conventional and CA-based innovative systems at two levels of fertilizer application. The yields were measured on a researcher-managed plot (based on real-scale elementary plot of more than 2,000 m^2), initiated in 2009, which was chosen from the target zone for its severely degraded soil condition. On the other hand, Figure 4.5 presents the gross profit margin (GPM) of the different maize crop management systems.

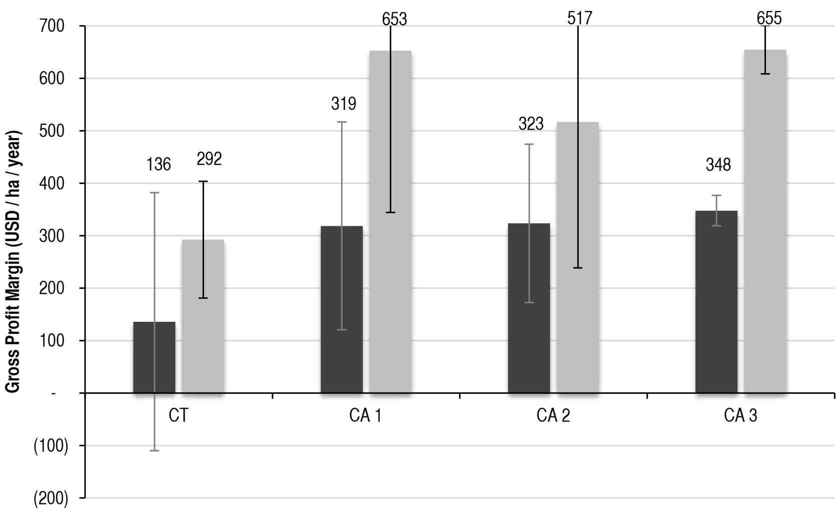
The results confirm the expected improvement in the technical and economical performances of the tested CA cropping systems. Based on the results, crop yields of those under CA increased, on average, by more than 0.5–1.0 t/ha, with GPM of USD 200–350 per hectare. Under a severely depleted soil condition, increasing the application of fertilizers provide marked benefits. These extra fertilizers, when combined with CA system, should be considered as an investment in soil capital recovery rather than as an annual extra charge.

Figure 4.4. Maize yield under CT and CA systems, 2012–2014



Notes: (1) Left bar = F1 fertilization of 70-30-30 NPK; right bar = F2 fertilization of 116-110-60 NPK (2) Yields were measured from a three-year CA practice plot with degraded and shallow mollisol. (2) CA = conservation agriculture; CT = conventional tillage (3) CA 1 = monocropping of maize; CA 2 = biannual rotation of maize and cassava; CA 3 = biannual rotation maize and soybean

Figure 4.5. Gross profit margin of maize with F1 and F2 fertilization levels under CT and CA systems, 2012–2014



Notes: (1) left bar = F1 fertilization of 70-30-30 NPK; right bar = F2 fertilization of116-110-60 (2) CA = conservation agriculture; CT = conventional tillage (4) CA 1 = monocropping of maize; CA 2 = biannual rotation of maize and cassava; CA 3 = biannual rotation maize and soybean

In addition, the CA-based cropping systems designed under the DATE have adapted better to climate change. The physical properties of the soil under CA improved; water storage and drainage capacity of the soil improved owing to the cancellation of the tillage practice. The improved water storage and drainage capacity of the CA plots also helped crop production as they helped to resist waterlogging (due to flooding) and drought. This was experienced in the October 2013 flash flood and in the 2012 and 2014 drought in Battambang. In October 2013, more than 600 millimeters (mm) of rain fell in Battambang, of which 400 mm fell in a span of 10 days, which consequently led to the flash flood. Meanwhile, although the drought in 2012 was drier than that in 2014, the latter dry spell had more severe consequences. The month of June in 2014 offered very good climate conditions for sowing; however, this was followed by 45 consecutive days of less than 100 mm of rainfall, triggering the dry spell. During these incidents, maize productivity under CA was approximately 30 percent higher than that under conventional tillage (CT). Furthermore, pigeon pea with maize can produce an additional 0.5–0.7 t/ha yield without any extra input cost, thereby enabling farmers to employ family labor capacity in low activity period while gaining additional income during the dry season.

Likewise, changing the conventional practice of growing mungbean by soil tillage, manual broadcast, and harrowing during the secondary season to manual broadcast after early maize harvest by mid-October resulted in a higher level of adaptation for better establishment, higher mungbean productivity, and better market price. With this new system, farmers can have a GPM of as much as USD 300-500/ha, as compared to a possible loss of USD 150/ha under conventional mungbean. Thus, the system not only reduces the cost and risks of farmers, it also helps to avoid soil tillage for broadcasting. Farmers prefer this better than the no-till sowing in order to reduce their production cost.

Moreover, shifting the planting schedule of cassava to mid-September (rather than at the onset of the rainy season in April), after the early planting of maize under a CA management, offers a remarkable adaptation against and flexibility to drought, rainfall variability (especially during the secondary season), and market fluctuations. The system significantly reduces the risk of crop establishment failure and the costs of soil preparation and weed control. Crop establishment failure can cost farmers by as much as USD 300–400/ha, whereas savings under CA can be as much as USD 200/ha; farmers can also save by as much as USD 50–100/ha from weed control.

In addition, flat planting without the ridging practiced in conventional management can facilitate the intercropping of short-cycle grain legumes such as cowpea. The system can be adjusted with different possible dates of harvest, according to tubers development and/or price. Harvesting cassava in mid-July (after 10 months cycle) allows a succession with maize; harvesting mid-September (after 12 months cycle) allows a succession with secondary cash crops such as sunflower, sorghum, mungbean, etc. or during the dry season (after about 18 months cycle). Aside from adaptation to the length and severity of the dry season following the cassava planting, which conditions the development of the tubers and the possibility of early harvest after 10-month cycle, such flexibility provides farmers with better cash flow, better choices of crops to be produced and marketed, and maximizes farm labor.

For instance, the yield from the production of cassava within an 18-month period is more than double than that from a 10-month cycle; this translates to a gain of 10 t/ha from harvesting dried tuber or USD 1,500/ha (price in 2014), without any additional input costs.

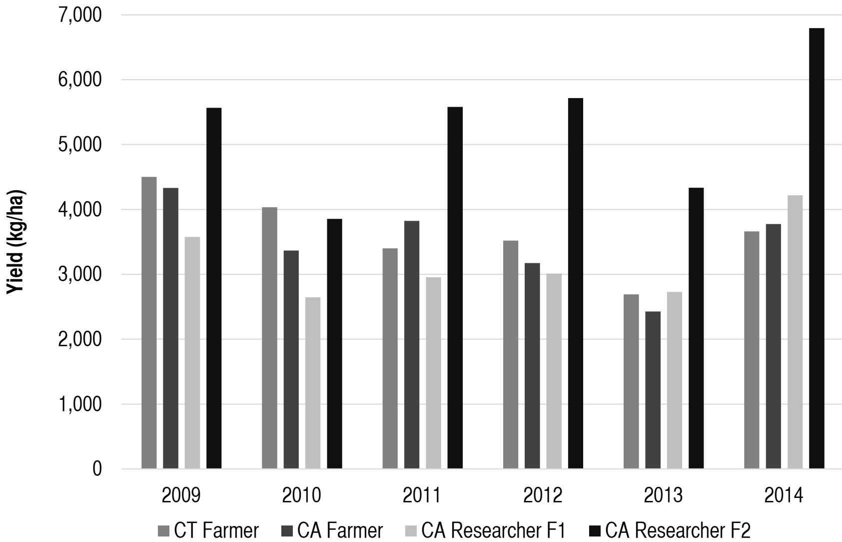
Figure 4.6 compares the maize yields from CT- and CA-based plots. Site 1 (Figure 4.6a) was initiated in 2009 on a plot with degraded soil condition, whereas Site 2, located in the same village (Figure 4.6b), started in 2010 on less shallow and depleted soil.

In Figure 4.6, *CT farmer* represents the average yield recorded on a network of 30 plots, divided among the four communities located within the 10-kilometer radius of the two experiment sites. Meanwhile, *CA farmer* represents the average yield recorded from the pilot extension network initiated and monitored by the project implementers since 2009. This set of plots had reached a stable volume of about 100 households and 300 ha in 2012, but its composition has evolved due to the high turnover of participating farmers. At this site, five plots have been continuously cropped under the CA system between 2009 and 2014.

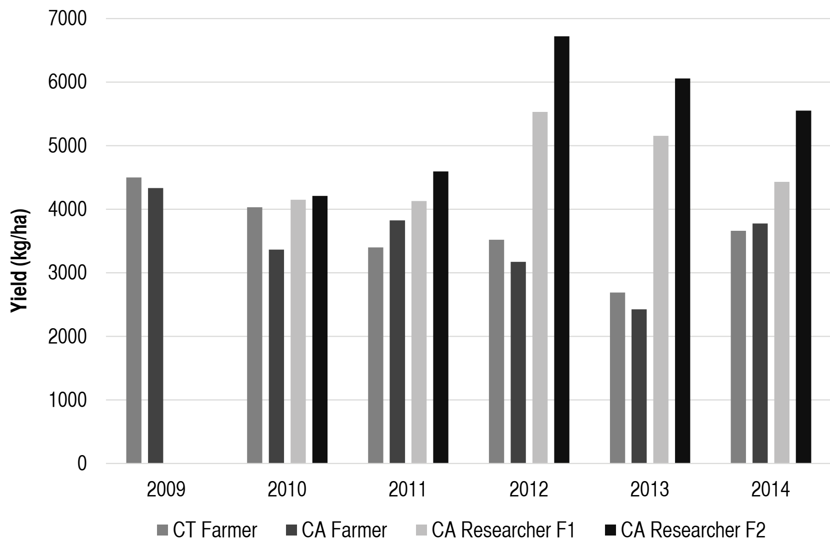
Most of the farmers adopted CA in one of their plots—usually in the worst area of the farmland—for one or two years before they decide whether or not to abandon the system. Some of the cited reasons for abandoning CA are as follows:

1. Farmers experienced technical difficulties in applying the introduced practices; notably the weed control in the first two years after suppressing tillage and banning Atrazine (a highly polluting herbicide used in CT-based management).
2. Some abandoned CA farming because there is a no market for pigeon pea, even if its production requires minimal extra labor.
3. Some reasoned that they wanted to return to the two-crop cycle in annual succession.
4. Some cited economic reasons such as they could not afford the cost of fertilizers required in CA management and the reduced profit margins during the initial years of CA farming.
5. Other reasons were not related to CA experience such as deciding to shift to perennial crop, change in land tenure, and shifting livelihood activities to off-farm activities.

Figure 4.6. Yield gap of maize between CT and CA under farmer- and researcher-managed plots, 2009–2014



a. Site 1 = maize crop planted on plots with degraded soil



b. Site 2 = maize crop planted on plots with less shallow and depleted soil

Notes: (1) CA farmer used F1 level of fertilizer application (70-30-30 NPK) until 2012; thereafter, fertilizer application was the same as that in CT; (2) Figure 4.6a compares the two farms' plots sets with the yield of CA1 in the first researcher-managed site (degraded and shallow mollisols soil); Figure 4.6b compares the two farms' plots with the yield of CA1 in the second researcher-managed site (representative mollisols soil type with average fertility conditions).

This rapid turnover, after testing CA one or two years with limited fertilizer application and cover crop biomass inputs, prevents most farmers from getting clear benefits from CA, which start to emerge only after two or three years of continuous practice. Meanwhile, for those farmers who managed to continue CA farming, their level of understanding of the rationale behind keeping crop residues on field to prevent soil erosion and to improve soil fertility have increased significantly. Crop residues that used to be burned after harvest are now being conserved or incorporated into the soil by plowing (if they could not guarantee their access to the no-till sowing service).

However, one key and urgent constraint that needs to be addressed is the availability and affordability of CA-required equipment like no-till planters and chisel. Currently, farmers are totally relying on the sowing service provided by the program. As the program proponents cannot assure the farmers that such equipment will be provided whenever they need them, farmers prefer to plow the plot in preparation for sowing either through the no-till planter or through conventional ones. At this point, they have not yet observed any clear difference between CA and CT, and thus prefer to not rely on the limited program logistic when it is time to sow. Similar bias linked to material access was observed in cassava production under CA due to a limited service offer for strip tillage with chisel equipped with mulch-cutting disc (disc coulters).

Another strategy that could greatly encourage the farmers to adopt the CA practice is the development of a market for pigeon pea grain using a threshold price of USD 400/t. Having a market for this produce can effectively make the farmers interested in CA, and consequently help them to experience the benefits of CA practice.

Meanwhile, the monitoring and analysis of the cited technical difficulties experienced by farmers are at the heart of the DATE methodology, which feeds on the process of the cropping systems design and adaptation. The feedback mechanism serves as beacons with regard to the possibility and conditions of appropriations by the various types of farmers. It orients researchers and farmers on how to create the accompanying measures to support dynamic extension and to enlarge the socioeconomic domain of diffusion, notably toward smaller farms that are too constrained to invest time and resources in CA adoption without supports. These flanking measures to ease the adoption process should rest on the farmers' access to economic production factors as the following:

1. *Money or other financial tools* to address the usual household cash flow deficit and the investment requirements (e.g., for soil fertility restoration, specific CA equipment) during the onset of the crop planting season;
2. Minimum *land tenure security,* which is a key precondition for farmers to convert from CT- to CA-based crop management;
3. Farm decision regarding *labor allocation*, which is directly influenced by farm structure. This can be improved if support (technical or financial) could be provided to producers so that they can enhance their farm organization and coordination as well as access to mechanization (e.g., individual or collective equipment, contractors' offer, etc.).

The R&D process could also be improved through developing ways to help farmers access specific technical elements that will help ease the implementation of the designed cropping systems. Initial inputs could be through improving farmers' access to cover and fodder crops seeds and access to specific farming tools such as roller-crimper, planter and seeder, boom sprayer, among others.

R&D Methodology and Linkage with Agricultural Development

Characteristics of the CA cropping systems and precautions in the design process

This section highlights the essential features of the CA-based cropping management systems and some precautions that researchers and farmers need to consider when designing such systems. In the design and implementation process, researchers and farmers need to consider two major ontological characteristics of CA cropping systems:

- CA-based systems should be viewed as a "technical object" that belongs to the "method" type, which means that they are not characterized by their proper structure and functioning scheme, such as tools and machines, but by the shape and functions they confer to a "medium" of application (i.e., the plots and its soils).
- The major and essential factor in "medium shaping" is done indirectly through the complex biological processes triggered during the implementation of the CA cropping systems. These biological processes are nurtured through the combined application of the three CA principles.

The design process focuses both on the operational sequence of crop production and on the transformation of the agro-system into a cultivated ecosystem. Farmers can give a short-term assessment of the newly developed cropping methods in terms of their capacity to produce yield (i.e., grain yield and biomass inputs) and feasibility as a crop production method. However, at this level, farmers and researchers may assess this crop production system as ineffective due to factors such as mismanaged operations (e.g., sowing, weeds control). As such, the lack of skills in implementing CA-based practices and the perceived difficulty in trying new practices can lead farmers to abandon a good system prematurely.

However, such rapid assessment still does not consider the medium- to long-term evolution of the fertility parameters and changes in the bio-aggressors regulations. During the design phase, those evolutions can hardly be forecasted; the effects can only be observed, analyzed, and evaluated after a certain period of time—a kind of "relaxation" time of the agro-ecosystem in its "oscillations" toward a new "equilibrium." By transforming the crops' environment, these evolutions modify the effect of the technical operations which, in turn, needs to be adapted along this transition phase.

Thus, the technical design process of the CA-based cropping systems (i.e., type, sequence, pattern, and modality of operations) needs to be carried out in consonance with the evolution of the biophysical elements of the field (biological diversity and function, structure, composition).

A premature evaluation is risky due to factors such as improper management and insufficient biophysical transformation of the environment and concretization of biological functionalities. In this transition phase, the technical operations should be adjusted in relation to the environment, and should engage in a continuous process of experimentation and innovation through adjusting the operations in accordance with the evolving conditions of the field. The whole process is complex; some procedures can get temporarily lost in deadlock, but it ultimately leads to simpler crop management methods owing to the increasing number and efficiency of the integrated ecological services. Designing CA-based cropping systems is a reflexive process, in which the techniques should be adjusted in accordance with and should be adapted to the biotic evolutions of the crops' environment.

The deliverables in this R&D process must be twofold:

1. the designed cropping systems at the plot level within built agro-ecosystems, and
2. the transitional technical stage(s) to be used as a simplified procedure for converting CT farming practices to CA-based crop management.

The first output involves a technical description of the crop and cover crop management systems of the different annual successions of the rotation. These recommendations are completed by introducing options and decision-making rules for adjusting the operations in accordance with the physical and/or economic conditions (e.g., climate, crop cover development, market price, etc.). Meanwhile, the second output involves specific technical guidelines to manage the conversion of cropping systems from CT- to CA-based. This second output is rarely done, which contributes to the confusion between the collaborative and complex innovation process of the cropping systems and the initial stage of the extension and development operation.

The research and design process must be continuous and should entail constant monitoring, evaluation, and adjustments in order to

1. improve the technique in accordance with the conditions of the field,
2. make the cropping systems resilient to climate change through the development of decision-making patterns that will address climatic and economic blips, and
3. integrate into the thematic adjustments of the systems the acquired knowledge on the mobilized biological processes.

Specificities of CA cropping systems and precaution in the knowledge-sharing process

When practitioners (farmers, technicians, and agronomists) shift from CT- to CA-based cropping system, their mindsets have to undergo a tremendous adjustment as to how they perceive their farm work—a shift from the direct and immediate construction of an artificial crop substratum, which is associated with a comforting (but largely illusory) perception of control, to an indirect and progressive elaboration of a field ecosystem through biological processes that are induced. Although this is favored, it remains partly controlled and largely unknown.

This change is even more difficult to operate for "pioneer" farmers who have been involved in the participatory design process because they face the risk of committing mistakes and go through the complex stages of mastering the technical steps. This apparent progression via trial and error, but framed by agronomical laws mobilized with CA principles, reinforces the perception of risk and complexity attached to any novelty. The feeling stems from the strength of any well-established and shared habits and the initial lack (in the farm environment) of technical elements needed to implement the coinvented technique.

Addressing the first type of resistance that farmers experience against the CA-based cropping system (i.e., technical difficulties in applying the introduced CA-based practices) requires changing stakeholders' perception with regard to traditional practices—from the community to administrative and policy makers' levels. Landcare, as developed and implemented in Australia and the Philippines, is an efficient approach to diffuse and infuse innovation (e.g., natural vegetative strip in Mindanao, Philippines) across farmers groups. In the meantime, it reverses vision on natural resources protection and norms for farming practices among stakeholders arranged in networks (Landcare Foundation 2009).

Alongside this, developing a favorable technical environment within farming communities could significantly encourage farmers to continue with the implementation of the introduced cropping system. In this case story, the initiatives undertaken toward this goal includes providing farmers with access to specific inputs and tools such as

- seeds of cover crops, which have to be accessible and affordable both in terms of quantity and quality; and
- specialized CA planters through the local development of a small-scale power tiller draught units (Figure 4.7a) for individual investment, and medium-scale tractor draught units (Figure 4.7b) to support the development of contractor services.

Figure 4.7. Collaborative design between the pilot farmers' network and Machine Auto Part Co., Ltd. on different appropriate scale planters

a

b

Other inputs that could be provided are inoculum for soybean, bio-pesticides, and other machinery like roller or boom sprayers. For each of these elements, the codesign phase is about refining the specification (e.g., shape, size, active ingredient, dose, etc.) of the cropping system and the socioeconomic arrangements for the supply of inputs. This duality of the "what" and "how" in the supply chain of the technical requirements should also be extended to include the classical economic production factors. In a process of co-innovation, issues such as access to money, land, and labor in relation to the variable interests, opportunities, and capacities of farms would contribute to the determination of the precise limitations of an "extension domain," and would define social pathways and institutional support for the inclusion of the poorer households. These considerations tend to set the construction of a technical innovation against one of its technical and economic "medium." In other words, if the innovation process involves needing to adjust the cropping method in order to adapt to farm structures and contexts, the improvements in productivity and ecosystemic services attached to CA-based innovations should allow for raising concurrent questions regarding the farms' context organization.

These series of remarks highlight the complex elaboration of the CA-based technical pattern. The cropping system design process has to progress in relation to the triggered biological transformations of the agro-ecosystems at the field and landscape levels; it also has to evolve through and under an evolutionary perception and appropriation of the new practices of farmers.

CONCLUSIONS

This research and development program conducted in the pioneer front of the western regions of Cambodia illustrates the capacity of CA to restore soil conditions and dramatically improve crop productivity. It proves that CA opens ways to set the technical basis of sustainable intensification of smallholder farmers' production systems. It can thus help to enhance and secure agro-industrial sectors linked to the annual crop production in the basin. However, in order for new proposals for agro-technical validation process to progress, relay research work is still needed in order to enable researchers and farmers to continuously validate, based on multi-year and multi-location assessments, the performance of the systems and their impacts on natural resources (e.g., positive balance of SOC, nutrient cycles, xenobiotic dynamic, etc.).

The DATE approach has proven to be effective in inducing a dynamic participatory design process of cropping systems. It appears well embedded, and it suits the complex evolutions of the recent pioneer front. In this context, the farms' environment is notably marked by rapid changes in its biophysical and socioeconomic conditions.

With sound choices of agro-ecological zones for implementation, this holistic approach addresses real situations representing important challenges. The complexity of the biological and cognitive changes sought for calls for an "in vivo" process conducted "on farm, with, and for farmers" established for several years. The designed techniques are composed of combinations of context-specific and context-generic features. Through the latter, channels are created to initiate the application of designed proposal from one context to another one. This can be exemplified in the case of the CA-based cassava cropping systems that had been developed in the central upland regions between 2007 and 2012 (Boulakia et al. 2013). When cassava appeared to be the next key annual crop in the western regions in 2013, designing pre-developed systems using the DATE platform was quickly achieved.

This capitalization in codesigned systems then allows for a fast reaction to the brutal changes occurring in the farm environment; it is a way to build up "antibodies" to strengthen the resistance and resilience capacity of smallholder farmers in face of external chocks.

The presented R&D methodology in this chapter offers clear benefits and provides a holistic approach for identifying technical, socioeconomic, and institutional elements for a sustainable and more inclusive intensification of the production systems of smallholder farmers. Integrating this action-research process into agriculture and rural development programs is therefore recommended in order to induce and support the shift in farmers' production patterns that would address the increasing climate variability and include the poorest farm households.

In this regard, such R&D platform could be considered as a public investment in natural resources restoration and conservation. Such perception could help proponents to develop new and shared financing mechanisms in support of conservation agriculture. This will be made easier if the presented R&D process and the expansion of this program can be clearly articulated to be proposed for adoption under public-private partnership programs in Cambodia.

ACKNOWLEDGMENT

The authors would like to express their sincere appreciation to the Southeast Asian Regional Center for Graduate Study and Research in Agriculture and the Oscar M. Lopez Center for Climate Change Adaptation and Disaster Risk Management Foundation Inc. who jointly organized the meaningful writeshop on Climate Change Adaptation in Inclusive and Sustainable Agricultural and Rural Development. Gratitude is also addressed to the writeshop coordinating team who provided comprehensive information and guidelines for writing this case story and followed up afterward. Lastly, the authors would like to thank all the technician teams for their hard work on the field in order to produce interesting results for this case study.

REFERENCES

Boulakia S., S. Chabierski, P. Kou, S. San, R. Kong, V. Leng, V. Sar, C. Chhit, and L. Séguy. 2012. "Adaptation of Direct-Seeding Mulch-Based Cropping Systems for Annual Cash Crop Production in Cambodian Rainfed Uplands." In *Proceedings of the Conference "Conservation Agriculture and Sustainable Upland Livelihoods: Innovations For, With, and By Farmers to Adapt to Local and Global Changes"* edited by D. Hauswirth, T.S. Pham, O. Nicetic, F. Tivet, D. Le Quoc, E. Van de Fliert, G. Kirchhof, S. Boulakia, S. Chabierski, O. Husson, A. Chabanne, J. Boyer, P. Autfray, P. Lienhard, J.C. Legoupil, and M.L. Stevens, 92–108. Montpellier, France/ Phu Tho, Vietnam/Brisbane, Australia: CIRAD/NOMAFSI/Brisbane.

Boulakia S., R. Kong, and M. Eberle. 2013. *Sustainable Farming to Sustain Cambodia's Future* (33-minute documentary film). Phnom Penh, Cambodia: Asia Motion and the General Directorate of Agriculture, Ministry of Agriculture, Forestry, and Fisheries of the Royal Government of the Kingdom of Cambodia.

Boulakia S., V. Pen, V. Sann, S. Chabierski, O. Gilard O. 2013. “Conservation Agriculture in Cambodia: A Triple-Win Option.” In *The Environments of the Poor in Southeast Asia, East Asia, and the Pacific* edited by A. Ananta, A. Bauer, and M.P. Thant, 159–169. Manila, Philippines: Asian Development Bank.

Diepart, J.C., and D. Dupuis. 2014. “The Peasants in Turmoil: Khmer Rouge, State Formation, and the Control of Land in Northwest Cambodia.” *The Journal of Peasant Studies* 41(4): 445–468.

Husson O., H.T. Quoc, S. Boulakia, A. Chabanne, F. Tivet, S. Bouzinac, P. Lienhard, R. Michellon, S. Chabierski, J. Boyer, F. Enjalric, Rakotondramanana, N. Moussa, F. Jullien, O. Balarabe, B. Rattanatray, J.C. Castella, H. Charpentier, and L. Séguy. 2015. “Codesigning Innovative Cropping Systems that Match Biophysical and Socioeconomic Diversity: The DATE Approach to Conservation Agriculture in Madagascar, Lao PDR, and Cambodia.” *Renewable Agriculture and Food System* 1:1–19.

IFAD (International Fund for Agricultural Development). 2013. “Cambodia Environmental and Climate Change Assessment.” *IFAD ECCA* No. 3215-KH. Washington, D.C., VA: IFAD.

Landcare Foundation. 2009. *Landcare in the Philippines: A Practical Guide to Getting it Started and Keeping it Going*. Manila, Philippines: Landcare Foundation Philippines.

Pilgrim J., C. Ngin, and J.C. Diepart. 2012. “Chapter 1: Multiple Migrations, Displacements and Land Transfers at Ta Kream in Northwest Cambodia.” In *Migration, Rural Livelihoods, and Natural Resource Management* edited by S. Hecht, S. Kandel, and A. Morales, 33–56. Ottawa, Canada: International Development Research Centre of Canada/Ford Foundation/PRISMA Foundation.

A teenage boy wading through a flooded rice field in the Philippines
Photo by Nonie Reyes, courtesy of World Bank

CASE STORY 5

LiDAR and GIS Mapping Tool as Climate Change Adaptation Measures of Farmers in Flood-Affected Areas

John Colin E. Yokingco[1], Perlyn M. Pulhin[1], and Rodel D. Lasco[1]

ABSTRACT

This case story presents the study conducted by the Oscar M. Lopez Center for Climate Change Adaptation and Disaster Risk Management Foundation Inc. (OML Center) and the University of the Philippines-Disaster Risk and Exposure Assessment for Mitigation (UP-DREAM) on how new technologies, combined with participatory approaches, can help farmers to plan and respond effectively to the threats posed by intensified flooding due to climate change. The use of light detection and ranging and geographic information systems was tested in the municipality of Apalit, Pampanga province, which is a rice-producing area in the Philippines. The research demonstrates how through using technology, farmers can determine which areas should be planted with certain submergence-tolerant rice varieties. Through this study, farmers and decision makers can effectively plan for future flooding conditions by knowing where to plant certain varieties (based on the depth and duration of floods) for optimal planting.

INTRODUCTION

Floods are one of the most frequent and recurring natural catastrophes. The destruction caused by flooding threatens and poses serious hazards to the economy, population, and environment not only in the Philippines but in many parts of the world as well. According to the Federal Emergency Management Agency of the United States, floods are the second most common and widespread of all natural disasters. They usually result from the increased amount of surface run-off due to heavy rainfall, and in some cases, from the overflowing of rivers found within an area. The increased run-off can damage properties and can even cause human casualties. In particular, floods can damage crops such as rice. Submergence inhibits the bio-chemical processes of rice crops, and can cause severe damages to the plant or even kill it (Setter et al. 1997).

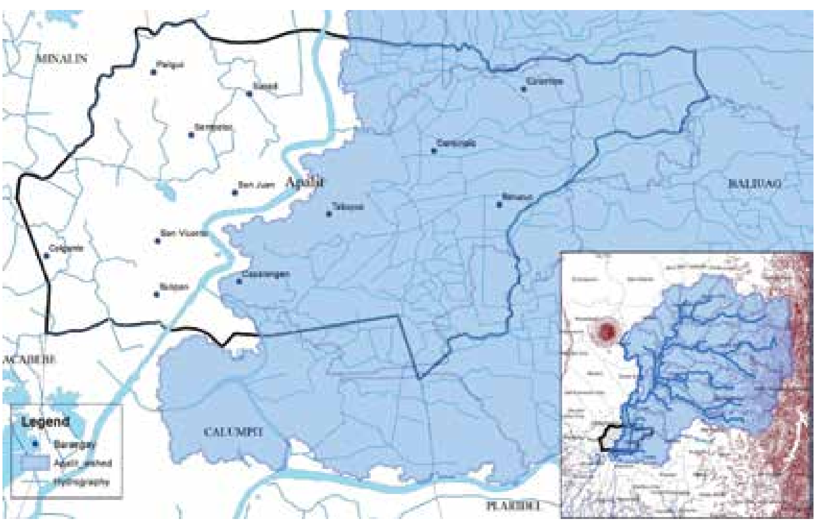
---

1 Oscar M. Lopez Center for Climate Change Adaptation and Disaster Risk Management Foundation Inc.

In the municipality of Apalit, Pampanga province in the Philippines, such problems and conditions are evident. The municipality of Apalit is one of the rice-producing areas in Pampanga. It has relatively flat terrain, with the Pampanga River running through its center (Figure 5.1). The natural source of irrigation, combined with its topography, makes Apalit favorable for rice cultivation (Figure 5.2). However, the same factors make it prone to flooding.

Figure 5.1. Map of the study site: Apalit, Pampanga

Figure 5.2. Hydrology of Apalit, Pampanga



As of 2012, about 32 percent of the Philippine population is engaged in agriculture (World Bank 2012). These farming communities are mostly located in lowland areas where irrigation can easily be found; however, this also exposes them to the effects of flooding (Zoleta-Nantes 2007). Thus, a significant portion of the Philippine population is susceptible to flooding.

The farming communities in Apalit are examples of those who are significantly affected by flooding. A large portion of the municipality is engaged in rice farming, with 11 out of 12 *barangays* (villages) producing rice. The livelihood of these farming communities is currently under threat. In 2000, about 70 percent of Apalit land area was used for agriculture. However, based on the recent land-use mapping conducted by the researchers, only about 63 percent of Apalit land area is now being used for that purpose. This decrease can be attributed to the prevalent flooding that results in a number of farming communities to convert their farmlands to other uses.

In agriculture-dominated countries like the Philippines, the extent of damages to croplands due to heavy and frequent flooding is quite high (Samantaray 2015). An average of USD 23.76 million is lost annually in rice farming due to the damages caused by flooding (Israel 2012). This number may even increase due to the effects of climate change, which is projected to negatively affect crop production, more so in subsistence sectors (IPCC 2007).

Over the years, the duration and intensity of the floods in Apalit have increased, which have inhibited farmers' cropping activities. Some farmers have resorted to measures such as reducing their cropping cycle to once a year, shifting their cropping calendar from the wet season to the dry season, or even converting their cropland to other uses such as fishponds. Consequently, this has reduced the yield and productivity of farmers.

Due to these factors, the development of strategies that will help farmers to plan effectively against climate change needs to be prioritized, particularly the development and use of submergence-tolerant rice varieties (Mitin 2009). Submergence-tolerant rice varieties exhibit characteristics, such as stem elongation when submerged, that will help the crop to survive prolonged submergence of up to 14 days (IRRI 2009). However, there are weaknesses to these rice varieties. For example, IR64-Sub1 is a submergence-tolerant rice variety that does not have the same high-yielding and pest-resistant qualities that modern varieties have. Most farmers prefer to use rice varieties that are high-yielding, pest-resistant, and have short-duration maturity (Manzanilla et al. 2010).

Farming communities in Apalit had once used the IR64-Sub1 rice variety, but it soon fell out of use. This was mainly because the variety could not compete with the yield and pest-resistant qualities of the newer varieties available in the municipality. However, due to the apparent worsening of flood conditions, there may be a need to reintroduce this variety in the municipality.

In order to reintroduce the submergence-tolerant rice varieties in Apalit, a team from the Oscar M. Lopez Center for Climate Change Adaptation and Disaster Risk Management Foundation Inc. (OML Center) and the University of the Philippines-Disaster Risk and Exposure Assessment for Mitigation (UP-DREAM) attempted to bridge the use of flood-tolerant rice varieties to its environment. Using light detection and ranging (LiDAR), geographic information system (GIS), and flood modeling techniques, rice cultivation area maps were developed in Apalit. These maps display the flooding conditions of the municipality based on the extent, depth, and duration of the floods that occur in the area. The maps also identify the areas within the municipality where submergence-tolerant and regular rice varieties would be most productive.

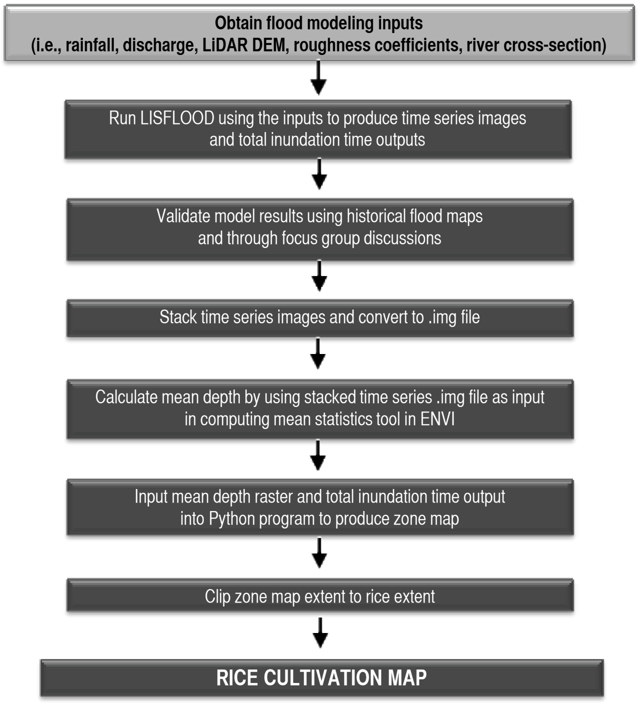
THE CCA STRATEGY

To create the cultivation maps in Apalit, the research team used LiDAR, a powerful remote sensing technology that uses rapid laser pulses sent from an airplane to map out the terrain of an area. The terrain data obtained from LiDAR is then used to create a digital elevation model (DEM). DEMs display the topography of an area and are usually used for purposes such as GIS and flood modeling. What makes this technology powerful is it can map out a large area and produce images with a resolution of 1 meter (m) and a vertical accuracy of +/– 20 centimeters (cm). This is a very high resolution, especially when compared to other remote sensing technologies such as Shuttle Radar Topographic Mission, which only has a 90-meter spatial resolution and +/– 1 m vertical accuracy. Thus, using LiDAR-generated terrain models as inputs to the flood models will produce results that are highly accurate (Brandt and Lim 2012; Sole et al. 2008).

In order to utilize the LiDAR technology fully, the research team used techniques that are specifically designed for developing cultivation maps, such as GIS and flood modeling. Flood modeling was used to characterize accurately the flood conditions necessary for developing the cultivation maps. GIS was used to relate the flood conditions to other map layers such as land use.

The first step in developing the cultivation maps is to collect the data necessary to develop the flood models (Figure 5.3). The needed inputs are rainfall data, riverine discharge, land use for the friction coefficients, and DEM of the area (Figure 5.4). In the study, the researchers used rainfall data from the Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA) Port Area rain gauge. The riverine discharge data was obtained from the Sto. Niño bridge in Pampanga. The rainfall data and discharge were based on 1:5-, 1:25-, and 1:100-year rain return scenarios. The study made use of the DEM obtained from LiDAR that had been gathered by the UP-DREAM program (Figure 5.5).

Figure 5.3. Framework for rice cultivation area mapping



Note: LiDAR DEM = digital elevation model of the light detection and ranging; ENVI = environment for visualizing images

Figure 5.4. Land-use map, Apalit, Pampanga

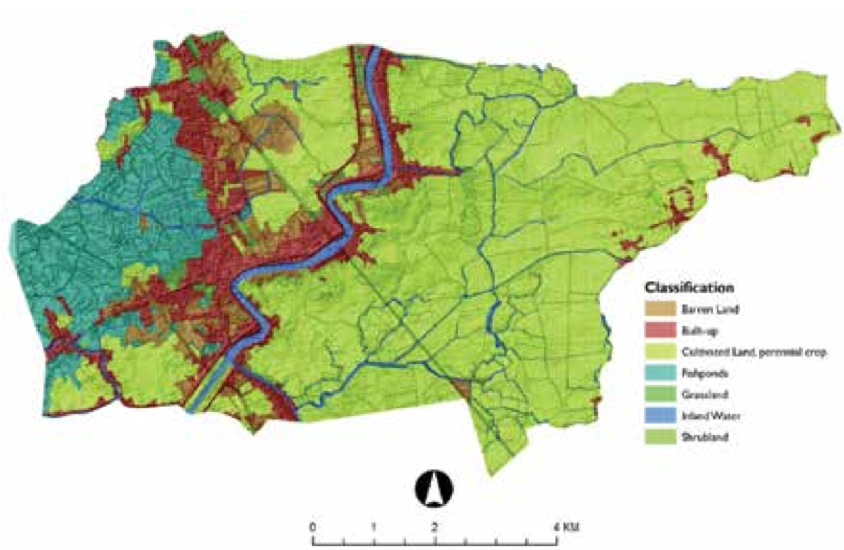
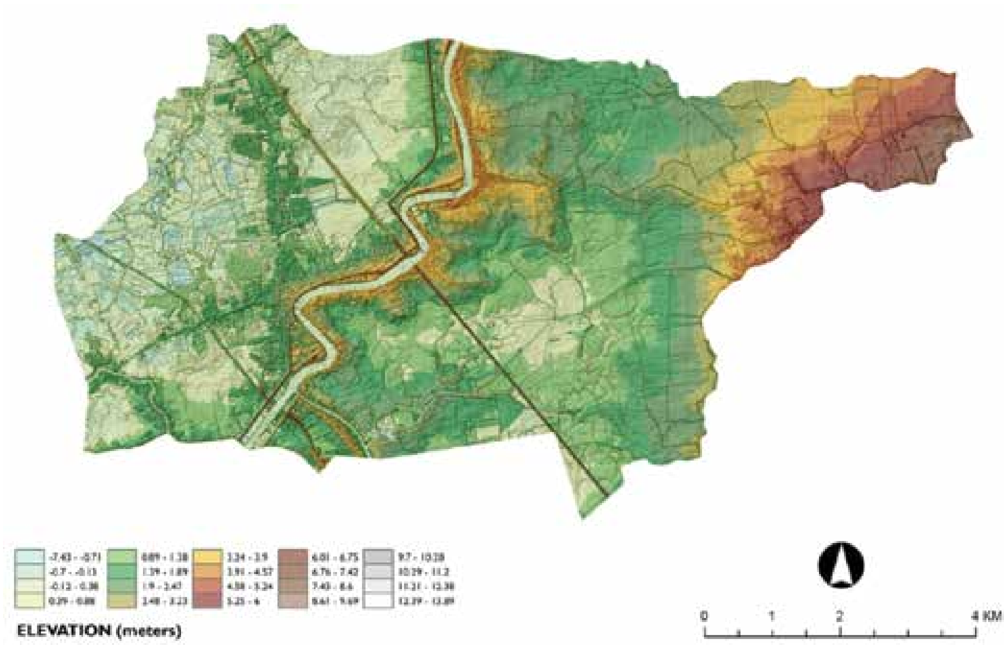


Figure 5.5. LiDAR-based digital terrain model



The researchers then used LISFLOOD-FP to model the floods. LISFLOOD-FP is a flood modeling software that can model the behavior of the flow of floodwaters on the surface as well as within a channel such as a river or stream. The software does this by computing the flow per cell in a DEM as a factor of the cell's friction value, water slope, and local water acceleration. The amount of water that runs through the model comes from the rainfall and discharge data, the friction values come from the land use, and water slope is derived from DEM. The main outputs that the LISFLOOD-FP generated in the study, which were then used for the cultivation map, were (1) time series images that depict the flood extent and depth at different time intervals, and (2) a map displaying the total inundation time within the area.

The outputs obtained from LISFLOOD-FP were then validated through focus group discussions (FGDs) and through comparisons with historical floods. The FGDs were conducted not only to validate the models, but also to gain insights on the current rice varieties that farmers use in the municipality. The information gathered from the FGDs with farmers included their experiences in cropping activities and the rice varieties they use (Table 5.1).

Table 5.1. List of local rice cultivars and their characteristics

Name of Variety	Type of Rice Variety	Cost (PHP/kg)	No. of Days to Maturity	Yield (cavans/ha)	Plant Height (cm)
NSIC-RC216 (Tubigan 17)	Irrigated lowland	1,200–1400/40 kg	110	90–120	96
PSB-R10 (Pagsanjan)	Drought-tolerant, irrigated lowland	1,200–1400/40 kg	90	110–130	77
NSIC-RC222 (Tubigan 18)	Irrigated lowland	1,200–1400/40 kg	90	90–100	101
Hybrid (SL-8H)	Irrigated lowland	4,800/15 kg	120	160	118
NSIC-RC290	Saline-tolerant	1,200–1400/40 kg	90	–	–
IR64	Submergence-tolerant	–	110	130–140	105
NSIC-RC150	Irrigated-tolerant	1,265/40 kg	110	5	96

Note: Cavan is used in the Philippines as a unit of dry capacity. One cavan is equal to 50 kg.

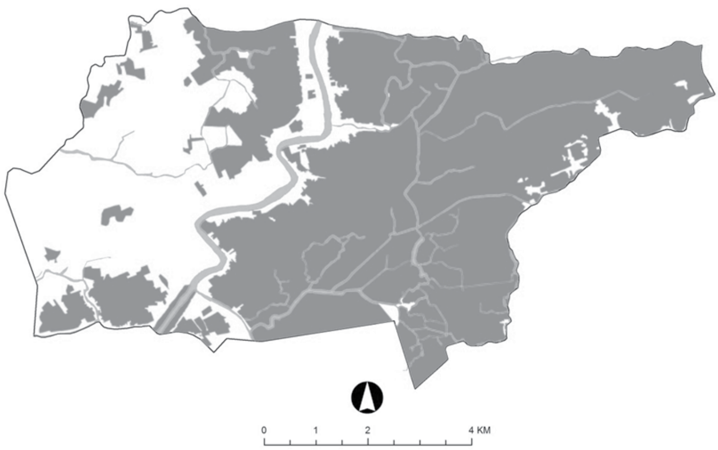
After validating the results, the time-series images were then stacked together using a stack simulation program in order to produce an image in .img format. A single file of an .img image contains all the time-series images obtained from LISFLOOD-FP that are stacked one on top of the other. In the study, the .img file was then processed in environment for visualizing images (ENVI) using its statistics sum tool in order to derive an image that displays the mean depth of inundation per area in Apalit. The researchers then used this mean depth image, along with the total inundation time map, as inputs to a python program to create a zone map that shows which areas can be used for rice production based on flood depth and duration (Table 5.2). The depth value of 20 cm used for the zoning is the threshold at which common rice varieties can survive when submerged (Mackill et al. 2010). Likewise, the duration of seven days is based on the duration at which common rice varieties can survive when submerged (Salam, Biswas, and Rahman 2004).

The zone map was then further processed in a GIS where its extent was clipped based on the current rice cultivation areas (Figure 5.6). The resulting map shows the final product, which is the rice cultivation map. Using GIS, the total area of the cultivation zones was calculated, the values of which were used to assess how extensively certain varieties are needed.

Table 5.2. Zone values

Zone	Conditions	
	Depth (cm)	Mean Total Duration (Days)
1	≥ 200	≥ 7
2	≤ 200	≥ 7
3	≤ 200	< 7
4	≥ 200	< 7

Figure 5.6. Rice cultivation area



Note: The areas shaded in gray represent the rice cultivation area.

CURRENT OUTCOMES

Figures 5.7, 5.8, and 5.9 show the cultivation maps for the 5-, 25-, and 100-year rain return scenarios, respectively. In particular, the figures show the areas within the municipality where specific varieties can be planted. As flood depth and duration increase, certain rice varieties have to be used (Figure 5.10).

Areas within Zone 3 could use common non-submergence-tolerant varieties. Zones 2 and 4, on the other hand, would be conditional areas. Zone 2 would require varieties that can survive only short periods of submergence but with deep water depths; thus, submergence-tolerant varieties are recommended for this zone. Zone 4, on the other hand, would require varieties that can survive long submergence periods, but with shallow water depth; perennial varieties and regular varieties are therefore recommended. Submergence-tolerant varieties would be needed in Zone 1 (Figure 5.11).

Through the FGDs, the flood conditions displayed in the maps were verified (Table 5.3). The results of the FGDs verified that the lower east sides of Apalit experience the deepest and longest submergence periods. These areas include Barangays Tabuyuc, Capalangan, and Sucad. Also, according to the farmers, the NSIC-Rc150 variety (Tubigan 5.9) fares well with submergence.

Figure 5.7. Five-year flood rice cultivation classification

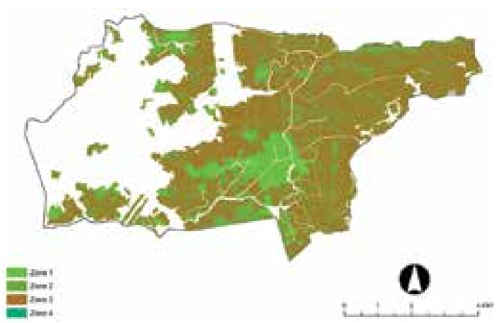


Figure 5.8. 25-year flood rice cultivation classification

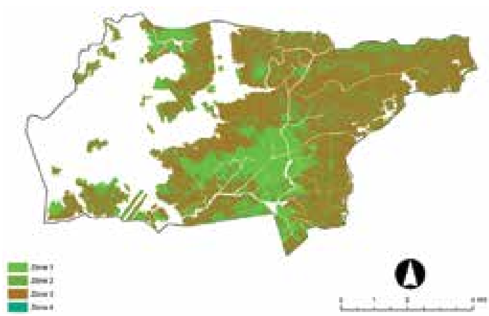


Figure 5.9. 100-year rice cultivation classification

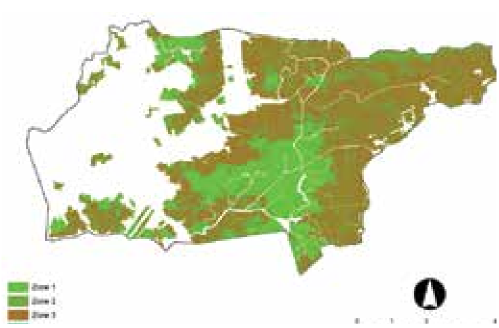


Figure 5.10. Recommended varietal type and characteristics per cultivation zone

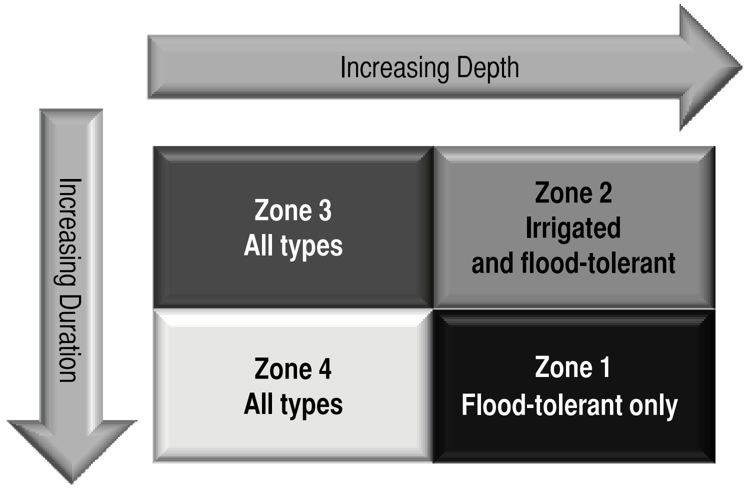


Figure 5.11. Zone classes and their flood depth and duration

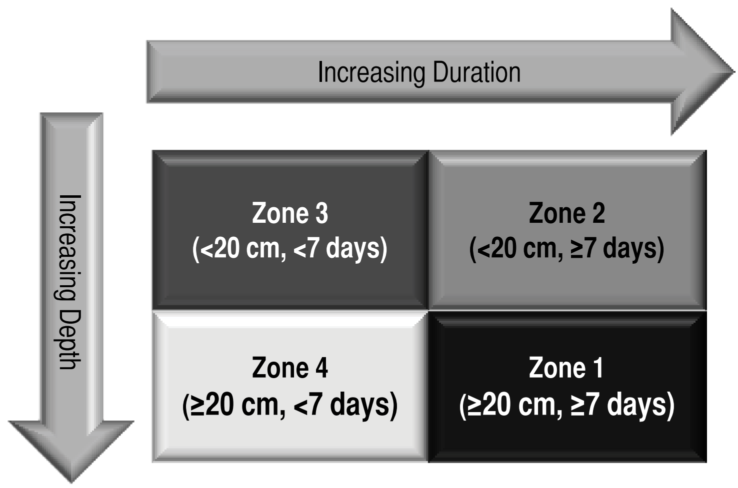


Table 5.3. FGD flood validation

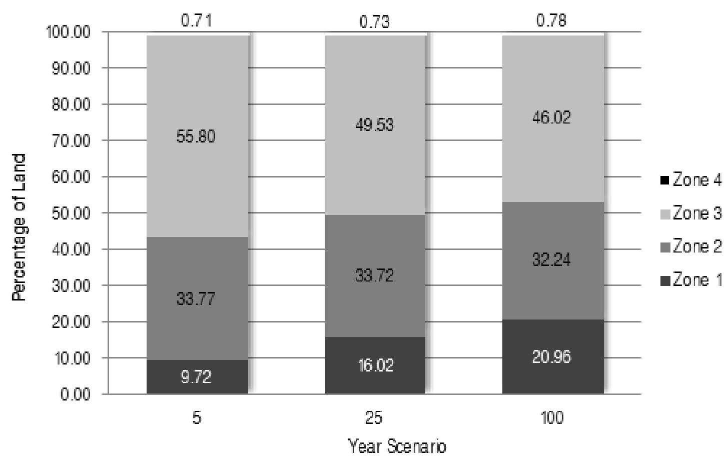
Indicator	Villages East of the Pampanga River				
	Balucuc	Calantipe	Cansinala	Capalangan	Tabuyuc
Depth of flood (average)	–	–	Above head/ Chest-deep	Chest-deep	Neck-deep
Frequency of flooding (annual) e.g., mostly during monsoon season	August to October				
% rice affected by flooding	80% (not high)				
Submergence period	1 month	–	1 month	1 month	1 month
Most severe flood event/s	Ondoy and Habagat				
Submergence period	1 month	–	2 weeks	1 month	2 weeks
Responses/ adaptation measures	Fish farming, rat hunting, adjustment of cropping calendar				

Table 5.3. (continued)

Indicator	Villages West of the Pampanga River						
	Paligui	Sampaloc	San Juan	San Vicente	Sucad	Sulipan	Colgante
Depth of flood (average)	Chest-deep	Waist-high	Above head (farmland), None (street)	Knee-high	Negligible (northern area) above head	–	Knee-high
Frequency of flooding (annual) e.g., mostly during monsoon season	August to October						
% rice affected by flooding	90% fishpond; 5% rice fields during rainy season	70%	Urbanized	Urbanized	60%	50%	50%
Submergence period	3 months (stagnant water)	3 months	–	–	60% 5–6 months	1 month	4 months (low-lying village)
Most severe flood event/s	Ondoy and Habagat						
Submergence period	6 months	6 months	–	1 week	1 month northern area/ 5–6 months (60% of Sucad)	1 month	4–7 months
Responses/ adaptation measures	Fish farming, rat hunting, adjustment of cropping calendar						

The total area of cultivation areas that can still use regular varieties would decrease as rainfall intensity increases. In the five-year rain return scenario, 55.80 percent of the municipality can still use the regular variety. This percentage would decrease to 49.53 percent in the 25-year rain return scenario, and would finally fall to 46.02 percent in the 100-year return scenario. Conversely, as rainfall intensity increases, the number of zones that needs to use submergence-tolerant varieties would increase. Approximately 9.72 percent, 16.02 percent, and 20.96 percent of the municipality would need to adopt submergence-tolerant varieties (i.e., NSIC-Rc150) in preparation for the 5-, 25-, and 100-year rain return scenarios, respectively. The area of Zone 2 would remain consistent in any rain return scenario, with values ranging from 32%–34%. The areas in Zone 4, on the other hand, would be negligible (Figure 5.12).

Figure 5.12. Area percentages of zones for each rain-return scenarios



SUMMARY AND PROJECTED OUTCOMES

Cultivation maps in the municipality of Apalit, Pampanga province were created in order to bridge the gap between technologies (i.e., submergence-tolerant rice varieties) to its environment (i.e., flood-prone area). By employing a powerful technology such as LiDAR to create cultivation maps, the use of submergence-tolerant rice varieties could be maximized through the description and display of the exact areas where they can be planted appropriately. The participation of farmers in the creation of such cultivation maps is also important since they are the ones who have the experience in using the rice varieties. Farmers' inputs, especially in terms of which newer varieties should be used, need to be taken into account in planning for climate change adaptation measures. The current varieties they use could be compared to submergence-tolerant varieties in order to make a more comprehensive recommendation that could include those varieties that are already available in the area. For instance, during the FGDs, the farmers shared that NSIC-Rc150 can thrive under submerged conditions.

The maps and methods used in this study could aid decision makers and farmers in maximizing the productivity of their croplands under changing climatic conditions. The areas that require adaptation strategies, such as switching to other rice varieties, can be easily and accurately identified with the use of powerful technologies such as LiDAR.

In the case of Apalit, these maps will be handed to the municipal agricultural office and will then be shared to the local farmers. As such, farmers will be informed of the zoning classification of their area and of the rice variety recommended for each zone. The municipal agriculture office and rice farmers could then stock and begin using the suggested rice varieties.

Submergence-tolerant varieties such as IR64-Sub1 could also be reintroduced to the local farmers in Apalit. Once the rice farmers are informed and subsequently start using the suggested varieties, cropping activities could be monitored to determine if there are any differences in yield. Accordingly, the accuracy and effectiveness of the rice varieties recommended for each zone could be evaluated, and cropping activities could then be improved.

The research presented in this chapter could be used as a basis for further studies in other lowland rice-farming areas. Future studies could include other factors such as flood velocity and soil quality to further enrich the zoning and varietal recommendation.

In summary, this study shows how certain tools could be used to assess the areas where certain rice varieties can be planted. It could also lead to follow-up studies on the selection and development of appropriate rice varieties toward rice adaptation mapping and resilience farming.

ACKNOWLEDGMENTS

This study was done as a part of the project Flood Inundation Modelling Using LiDAR and GIS of the OML Center. The authors wish to acknowledge the following individuals and organizations: Mr. Luigi Toda of the OML Center, who headed the development and execution of the project, and without whom this story would not be possible; the municipal government of Apalit, Pampanga, who allowed the study to be conducted in their municipality; the Department of Science and Technology and UP-DREAM, particularly Dr. Enrico C. Paringit, for the technical guidance, LiDAR and discharge data, and for allowing us to use their software; the National Mapping and Resource Information Authority for sharing their boundary data; and PAGASA for the rainfall data.

REFERENCES

Brandt, S.A., and N.J. Lim. 2012. "Importance of River Bank Floodplain Slopes on the Accuracy of Flood Inundation Mapping." Paper presented at the International Conference of Fluvial Hydraulics: "River Flow 2012," 5–7 September 2012, San Jose, Costa Rica.

IPCC (Intergovernmental Panel on Climate Change). 2007. *Climate Change 2007: Impacts, Adaptation, and Vulnerability*. Cambridge, UK: Cambridge University Press.

IRRI (International Rice Research Institute). 2009. "Climate Change-Ready Rice." Accessed on 12 February 2014. http://irri.org/index.php?option=com_k2&view=item&id=9148:climate-ready-rice&lang=en

Israel, D. 2012. "Typhoons, Floods, and Droughts: Regional Occurence and Value of Damages to Rice Farming in the Philippines." *PIDS Policy Note* No. 12. Makati City, Philippines: Philippine Institute for Development Studies.

Mackill, D., A. Ismail, A. Pamplona, D. Sanchez, J. Carandang, and E. Septiningsih. 2010. "Stress Tolerant Rice Varieties for Adaptation to a Changing Climate." *Crop, Environment & Bioinformatics* 7: 250–259.

Manzanilla, D.O., T.R. Paris, G.V. Vergara, A.M. Ismaila, S. Pandeya, R.V. Labios, G.T. Tatlonghari, R.D. Acdac, T.T.N. Child, K. Duongsila, I. Siliphouthone, M.O.A. Manikmas, and D.J. Mackill. 2010. "Submergence Risks and Farmers' Preferences: Implications for Breeding Sub1 Rice in Southeast Asia." *Agricultural Systems* 104(4): 335–347.

Mitin, A. 2009. *Documentation of Selected Adaptation Strategies to Climate Change in Rice Cultivation*. Quezon City, Philippines: East Asia Rice Working Group.

NSCB (National Statistical Coordination Board). 2010. *2010 Census of Population and Housing*. Quezon City, Philippines: National Statistics Office.

Salam, M.A., P. Biswas, and M.A. Rahman. 2004. "Rice Research and Development in the Flood-Prone Ecosystem." Proceedings of the International Workshop on Flood-Prone Rice Systems in Gazipur, Bangladesh. Laguna, Philippines: International Rice Research Institute.

Samantaray, D., C. Chatterjee, R. Singh, P. Gupta, and S. Panighry. 2015. "Flood Risk Modeling for Optimal Rice Planning for Delta Region of Mahanadi River Basin in India." *Natural Hazards* 76(1): 347–372.

Setter, T.L., M. Ellis, E.V. Lureles, E.S. Ella, D. Senadhira, S.B. Mishra, S. Sarkarung, and S. Datta. 1997. "Physiology and Genetics of Submergence Tolerance in Rice." *Annals of Botany* 79(1): 67–77.

Sole, A., L. Giosa, L. Nolè, V. Medina, and A. Bateman. 2008. "Flood Risk Modelling with LiDAR Technology." *Flood Recovery, Innovation, and Response* 1: 27–36.

World Bank. 2012. "Employment in Agriculture (% of total employment)." Accessed 26 May 2016. http://data.worldbank.org/indicator/SL.AGR.EMPL.ZS

Zoleta-Nantes, D. 2007. "Flood Hazards in Metro Manila: Recognizing Commonalities, Differences, and Courses of Action." *Social Sciences Diliman* 1(1): 60–105.

A Thai rice farmer transferring rice from a combine harvester to a truck
Photo by Thierry Falise, courtesy of ILO Asia and the Pacific

CASE STORY 6

Climate Change and Civil Society Planning

The Case of Kularonghai Field in Northeast Thailand

Vichien Kerdsuk

ABSTRACT

Kularonghai field, an area located in Northeast Thailand, is the jasmine rice belt of Thailand. This area is highly sensitive to climate variability, and thus highly exposed to climate risks. In particular, droughts and flooding have affected the rainfed rice production in this area, with damage costs estimated to be at an average of 45.5 percent of a household's total productivity. About 77 percent of the farm households in Kularonghai field are vulnerable to extreme climate events, whereas only about 23 percent are considered climate-resilient.

Throughout history, farmers have adapted to the climate-induced environmental changes in the area. The adaptation strategies adopted by Kularonghai farmers include autonomous adaptation approaches and on-farm and off-farm measures implemented at the household level. However, despite these mechanisms, Kularonghai farmers are still exposed to climate risks, and some of the adaptation measures that they currently implement may no longer be effective under future climate conditions.

Raising the awareness of a community to the impacts of climate change can drive different stakeholders to collaborate and develop a civil society plan for climate change adaptation (CCA) in order to enhance the community's robustness and resilience to the effects of climate change. Accordingly, the different stakeholders in Kularonghai field adopted this approach; they developed a three-year strategic plan and integrated climate information into the CCA planning process such that the local policy makers and planners in Kularonghai field can develop feasible and effective measures to address the foreseen effects of climate change on the farming communities.

---

1 Research and Development Institute, Khon Kaen University, Thailand

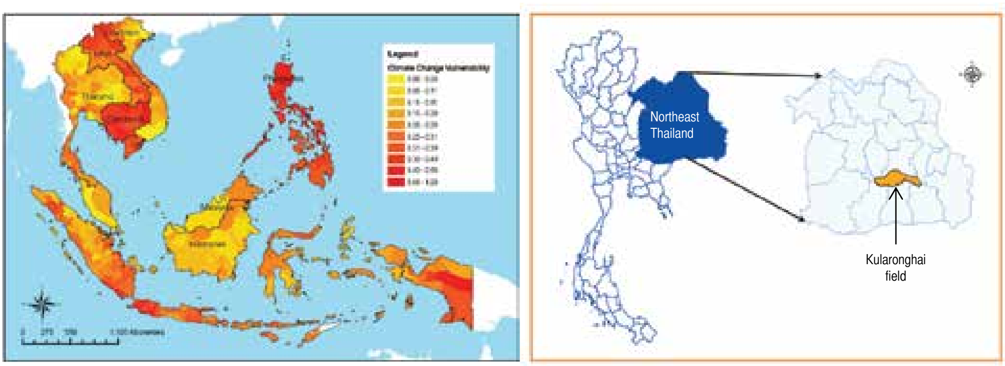
INTRODUCTION

Southeast Asia is a region that is vulnerable to the hazards or stressors caused by climate variability. Kularonghai field in Northeast Thailand is one particular area that is highly exposed to such hazards (Figure 6.1) (Yusuf and Francisco 2009). Kularonghai field has an area 336,000 hectares and covers five provinces: Roiet, Surin, Sesaket, Mahasalakam, and Yasoton. Most of the land area in Kularonghai field is used for rice production, with 60 percent of the rice production devoted to growing jasmine rice (KDML105).

Land-use changes can cause an imbalance between the existing natural resources and society's demand for resources. For one, many water resources in Southeast Asia have deteriorated in terms of quality and quantity, leading to water shortages during the dry season and lack of water catchment during the rainy season. In recent years, flood occurrences have become more frequent in the region, which have consequently damaged agricultural areas and caused devastating effects on local communities. The low-income group, whose livelihoods are highly dependent on natural resources, should therefore acknowledge the current situation and work together as a community network to combat such threats.

The residents of Kularonghai field are mostly composed of commercial farmers who are engaged in rice production and cater to both the national and international markets. Farmlands are generally medium-sized, and only a single crop is produced each year using mechanized and modern technologies. A formal organization exists in the area to support farm operations. The main source of income of Kularonghai farmers come from production and sale of rice. Accordingly, their incomes are primarily used to support the basic needs of their families, which include rice for household consumption. The rice they purchase for household consumption is usually cheaper and of different quality and texture from the rice they produce. Because the natural forest in the area has already deteriorated, it can only provide farmers with limited alternative source of food and income (Kerdsuk, Kerdsuk, and Sukchan 2005).

Figure 6.1. Climate change vulnerability mapping in Southeast Asia and Kularonghai field



Climate risks are not new to the farmers in Kularonghai field and in the lower basin of Mekong River. Throughout history, they have adapted to the environmental changes due to changes in climate; as a result, their adaptation strategies for managing such risks have evolved over time. The strategies and specific measures that these farmers have employed over the years are generally similar across the village or community, although there are also a number of important differences.

The major climate risk concerns of farmers vary from location to location, depending on the geographical characteristics of the farmland, farming practices of the community, and the local climate features. Kularonghai field farmers have identified two main phenomenal climate hazards in their area:

1. dry spell during the rainy season because such phenomenon damage rice seedlings, and
2. flooding during the latter part of the rainy season or before the harvest period, which severely affects their rice yield.

This case story focuses on (1) the impacts of climate change on the farming communities in Kularonghai field, (2) their vulnerability to these impacts, and (3) how they adapted to the phenomenon through the development of the civil society plan for climate change adaptation (CCA).

DESCRIPTION OF THE ADAPTATION

This section discusses the participatory action research (PAR) project for CCA conducted in Meuang Bua district, amphoe Kastvisai, Roiet province, Thailand.

Meuang Bua district is one of the districts located in Kularonghai field where the livelihood of most residents is rice farming. However, the agricultural system in this area is exposed to climate hazards, particularly to flooding and drought; it is also highly vulnerable to the effects of climate variability. It is predicted that the risk exposure of the community's livelihood and agricultural system would be higher under future climate scenarios (Kerdsuk and Kerdsuk 2013).

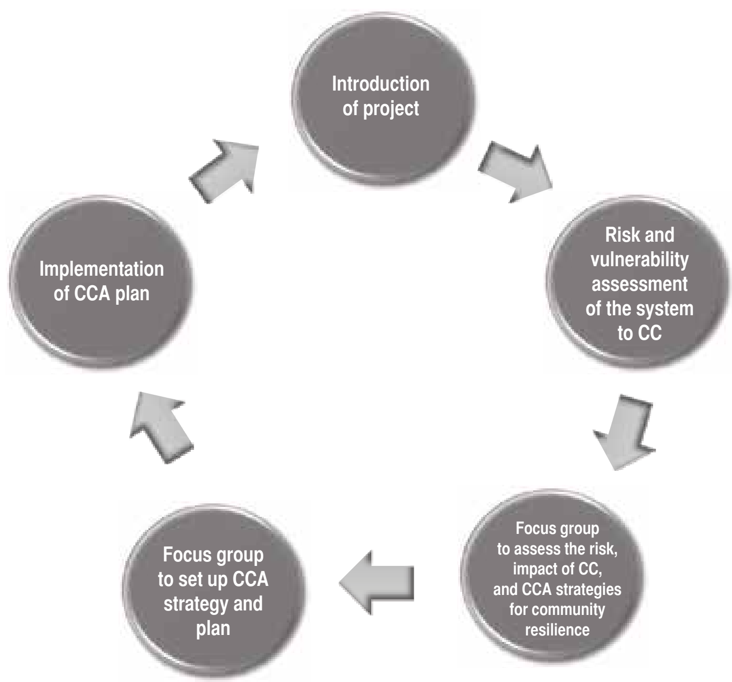
The PAR project conducted in Meuang Bua district aimed to help the farming communities improve their resilience to the effects of climate change. The project was implemented by a research team from Khon Kaen University, in collaboration with the local government of Meunang Bua district (i.e., Meuang Bua council and administrators), the village leaders, and civil society and women's groups in the area.

In the project, the project researchers used science-based knowledge and tools (e.g., flood and drought risk maps, infrastructure map, climate information based on the weather data set of the climate model—the ECHAM4-A2 GCM downscaled by PRECIS regional climate model, etc.) in the conduct of the following activities:

1. Flood and drought risk mapping of Kularonghai field,
2. Impact assessment of climate change on jasmine rice production in Kularonghai field,
3. Risk and vulnerability assessment of Kularonghai farmers to current and predicted changes in climate conditions, and
4. Strategic planning of Meuang Bua municipal district for CCA.

The first three activities served as inputs to the civil society planning for CCA of the district. In general, civil society planning for CCA is a community-based strategic planning in response to the threats imposed by the current and foreseen climate changes. It is grounded on science-based knowledge that integrates the current and foreseen climate risks into the whole community planning process in order to ensure that CCA measures will be effective and feasible under current and predicted climate changes. It is an interdisciplinary and collaborative effort among the different stakeholders (i.e., academe, the local community, and the local government) that ensures community ownership, and aims to enhance the community's robustness and resilience to the effects of climate change. Figure 6.2 illustrates the development process of the civil society planning for CCA.

Figure 6.2. CCA planning process of the civil society



Note: CC = climate change; CCA = climate change adaptation

Flood and Drought Risk Mapping

The project researchers conducted a flood and drought risk mapping of Kularonghai field to determine the risk exposure of the farmers under current climate conditions. Results show that the flood risk exposure in the area is medium to high, although more areas in Kularonghai field are assessed to be at medium-risk (Figure 6.3). Meanwhile, Figure 6.4 shows that Kularonghai field faces low- to high-risk drought scenario, although the high-risk areas are small.

Figure 6.3. Flood risk map, Kularonghai field

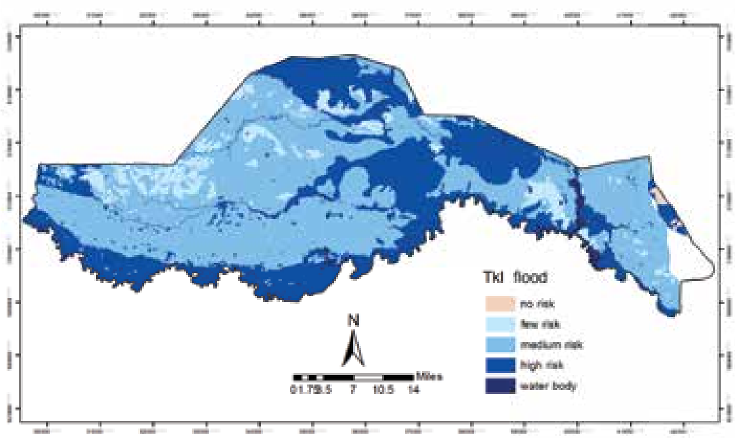
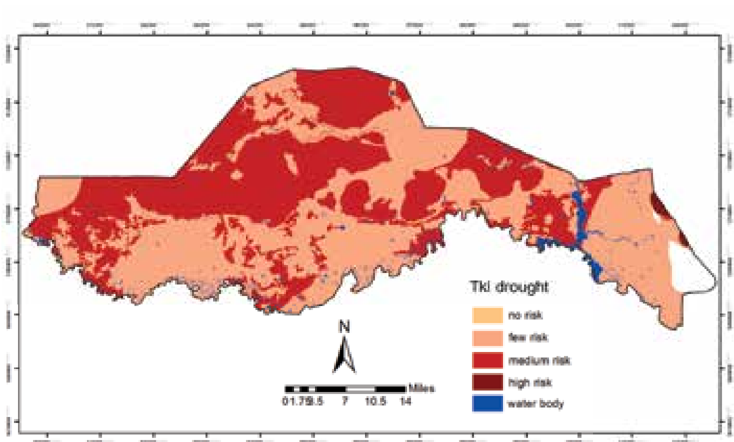


Figure 6.4. Drought risk map

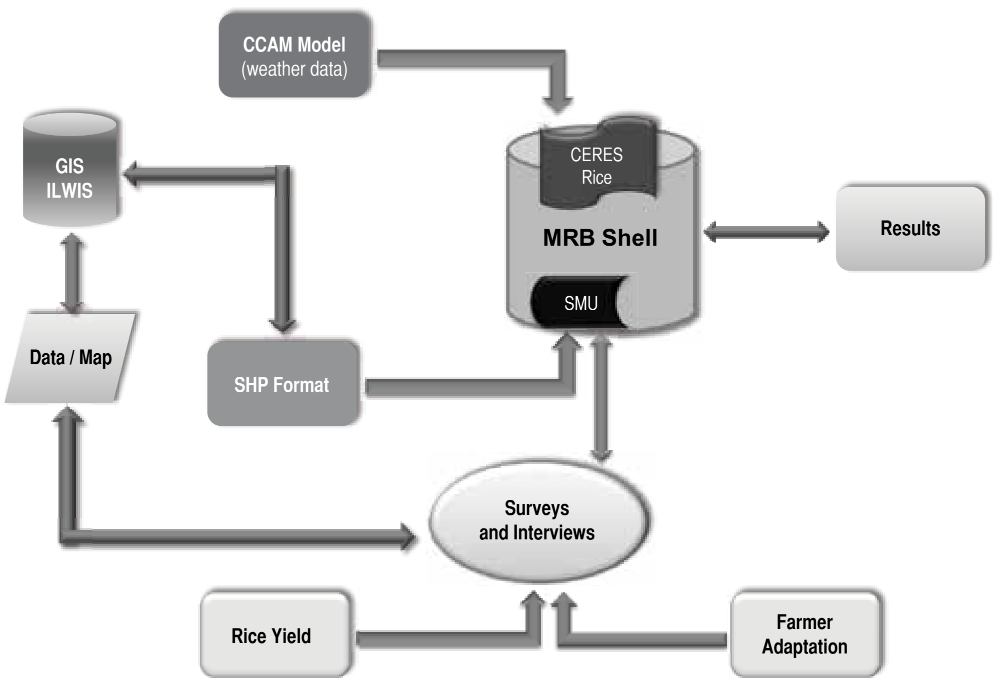


Impact Assessment of Climate Change on Jasmine Rice Production

The project researchers evaluated the impact of climate change on the jasmine rice (KDML105 rice) production in Kularonghai field by using the CERES Rice model, which is a model of rice crop growth and development as affected by soil and weather conditions. The model was then inputted into the MRB shell software to link the model to a spatial database. Using weather data for different periods in Kularonghai field, the researchers developed models that simulate the impact of climate change on jasmine rice production. Figure 6.5 shows how the impacts of climate change on jasmine rice production can be used using the MRB Rice shell structure.

Jasmine rice production was modeled with the use of a simulated weather data from the Conformal Cubic Atmospheric Model (CCAM), a type of climate model, and covered three time periods (i.e., 1989–1989, 2040–2049, and 2060–2069).

Figure 6.5. Modular structure of MRB-Rice shell



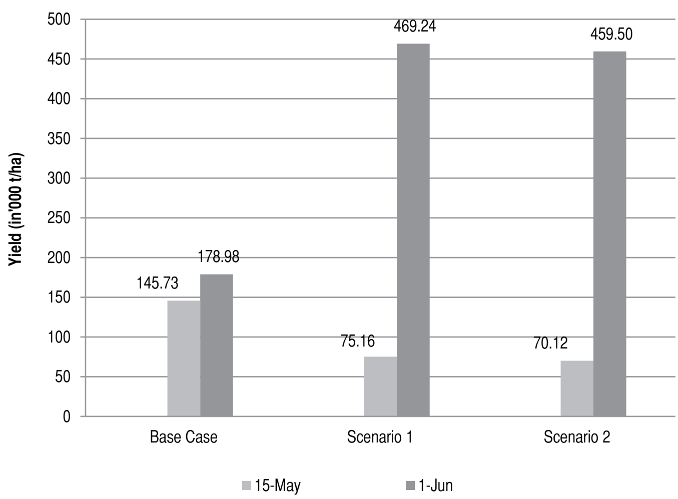
Note: CCAM = Conformal Cubic Atmospheric Model; GIS-ILWIS = integrated land and water geographic information system; SHP = shape file data format; SMU = Simulation Mapping Unit

Specifically, the simulation model has the following assumptions:

1. *Rice production*. Jasmine rice would be grown under direct seeding; yield would be measured on May 15 and June 1.
2. *Scenarios*. Three climate scenarios were developed using CO_2 level and air temperature as the parameters in the model. These two parameters are critical in the photosynthesis of crops, and thus to agriculture production. The data on daily temperature (minimum and maximum temperature) was inputted into the CERES-Rice model. The scenarios developed in the simulation are as follows:
   - Base Case Scenario (1980–1989) – actual CO_2 level was 330 parts per million (ppm) during the period (IPCC 1990 as cited by Barrett 2000)
   - Climate Scenario 1 (2040–2049) – predicted climate condition during the period, with CO_2 level at 495 ppm (1.5 times higher than that in the base case scenario)
   - Climate Scenario 2 (2060–2069) – predicted climate condition during the period, with CO_2 level at 660 ppm (2.0 times higher than that in the base case scenario)

Based on the results, climate change would have a positive impact on the jasmine rice production in Kularonghai field in the future. In Climate Scenario 1, rice production would be higher than that in Climate Scenario 2. Likewise, total rice yield would be significantly higher on the 1 June planting period than on 15 May planting in both Climate Scenarios 1 and 2 (Figure 6.6) (Kerdsuk, Kongton, and Jintrawet 2004).

Figure 6.6. Yield comparison of Jasmine rice (KDML105) (15 May vs 1 June)



Note: Base Case = actual CO_2 level in 1980–1989 at 330 ppm; Scenario 1 = predicted climate condition in 2040–2049, with CO_2 level at 495 ppm; Scenario 3 = predicted climate condition in 2060–2069, with CO_2 level at 660 ppm

Risk and Vulnerability Assessment of Kularonghai Farmers

The project implementers also assessed the risk exposure and vulnerability level of Kularonghai farmers to climate change. A total of 632 farm households in Kularonghai field were interviewed based on a multiple set of criteria on sensitivity, risk exposure, vulnerability, and coping capacities of the farmers to the impacts of climate change. In particular, the farm household's economic condition, dependence on agricultural production, and coping capacity to climate impacts served as proxies for each criterion; each set of criteria was explained by multiple indicators (Figure 6.7 and Table 6.1).

Based on the results, under normal climate conditions, farm households in Kularonghai field can be categorized as follows:

1. low-risk group (8.8% of farm household in Kularonghai field),
2. moderate-risk group (61.6%), and
3. high-risk group (29.6%).

Figure 6.7. Risk and vulnerability assessment analysis

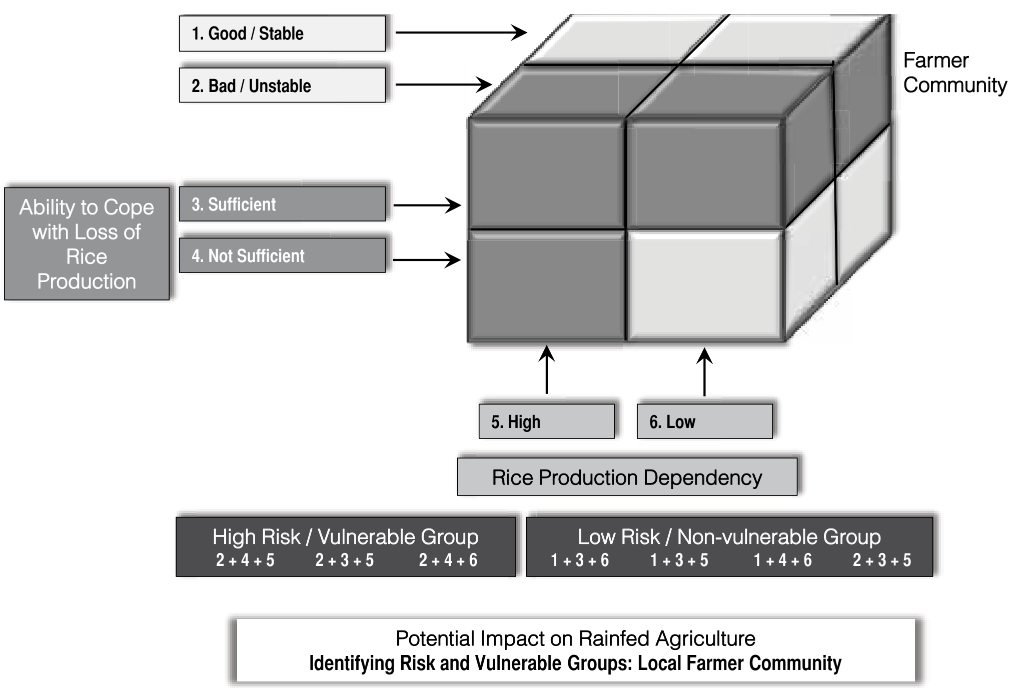


Table 6.1. Criteria and indicators in the vulnerability assessment

Criteria	Indicator	Measurement	Scoring	Min Score	Max Score	Weight
HH Economic Condition	Sustained HH consumption	$\frac{\text{Total HH consumption}}{\text{Total HH production}}$	< 1 = 0 ≥ 1 – 1.2 = 1 > 1.2 = 2	0	2	1
	Sufficient production resources	Total production resources (sufficient vs insufficient)	Sufficient = 0 Insufficient = 1	0	1	2
	Debt vs Total HH savings	$\frac{\text{Debt}}{\text{Total HH savings}}$	0 = 0 > 0 – 0.2 = 1 > 0.2 = 2	0	2	1
TOTAL				0	5	
Coping Capacity	Ability to cope with CC impact	$\frac{\text{Total HH consumption + Total cost of production}}{\text{Total HH saving + Total off-farm income + Extra income}}$	≤ 1 = 0 > 1 – 1.3 = 1 > 1.3 = 2	0	2	1
	Food security (capacity to have reserved food)	$\frac{\text{Total food consumption}}{\text{Reserved rice + Preserved food + Natural product}}$	≤ 1 = 0 > 1 – 1.3 = 1 > 1.3 = 2	0	2	1
	Access to external support (source of fund)	Sufficient / Insufficient / Not available	S = 0 I = 1 NA = 2	0	2	1
TOTAL				0	6	

Table 6.1. (continued)

Criteria	Indicator	Measurement	Scoring	Min Score	Max Score	Weight
On-Farm Production Dependency	Income diversification (capacity to have off-farm livelihood to support HH requirements)	$\frac{\text{Total HH consumption}}{\text{Fixed off-farm income}}$	≤ 1 = 0 > 1 – 1.5 = 1 > 1.5 = 2	0	2	2
	Food security from on-farm production	$\frac{\text{Total food consumption}}{\text{Total rice production + Natural product}}$	≤ 1 = 0 > 1 – 1.3 = 1 > 1.3 = 2	0	2	1
TOTAL				0	4	
			Low risk		0	6
			Moderate risk		>6	12
			High risk		>12	18

Note: CC = climate change; HH = household

As discussed in the previous sections, the climate change-related hazards affecting the rainfed rice production in Kularonghai field are drought and flooding. These incidents have affected rice production in the area at an average of 45.5 percent of the total household's productivity. When this factor was applied to the risk analysis as a proxy for the climate impacts, the number of farm households exposed to the risks of extreme climate events accordingly changed. About 7.6 percent of the total farm households in Kularonghai compose the low-risk group (as opposed to the 9% under normal climate conditions); moderate risk, 50 percent (normal, 62%); and high risk, 42 percent (normal, 29%) (Figure 6.8).

Meanwhile, the vulnerability of rainfed farmers was assessed based on the sensitivity of the farmers' livelihood to climate impacts. The risk profile of farmers under normal climate conditions were then compared with that under climate-stressed conditions. The analysis shows that 77 percent of the total surveyed households in Kularonghai field are vulnerable to extreme climate events, whereas only 23 percent can be considered as climate-resilient (Figure 6.9).

Figure 6.8. Percentage of farming communities exposed to climate risks in Kularonghai field

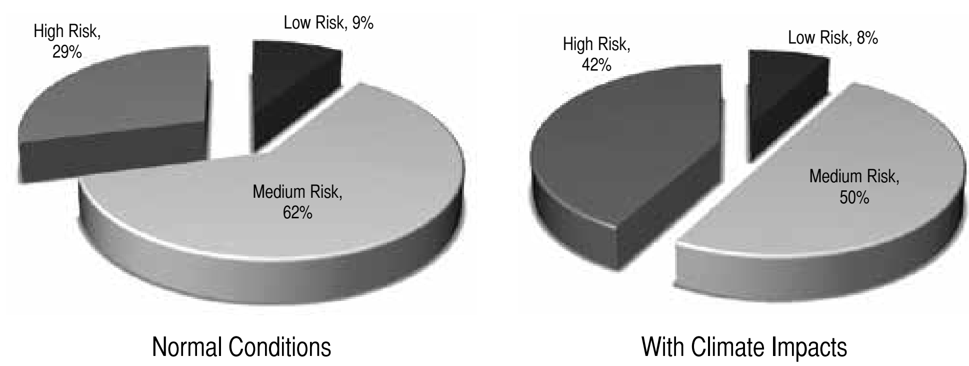
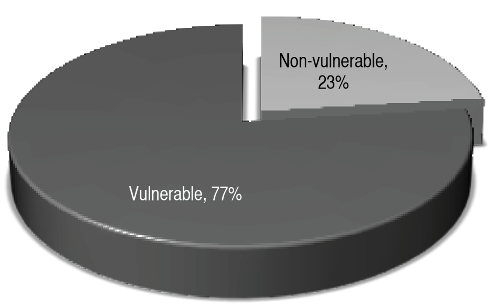


Figure 6.9. Percentage of Kularonghai field farmers vulnerable to the effects of climate change



Based on the assessment, majority of the farm households' livelihoods may not be sustainable in the long run under future climate conditions (should they fail to adapt to the effects of climate change), since most of them are engaged in rice production. Moreover, most of the vulnerable households are deep in debt; thus, should extreme climate events become more frequent, these farmers will not be able to recover from their debt condition and may consequently shift to non-agricultural activities (Kerdsuk, Kongton, and Jintrawet 2004).

Farmers' Climate Change Adaptation Measures

All of the simulation models in Kularonghai field point toward scenarios with higher temperature, higher amount of precipitation, and stronger storm intensities during the rainy season. *Adaptation* and *mitigation* are two approaches that can help alleviate the effects of global warming. *Climate change mitigation measures* are suitable for adoption in the energy and transport sectors. Meanwhile, *climate change adaptation measures* are more appropriate for communities, especially for farmers since their land is an important resource that needs to be conserved and protected so that their livelihoods will be sustainable.

Based on the survey results among the 632 farm households, the implementation and effectiveness of the adaptation measures used by Kularonghai field farmers differ depending on the location and geographical characteristics of their farmland (Kerdsuk, Kerdsuk, and Sukchan 2005). Farmer adaptation strategies include on-farm and off-farm measures that are implemented at the household level. Almost all of the farmers' adaptation measures can be considered as autonomous adaptation.[1]

The adaptation strategies employed by the farm households mainly focus on reducing their sensitivity to climate variability. Such measures include improving water and crop management, adjusting planting schedules, using different crop variety, adopting multiple crop/integrated farming, and engaging in livestock activities. Some of the farm household respondents have also suggested the need to further improve their current adaptation strategies so that they could better cope with future climate conditions. Establishing an early warning system, which can be implemented by the government, will also help farmers to better plan for climate impacts (Table 6.2).

1 Autonomous adaptation is an adaptation approach that does not constitute a conscious response to climatic stimuli but is triggered by ecological changes in natural systems and by market or welfare changes in human systems (also referred to as spontaneous adaptation).

Table 6.2. Adaptation measures of farmers to manage climate impacts, Kularonghai field

Adaptation Strategies			
Improve Water Management	Improve Crop Management	Change Planting Techniques	Shift Livelihood Activities
Household Level			
Build farm pond	Adjusting planting schedule of rice	Change planting method from rice transplanting to direct seeding	Raising livestock
	Change in rice variety	Integrated farming	Seasonal/personal migration
	Grow alternate crops between rice seasons	Use mobile machinery instead of animal and human labor	Harvest natural products
	Adopt multiple cropping system		Grow eucalyptus tree
	Change cropping pattern (i.e., in-season rice to double-rice field)		Catch fish in trap pond
	Grow field in paddy field		Off-farm income and non-farm enterprise
Community Level			
Manage water with small-scale irrigation, embankments			Promotion and adoption of sufficiency economy

Civil Society Planning for CCA

In the study done by Chinvanno and Kerdsuk (2012), the authors analyzed the community development strategies employed by the local communities in Thailand in response to the effects of climate change. The authors concluded that policy makers and planners need to recognize that CCA is an integral part of development at multiple levels—at the community, regional, and national levels. Adaptation need not always be planned by central government agencies, and then implemented through a top-down approach. Adaptation planning can also be effectively mainstreamed into the community development planning process. A top-down adaptation approach that frames sectoral strategies and plans can be supplemented by a bottom-up approach in order to build community resilience. The community plan could focus on specific actions that address current risk or development needs while factoring in the current and predicted effects of climate change.

As previously mentioned, the farmers' adaptation strategies in Meuang Bua district are mainly geared toward reducing their individual farms' sensitivity to climate impacts; similarly, most of the measures are considered autonomous adaptation measures. However, some of the CCA strategies—if adopted individually—may no longer be effective or suitable under future climatic conditions. This is because climate change is a complex issue, and addressing its effects requires mutual and interdisciplinary collaboration among different sectors. Multi-stakeholder coordination is thus an important part of the mechanism that would help resolve this issue.

The civil society plan for CCA that was developed in the project is based on a three-year strategy plan. A total of 34 CCA projects have been considered for implementation with the aim of increasing the resilience and robustness of the community to climate hazards. The CCA measures considered have been integrated into the six strategic plans of the Meuang Bua district as follows (Table 6.3):

1. Administrative and service development strategy;
2. Infrastructure development strategy;
3. Education and cultural development strategy;
4. Social, revenue generation, and sufficiency economy development strategy;
5. Public health, natural resource and environment conservation, and community scape development strategy; and
6. Community capacity building development strategy.

Due to the annual budgetary limitation of the Meuang Bua municipal district (MBMD), the proposed CCA projects have been divided into three periods: short- , medium-, and long-term. The MBMD is capable of financing the proposed projects listed in the short-term plan; funding for the medium- and long-term projects, however, would need to be sourced from the state agency and from other funding agencies.

Table 6.3. Proposed CCA projects included in the strategic plan of Meuang Bua municipal district

CCA Plan/Project	Project Goal/s	Period		
		Short	Medium	Long
Administrative and Service Development Strategy				
Disaster warning system	To monitor and disseminate critical climate information to communities	√		
Natural disaster aid project	To provide relief and rehabilitation operations for communities affected by natural disasters	√		
Infrastructure Development Strategy				
Improvement of water release system in flood-prone areas by installing culverts at Sieow River and Toa River and Ban Nongore (Moo 10) and by adding ridge in Toa River	To help address flood problem on the north of Ban Nongore (Moo 10)	√	√	
Installation of culvert at the 11th km of Road No. 214; water from the weir at Ban Somran (Moo 3) would flow through Moo 5 to relieve the blocked water way in Road No. 214. The problem in this area causes flooding in Kumtung area.	To help relieve flood problem in Ban Kumtung (Moo 5)	√	√	
Installation of culvert in the following areas: (1) two points in the area between Rongchangtai bridge and Tao bridge, (2) one point in Ban Namdaeng-Nangnang Chaiyarat field, and (3) one point in the area between Tao bridge and Ban Nam Dang junction	To help address flood problem by increasing the water released from paddy fields	√	√	
Construction of reservoir in areas owned by the local government e.g., Pon Namtang (Moo 2), Pon Yangarm (Moo 3), Non Noktha (Moo 8), Non Sang (Moo 13), and Non Epad (Moo 4)	To augment water supply for agricultural purposes to help address water shortages during the dry season		√	√

Table 6.3. (continued)

CCA Plan/Project	Project Goal/s	Period		
		Short	Medium	Long
Dredging of public swamp (Nong Ngo) at Ban Nongore (Moo 10),	To augment water supply during the dry season	√	√	
Dredging of monkey cheeks (Kaem Ling) in Tao River at two points: (1) Tao Klang area at Moo 11 (3.2 ha), and (2) Tao Tai or Wang Go area at Moo 10 (2.4 ha)	To augment water supply during the dry season To help address flooding in the area	√	√	
Dredging of Sieow River and Toa River to restore its original depth (width = 30 m; depth = 5–6 m)	To help address flood problem during rainy season and water shortages during dry season in Meuang Bua district (especially the repeated flooding in Ban Nongore, Moo 10)		√	√
Dredging of each branch canal of Sieow River and Toa River	To help address flood problem during rainy season and water shortages during the dry season in Meuang Bua district		√	√
Construction of a canal from Sieow River to Tao River that would help distribute water to the dry areas in the western side of Meuang Bua district (Moo 3); this canal would be parallel to the Kaset Visai occupation college road	To help address water shortages during the dry season in the agricultural areas		√	√
Construction of weir in Sieow River at Ban Nong Ore (Moo 10),	To help address flooding in Wanghang area To serve as water storage area for agriculture during periods of dry spell		√	
Construction of a water gate in Sieow River and Tao River	To improve water administration (flood and drought administration)		√	√
Acquisition of feed pumps	To help supply water to agricultural communities during dry spells		√	

Table 6.3. (continued)

CCA Plan/Project	Project Goal/s	Period		
		Short	Medium	Long
Removal of eucalyptus tree in the public areas of Pon Namtang, Pon Wa Ngarm, Non Noktha, and Non Ejan	To clear areas and convert lands for cash crop farming; this would help increase the income of the local community	√		
Implementation of electricity pump project in the areas encompassing the Sieow River: (1) Wang Fang Dang, Wang Tao, and Wang Jok to Ban Samran (Moo 3), (2) Ban Loa Ngam (Moo 9), and (3) dry area in the western of Meuang Bua district	To help address water shortage during dry spells		√	
Implementation of electricity pump project; this will supply water from the middle of Tao River (Torn Kloi area) to Pak Lam Nam Tao (distance of about 10 km)	To help address water shortage during dry spells		√	
Implementation of electricity pump project; this will supply water from Wang Fang Daeng to the Land Development Department's channel, Pon Nam Taeng, and Ponwangam	To help address water shortage during dry spells	√	√	
Adjust canal level from Moo 4 (Ban Pon Ngern) to Moo 3 (Baan Samran) and Moo 2 (Pon Namtang)	To help address water shortage during dry spells in Moo 4 and Moo 3	√	√	
Expand electricity coverage for agriculture project	To decrease petrol expenditure of farmers in their agricultural activities in order to encourage farmers to grow another crop for crop diversification	√	√	
Set up farm ponds	To help address water shortage during dry spells	√	√	
Supplement water supply by importing water from Chi or Mekong River to Sieow watershed	To help alleviate water shortage during dry spells by augmenting the water supply sourced from the watershed			√

Table 6.3. (continued)

CCA Plan/Project	Project Goal/s	Period		
		Short	Medium	Long
Education and Cultural Development				
Sufficiency economy project	To promote sustainable occupational development in community	√		
Social, Revenue Generation, and Sufficiency Economy Development Strategy				
Community occupational development of Meuang Bua project	To promote the establishment of occupational groups, who will be trained in other livelihood sources and nominated to participate in study tours that would enhance their existing knowledge on their area of trade	√		
Establishment of sufficient economic learning centers in Meuang Bua district	To promote knowledge sharing and establish community learning center for the development of sufficiency economy	√		
Promotion of agricultural occupational development project	To promote agriculture knowledge and occupation	√	√	
Promotion of good livestock raising	To augment household income from current rice cultivation To help reduce risk exposure of farming communities to the impacts of climate change	√	√	
Adoption of appropriate cropping systems suitable to a particular area in order to increase farming communities' resilience to the impacts of climate change (e.g., adoption of flood- and drought-tolerant rice varieties)	To promote adoption of cropping systems suitable to the topography of the area and for climate variability	√	√	
Promotion of organic farming	To decrease the use of chemical fertilizers, to mitigate global warming, and to promote use of organic fertilizers	√	√	

Table 6.3. (continued)

CCA Plan/Project	Project Goal/s	Period		
		Short	Medium	Long
Public Health, Natural Resources and Environment, and Community Scape Development Strategy				
Dengue hemorrhagic fever project	To control and prevent spread of dengue hemorrhagic fever	√		
Avian influenza project	To control and prevent spread of avian influenza To encourage knowledge transfer to farmers that would promote self-protection against diseases	√		
Promote and support community afforestation at river banks and public areas	To help address drought and flood problems	√		
Natural resource conservation project for youth	To raise awareness and consciousness among the youth with regard to natural resource conservation, energy conservation, and global warming mitigation	√	√	
Community Capacity Building Development Strategy				
Community potential development project	To empower the community by encouraging training and study tours about CCA strategies	√	√	

Note: CC = climate change; CCA = climate change adaptation; HH = household

OUTCOMES

Impact of Climate Change on Jasmine Rice Production

Under future climate change scenarios, farmers would have to grow rice before the month of June. It is predicted that in Kularonghai field, similar to the rest of the world, climate would be warmer and likely to be wetter. The trends of the climate simulation show that there would be greater amount of precipitation, and storms would be more intense during the rainy season. Consequently, flooding would be more frequent. Although the climate simulation models show that rice yields under future climate conditions would be higher than those in the present, the increase in the flood incidents would actually decrease farmers' rice yield.

Risk and Vulnerability of Farmers

The past and present effects of climate change have increased the risk exposure and vulnerability of farming communities to climate hazards. The results of the vulnerability assessment in Kularonghai field have shown that 77 percent of the farm households are vulnerable to extreme climate events, whereas only 23 percent can be considered climate-resilient. Majority of the livelihoods of the local communities in Kularonghai field are at risk since their main source of livelihood is rice production. Moreover, most of the vulnerable households are deep in debt; if climate change is predicted to cause more frequent incidents of extreme climate events, then these farmers would most likely be unable to recover from their debt condition, and may even leave farm production and shift to non-agricultural livelihood activities.

Thus, both the government and nongovernment sectors should establish measures that would reduce the risk exposure of these farming communities. They should also prioritize the most vulnerable groups in their CCA development efforts. CCA measures should cover flood protection and water supply security. If farming communities in Kularonghai field would fail to adapt to the effects of climate change, the proportion of vulnerable groups will increase and their plight can even worsen to the point of extreme poverty.

Adaptation of Farmers to Climate Change

The strategies that farmers in Kularonghai field have adopted to cope with the changes in climate include on-farm and off-farm measures implemented at the household level. As previously mentioned, most of the farmers' CCA measures are considered autonomous adaptation; likewise, only a few of them are implemented at the community level. Most of these measures may no longer be effective or suitable under future climate hazards. As such, the number of vulnerable farming communities would likely increase. This is because farming communities in Kularonghai field have limited knowledge and access to new and updated information on CCA. Thus, community capacity building is very important so that farming communities in Kularonghai field will be more resilient to the predicted effects of climate change.

Civil Society Planning for CCA

Planning for climate change should involve the whole community. In the MBMD, the community adopted the community planning process that involved multiple stakeholders. In particular, the Meuang Bua municipal government developed a three-year strategic CCA plan, categorized into short-, medium-, and long-term projects.

Planning for climate change should not be done autonomously, but should involve the different stakeholders coming from various disciplines. Additionally, the development of CCA options should not be a stand-alone process and should not be without solid basis. CCA planning should be grounded on reliable science-based information (e.g., using climate change scenarios, earth science, etc.) such that policy makers and planners can develop effective and feasible CCA measures to address future climate hazards, and thereby increase the community's resilience to the impacts of climate change.

SUMMARY OF LESSONS AND THE WAY FORWARD

Based on the implementation of the PAR project in Meuang Bua district in Kularonghai field, Thailand, the lessons can be summarized as follows:

1. Crop model, climate model, and geographic information system are effective tools for assessing the impact of climate change on crop production.
2. Under future climate conditions, climate change would still be a threat to farmers' livelihoods. Thus, farmers in Kularonghai field need to grow crops that are drought and flood tolerant in order to enhance their robustness and tolerance to the effects of climate change.
3. The community development plan should focus on specific actions that address the current hazards and development needs, while integrating the foreseen effects of climate change into the plan.

4. Climate change is a complex issue; addressing its effects requires cooperative interdisciplinary collaboration among different sectors. Multi-stakeholder coordination is, thus, an important part of the mechanism that would help resolve this issue.
5. A holistic approach needs to be adopted when formulating a community development plan for climate change. The measures included in the plan should not only consider how such CCA option would benefit a specific area; it should also consider how it would contribute to the development of the overall system (e.g., watershed system). As such, the overall resilience and robustness of the community will improve.

ACKNOWLEDGMENTS

This project was partially supported by the Thai Research Fund and the Southeast Asia START Regional Center. The author would like to express his gratitude to the Research and Development Institute of Khon Kaen University and to Dr. Attachai Jintrawet of the Center for Agricultural System Research, Chiang Mai University for assisting in the development and implementation of this project and for his encouragement during the conduct of this research.

The author would also like to thank the local communities in Kularonghai field for their willingness to share their stories and experiences.

Lastly, the author's gratitude goes to the Southeast Asian Regional Center for Graduate Study and Research in Agriculture for providing the author the opportunity to join the Regional Knowledge Sharing Writeshop on Climate Change Adaptation in Inclusive and Sustainable Agricultural and Rural Development.

REFERENCES

Barrett, S. 2000. "Political Economy of Kyoto Protocol." In *Environmental Policy: Objective, Instruments, and Implementation* edited by D. Helm. New York: Oxford University Press.

Chinvanno, S., and V. Kerdsuk. 2012. "Mainstreaming Climate Change into Community Development Strategies and Plans: Case Study in Thailand." *Adaptation Knowledge Platform Partner Report Series* No. 5. Bangkok, Thailand: Stockholm Environment Institute.

Chinvanno, S., S. Boulidam, T. Inthavong, S. Souvannalath, B. Lersupavithnapa, V. Kerdsuk, and N. Thun. 2008. "Climate Change Risk and Rice Farmer in the Lower Mekong River Basin." In *Climate Change and Vulnerability* edited by N. Leary, C. Conde, J. Kulkarn, A. Nyong, and J. Pulhin, 333–350. London, UK: Earthscan.

Kerdsuk V., and W. Kerdsuk. 2013. *Planning on Climate Change Adaptation: Meuang Bua District*. Khon Kaen, Thailand: Thailand Environment Institute and Khon Kaen University.

Kerdsuk, V., W. Kerdsuk, and Sukchan. 2005. *Impact Assessment and Adaptation to Climate Change: The Study of Vulnerability and Adaptation Option of Rainfed Farmer in Tungkularonghai Field, Northeast Thailand*. Khon Kaen, Thailand: Khon Kaen University.

Kerdsuk, V., S. Kongton, and A. Jintrawet. 2004. "Impact of Climate on Rice Production in Tungkula Field, Thailand." *Journal of Remote Sensing and GIS Association of Thailand* 5(2): 45–56.

Kerdsuk, V., P. Leuchuyalarak, and K. Vichakot. 2012. *Adaptation of Paddy Farmer in Kulalonghai to Climate Change*. Khon Kaen, Thailand: Khon Kaen University.

Yusuf, A.A., and H.A. Francisco. 2009. *Climate Change Vulnerability Mapping for Southeast Asia*. Singapore: Economy and Environment Program for Southeast Asia.

Farming communities in Bato-alatbang, Mayoyao, Ifugao province, Philippines
Photo by Nicasio S. Baucas

CASE STORY 7

Participatory Approach as a Way of Influencing Farmers' Capacity to Adapt to Climate Change

The Cordillera Experience

***Nicasio S. Baucas*[1]**

ABSTRACT

The initiative to enhance the adaptive capacity of those rural communities whose main livelihood is based on agriculture and are living in the mountainous areas is highly important, especially when their efforts have become sustainable. This was realized through the Millenium Development Goal Achievement Fund 1656 Outcome 3.1 project entitled Enhanced Climate Change Adaptation Capacity of Communities in Antiguous Fragile Ecosystems in the Cordilleras implemented by FAO and Philippine Department of Agriculture.

The Philippines has two main seasons: wet and dry seasons. The Cordillera Administrative Region (CAR), which is located in the northern region of the Philippines, is showered by two climate types: (1) Type II climate, which has no dry season and with pronounced maximum rain percentage from November to April, then wet for the rest of the year; and (2) Type III Climate, which has no pronounced maximum rain period and with a short dry season; the relatively dry season starts from November to April, with the rest of the year being generally wet. Over the years, the county's weather bureau has observed changes in the rainfall pattern and temperature in CAR based on existing model.

---

1 Cordillera Administrative Region Regional Field Office, Department of Agriculture, Philippines

The participation of various stakeholders—from the national agencies down to the village level—significantly contributed to the success of the project, particularly in terms of site selection, capacity building, identification and validation of good-practice climate change adaptation options (GP-CCA), and in the conduct of field demonstrations. The project highly recommends expanding the implementation of 13 GP-CCA options/technologies in four categories, namely, agroforestry and forest enrichment, crop production, soil management, and water management.

INTRODUCTION

The Cordillera Administrative Region (CAR) in the northern part of the Philippines has been known as the "Watershed Cradle of North Luzon" because its watersheds are the main source of water for the domestic, agricultural, and industrial use of the whole CAR and of significant portions of three other regions in the Philippines. The CAR is a land-locked region with rugged terrains and hilly and mountainous topography. Its peculiar environment has been appreciated by the local and indigenous group of people who have been living comfortably in the mountain range for years.

Over the years, however, the upland communities living in the Cordilleras have observed new climate and environmental trends in the region. They now experience extreme and adverse weather events that negatively affect their livelihoods, particularly those that fall under the agriculture sector. As a result, upland farming communities need to develop another level of adaptation strategies to cope with the changes in the environment caused by climate change, and thereby achieve sustainable rural development.

Climate change threatens the sustainability of agricultural development in the Cordilleras. The CAR is highly vulnerable to the changes in climatic patterns due to its inherent, yet fragile, mountain and lowland ecosystems that are compellingly managed for the agriculture and forestry sectors and for other land uses. In addition, the Cordillera region is highly sensitive to the increasing mean temperatures that have been occurring in recent years. The local residents have observed that the wet season is getting wetter; conversely, the dry season is getting dryer.

In the recent decade, the Cordillera region has been frequently affected by natural disasters, consequently putting the upland communities in a dismal position. The occurrences of landslides and erosions, overflow of water from riverbanks during heavy rains, flooding in low-lying areas with constricted outlets, and drying up of irrigation water due to extreme drought are among the common climate or weather-induced risks and disasters that have been frequently occurring in the area.

The natural balance of ecosystems tends to fall prey to the change in rainfall patterns. This confounds the risks in the Cordillera region due to its distinct climate. In particular, the region has the following types of climate:

1. Type II Climate – no dry season with a pronounced maximum rain percentage from November to April, then wet for the rest of the year; and
2. Type III Climate – no pronounced maximum rain period, with short dry season; the period from November to April is relatively dry, while the rest of year comprises the wet season.

Baguio City is the lone chartered city of the CAR with an elevation of 1,400 meters above sea level (masl). The city holds one of the weather stations of the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA), the country's weather bureau. Recent records from PAGASA have shown that the annual rainfall normal value of Baguio City from 1981 to 2010 reached 3,414.3 millimeters (mm) (PSA-NSCB 2014). Meanwhile, the minimum rainfall was 15.2 mm during the month of January from 1981 to 2010, while the maximum rainfall was 905.0 mm during the month of August. These values are higher than those in the past.

Another factor that contributes to the high vulnerability of the region to adverse climatic episodes is the complex interactions within the natural climate system of the Philippines, which is in turn affected by the semi-permanent cyclones and anti-cylones, principal air streams, ocean currents, tropical cyclones, and the geography and topography of the area. Moreover, the farming communities in the region find it difficult to cope with the unpredictable and extreme weather events that have been occurring in the region due to their low adaptive capacities.

Hence, the Philippine Department of Agriculture (DA), in partnership with FAO implemented the project Enhanced Climate Change Adaptation Capacity of Communities in Contiguous Fragile Ecosystems in the Cordilleras. The project aimed to address the upland farmers' vulnerability to climate change by enhancing farming communities' adaptive capacities through the demonstration of good-practice climate change adaptation (GP-CCA) options. This project employed participatory methods and approaches that cater to innovative adaptation measures or technologies for agriculture, water, watershed management, and biodiversity conservation.

CCA STRATEGY AND PROCESS

Participatory Approach: A Method in Inclusive Sustainable Development

Experiences from past projects have driven the project proponents to support the participatory process in implementing the project in the Cordilleras, which involved implementing community-based climate change adaptation (CCA) in agriculture in the region. Specifically, CCA strategies or processes were implemented in the following components of the project: (1) project site selection, (2) stakeholders and partners mobilization, (3) CCA option identification and validation, and (4) participatory field demonstration establishment.

Project site selection

One part of the proposal design stage was the selection of the provincial project site. Two provinces in the Cordilleras were identified, namely, Benguet and Ifugao provinces. The municipal and *barangay* (village) sites, however, were identified later in the process; the selection of the specific project sites were part of the project implementation activities.

In choosing a project site, it is crucial that the criteria used for selection are fully defined and described. Accordingly, the criteria used for the site selection were the following:

1. The site should be identified as vulnerable to climate change in terms of the biophysical and socioeconomic characteristics of the locality.
2. There should be commitment from the local collaborators in the area.
3. The area should represent the fragile ecosystems in the Cordilleras (high, middle, low elevation).
4. Indigenous innovative CCA practices should be present in the area.
5. The site should be accessible and visible for technological demonstrations.

The other factors considered were the disaster risk incidence in the area, local governments' commitment, presence of state colleges and universities that are capable of conducting studies, existence of organizations that will help in the implementation, and wealth of indigenous practices.

The demonstration sites that represented the agriculture and forest ecosystems were located in the low-, middle-, and high-elevation areas in the provinces of Benguet and Ifugao. The site for vegetable-based agriculture was situated in Benguet province, whereas Ifugao province represented the rice-based agriculture.

Benguet province is in the southernmost part of the Cordillera, and is located 256 km north of Metro Manila. The sociocultural setting of Benguet province is mainly influenced by two major populating ethno-linguistic groups: the Kankana-ey and Ibaloi ethnic groups. Both groups cultivate semi-temperate vegetable crops on the middle- and high- elevation areas.

From the 13 municipalities of Benguet, four were selected as the specific project demonstration sites to represent three elevations:

1. Barangay (Brgy.) Bayabas in Sablan municipality and Brgy. Taloy Sur in Tuba municipality for the low-elevation area (200–999 masl);
2. Brgy. Loo in Buguias municipality for the medium elevation (1,000–2,000 masl); and
3. Brgy. Paoay in Atok municipality for the high elevation (2,000 masl).

Ifugao province, on the other hand, is situated at the foot of the Cordillera Mountain Range. It is home to the Banaue Rice Terraces, which used to be included in UNESCO's World Heritage List. The community members in this province are mainly comprised of the Ayangan and Tuwali ethno-liguistic groups.

Its western portion has pronounced seasons: dry from November to April, then wet for the rest of the year. Meanwhile, the seasons in the eastern portions are not so pronounced: dry from November to April, then wet for the rest of the year.

The project demonstration sites representing the three elevations are as follows:

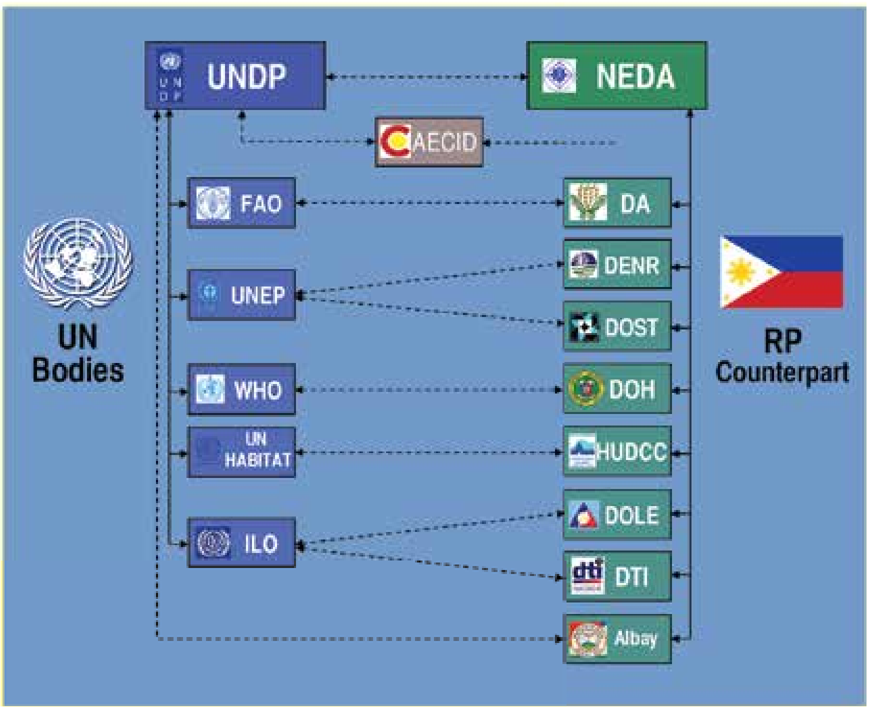
1. Brgy. Namnama in Alfonso Lista municipality for the low elevation,
2. Brgy. Nagacadan in Kiangan municipality and Brgy. Viewpoint in Banaue municipality for the middle elevation, and
3. Brgy. Bato-Alatbang in Mayoyao municipality for the high elevation.

Project stakeholders and partners mobilization

In the project, the sustainability of the rural development initiatives highly depended on the beneficiaries and their immediate partners. This was made possible through the capacity development activities initiated in the project. Part of the project implementation strategy was community empowerment; various stakeholders and partners were sensibly organized and mobilized.

Figure 7.1 shows the organization framework of the project stakeholders. In general, the international groups were composed of the United Nations Development Programme (UNDP) and FAO. On the other hand, the Philippine government counterparts were composed of the National Economic Development Authority (NEDA) and the DA.

Figure 7.1. Organizational framework of major project stakeholders



Note: AECID = Agencia Española de Cooperacion Internacional para el Desarrollo (Spanish Agency for International Development Cooperation); DA = Department of Agriculture; DENR = Department of Environment and Natural Resources; DOH = Department of Health; DOLE = Department of Labor and Employment; DOST = Department of Science and Technology; DTI = Department of Trade and Industry; HUDCC = Housing and Urban Development Coordinating Council; ILO = International Labour Organization; NEDA = National Economic Development Authority; RP = Republic of the Philippines; UNDP = United Nations Development Programme; UNEP = United Nations Environment Programme

The other stakeholders were composed of the project implementers, which were identified during project engagement.

The project implementation arrangements were multilevel, with the following committees, teams, and members comprising the project:

1. National Project Steering Committee, which was co-chaired by the DA Undersecretary of Operations and the FAO representative; the National Component Team Leaders (NCTL) served as the members;
2. National Project Component Management Team (NPCMT), which consisted of DA-Central Office staff and Regional Project Component Management Team (RPCMT) from DA-CAR;
3. Stakeholders from the provincial governments of Benguet and Ifugao through the Provincial and Municipal Agricultural Offices;
4. Part-time national consultants comprising of a team leader, agro-ecosystems specialist, agronomist/natural resource specialist, environmental science specialist, and monitoring and evaluation (M&E) specialist;
5. Two field coordinators (FC); representatives from state universities and colleges (SUCs), NGOs, national government agencies (NGAs), and local government units (LGUs); and
6. Local working groups (LWGs) and a regional working group (RWG).

The FCs provided technical assistance in various aspects of implementation. One FC was assigned in Benguet and another one was in Ifugao, although either one could cross visit for complementation. The full-time project manager handled the daily project operations. SUCs collaborated through letters of agreement to enable the SUC representatives to conduct special studies. NGOs were invited during focus group discussions to get their inputs at various levels: at the farmers' level, LWG level, and RWG level. NGAs, meanwhile, assisted in the project during workshops; they gave inputs in the identification of appropriate CCA initiatives in support of their agencies' respective mandates.

The LWGs per municipality and barangay site represented a range of stakeholders. They played a central role in the local identification, validation, and implementation of GP-CCA options for each season. In particular, the LWGs were composed of the municipal mayor, municipal agriculturist (MA), agricultural technologist (AT), municipal environment natural resources officer, *Sangguniang Bayan* (municipal council), chairs of the agriculture and environment committees of the municipality, community environment natural resources officer, barangay captain (village head), barangay councilor for agriculture, farmer representatives, farmer groups, and women's organizations.

The LWG and pilot demonstration team provided the following functions:

1. Facilitated the conduct of social mobilization activities, orientation meetings, community-level trainings/workshops, demonstrations, monitoring, reporting; and production of extension materials to promote CCA options at pilot sites;
2. Advised and assisted the pilot demonstration team in transforming the identified CCA options into locally usable and farmer-friendly information;
3. Ensured and enlisted the participation of local stakeholders (i.e., farmers' groups, community representatives, and women's representatives);
4. Reviewed seasonal work plans of the pilot demonstration team at the municipal level and assisted in coordinating the activities; and
5. Functioned as a clearing house at the municipal level for the implementation and replication of identified and successfully introduced CCA options in broader agricultural sectors.

The pilot demonstration team was a subset of the LWG. The team was in charge of the day-to-day operations that related to the pilot demonstration of the CCA option. The team was composed of farmer cooperators and the FCs and ATs assigned to the barangay project site. Specifically, the pilot demonstration team was responsible for the following functions:

1. Establishing and maintaining pilot demonstrations;
2. Collecting and processing monitoring data from pilot demonstration sites;
3. Preparing the seasonal work plans; and
4. Reporting regularly to the LWG on the status of field demonstrations, lessons learned, and farmers' feedback.

Three universities were commissioned to conduct a situational assessment and to develop simplified vulnerability assessment tools, namely, Benguet State University, Ifugao State University, and the University of the Philippines Foundation Inc.

Participatory CCA option identification and validation

The identification of CCA options was a crucial component of the project, which needed to be complemented by careful and sound validation. Thus, a systematic method that could be easily understood by the project implementers and beneficiaries was established.

Workshops were conducted at each site in order to identify the potential GP-CCA options for field demonstrations. Facilitated by the RPCMT and FCs with the support of the consultants, the workshops were attended by selected farmers, barangay officials, representatives from the provincial and municipal LGUs, and other project staff. Specifically, the workshops aimed to:

1. familiarize the participants with the project;
2. familiarize the participants with climate change concepts; and
3. identify local good practices in agriculture, in natural resources management in relation to agriculture, and in natural resources management relevant to CCA.

Through a series of workshops, the NPCMT, RPCMT, and project staff developed the following criteria for validation of potential good practice options: (1) increase in resilience, (2) socioeconomic efficiency, (3) positive environmental impact, (4) sustainability, (5) social and cultural acceptance, (6) potential for expansion, (7) immediate impact/response to urgent needs, and (8) promotion of participation and equal access to men/women.

Using the above criteria, two stages of validation were done: first at the LWG level, and thereafter at the RWG level. The RWG were composed of representatives from various bodies and agencies (i.e., NPCMT, RPCMT, research and development institutions, line agencies, SUCs, LGUs, and project staff).

Establishing participatory field demonstrations

The economic contribution of the GP-CCA options to the beneficiaries and to the community, as a whole, is an essential consideration in the selection of the CCA options. Thus, the field demonstrations that had to be implemented needed to be appropriately established and managed by competent recipients. The FCs, MAs, and ATs coordinated and supervised the establishment of the GP-CCA options in each demonstration site. The number of farmer cooperators varied considerably between categories and options. Hence, many of the GP-CCA options were managed by individual farmers; others were managed by a group of people or members of an association. Accordingly, the following outputs were successfully achieved/implemented:

1. A total of 506 farmer cooperators benefited from the CCA option.
2. A total of 25 CCA options were implemented in all areas.
3. A total of 94 demonstration sites were established—41 in Benguet and 53 in Ifugao.

The project provided support (in terms of establishing the CCA options) through the provision of training and hands-on in-situ coaching of the farmer cooperators in the areas of livestock management, early transplanting of rice, forest enrichment (i.e., coffee, rambutan, citrus, bamboo), agroforestry, organic banana, homestead gardening, apiculture, organic vegetable farming and composting, seed potato production, and nursery management.

OUTCOMES OF THE INTERVENTION

The economic, social, and ecological contributions of the demonstration sites to the inclusive and sustainable agriculture and rural development of those areas that are vulnerable to the impacts of climate change in CAR are likely embraced as an essential facet of the project.

The project implementers used a participatory-based M&E process to determine the performance of the field-tested CCA options. The field monitoring team consisted of FCs, the RPCMT, and M&E specialists. The M&E specialists developed M&E instruments, which started with the identification of the clusters of indicators of GP-CCA, followed by the identification of the aggregated indicators per cluster. The latter had been identified earlier during a series of discussions with the NPCMT, RPCMT, project management staff, and consultants.

The project implementers used the following criteria to evaluate the ability of the GP-CCA option to promote or increase resilience: (1) technological suitability, (2) environmental efficiency and effectiveness, and (3) sociocultural and economic acceptability. Likewise, the field monitoring team used the Multi-Criteria Analysis (MCA) framework, which is an ex-ante and ex-post approach for monitoring and evaluation.

The identified GP-CCA options were grouped into the following categories: (1) agroforestry and forest enrichment, (2) crop production, (3) soil management, and (4) water management. Meanwhile, the ability of the GP-CCA options to increase the climate change resilience of the upland farming communities were rated based on the following parameters:

1. Ability to address the slow onset of climate change impacts;
2. Ability to reduce risks and impacts of climate variability and extreme weather events (and other hazards), and
3. Ability to enhance livelihood security.

Using the process, the following outputs were accomplished:

1. Rating of the GP-CCA options (Table 7.1);
2. Recommendations per GP-CCA option (Table 7.2); and
3. Farmers' local observations of the impacts of climate change on farming under various phenomena (Table 7.3).

Specifically, the local upland farmers have observed that the main impacts of climate change in Benguet and Ifugao provinces were drought, change in rainfall pattern, more frequent incidents of typhoons and flooding, and change in mean temperature. On the other hand, the beneficiaries identified 13 GP-CCA options or technologies. These were evaluated according to the following categories: (1) agroforestry and forest enrichment (six GP-CCA options), crop production (five), soil management (one), and water management (one).

Finally, from the identified GP-CCA options or technologies, the following were highly recommended for expansion:

1. Riverbank rehabilitation using lanao bamboo,
2. Homestead gardening of season-responsive crops,
3. Planting of coffee for forest enrichment,
4. Planting of rambutan for forest enrichment,
5. Planting of pomelo for forest enrichment,
6. Early transplanting of tinawon rice,
7. Planting *gabi* (taro) in abandoned rice field,
8. Fallow cropping (i.e., garlic after rice),
9. Integrating lemon production into vegetable farming for slope protection,
10. Planting of KS-Kuroda carrot variety due to its tolerance to heavy and prolonged rains,
11. Potato seed production in greenhouses,
12. Improving soil property and fertility through composting using *Trichoderma*, and
13. Small water impoundment for irrigation to augment water supply for vegetable production.

Table 7.1 Category, elevation, and rate of GP-CCA options

GP Option and/or Technology	Category	Elevation/ Location	Rate/Parameters		
			A1	B2	C3
Riverbank rehabilitation using lanao bamboo	Agroforestry and forest enrichment	Low, Ifugao	High	High	Low
Homestead gardening of season-responsive crops	Crop production	Low, Ifugao	Medium	High	High
Coffee production for forest enrichment	Agroforestry and forest enrichment	Medium, Ifugao	High	Medium	Medium
Planting of rambutan for forest enrichment	Agroforestry and forest enrichment	Medium, Ifugao	High	Medium	Medium
Planting of pomelo for forest enrichment	Agroforestry and forest enrichment	Medium, Ifugao	High	Medium	Medium
Early transplanting of tinawon rice	Crop production	High, Ifugao	Medium	High	High
Planting *gabi* (taro) in abandoned rice field	Crop production	High, Ifugao	Medium	Low	High
Fallow cropping: garlic after rice	Crop production	Low, Benguet	Medium	High	High
Integrating lemon in vegetable farm for slope protection	Agroforestry and forest enrichment	High, Benguet	High	Medium	Low
Planting KS-Kuroda variety carrots as they are tolerant to heavy and prolonged rainfall	Crop production	High, Benguet	High	High	Low
Potato seed production in greenhouse	Crop production	Medium, Benguet	Low	High	High
Soil property and fertility improvement through composting using *Trichoderma*	Soil management	Medium, Benguet	High	High	Low
Small water impoundment for irrigation to augment water supply for vegetable production	Water management	Medium, Benguet	High	High	High

Notes: (1) GP = good practice; GP-CCA = good-practice climate change adaptation options (2) A1 = ability to address slow onset of climate change impacts; B2 = ability to reduce risks and impacts of climate variability and extreme weather events (and other hazards); C3 = ability to enhance livelihood security.

Table 7.2. Recommendations for the GP-CCA options/technologies implemented

GP Option and/or Technology	Recommendation
Riverbank rehabilitation using lanao bamboo	Highly recommended for expansion
Homestead gardening of season-responsive crops	Highly recommended for expansion
Coffee production for forest enrichment	Highly recommended for expansion
Rambutan production for forest enrichment	Highly recommended for expansion
Pomelo production for forest enrichment	Highly recommended for expansion
Early transplanting of tinawon rice	Recommended for further trial
Planting of gabi in abandoned ricefield	Highly recommended for expansion
Fallow cropping: garlic after rice	Highly recommended for expansion Highly recommended for testing in low-elevation areas
Integrating lemon production into vegetable farming for slope protection	Highly recommended for expansion
Planting of KS-Kuroda variety carrots due to its tolerance to heavy and prolonged rains	Highly recommended for expansion
Potato seed production in greenhouses	Highly recommended for expansion
Improving soil property and fertility through composting using *Trichoderma*	Highly recommended for expansion
Small water impoundment for irrigation to augment water supply for vegetable production	Highly recommended for expansion

Table 7.3. Farmers' observed climate change impacts

Phenomena	Observations
Drought	Prolonged dry season that causes springs and rivers to dry up
	Scarcity of water supply for irrigation
	Decreased quality of fruits and vegetables (abnormal sizes, unpalatable)
	Short panicle of crops (rice, tiger grass); stunted crops and animals; poor yields (corn, vegetables, rice)
	No planting due to drought, cracking of rice paddies in low-/medium-elevation areas
	Drought increases earthworm population through better aerated soils, which contributes to soil erosion of terrace walls and of irrigation system in medium-elevation areas
	Lifespan of plants becoming shorter in high-elevation areas
Change in rainfall pattern	Best planting season of crops such as pineapple is uncertain due to irregular rainfall
	Short season affects planting time and leads to low yields during late start of rainy season
	Floods, erosion, landslides, and field siltation occur when there are more heavy rains and deforestation

Table 7.3 (continued)

Phenomena	Observations
Typhoons and floods	Strong typhoons have been experienced for three successive years Typhoon duration increased from 1–2 days to 3–7 days Typhoon season has become longer to include December and January, which has led to water contamination, destruction of cash crops, and inaccessible roads More typhoons means more flooding and soil erosion during the wet season Local people are no longer able to predict typhoons. In high-elevation areas, the upland communities used to be able to predict the onset of typhoons through the appearance of rainbows, or when a bird called “kiling” (local name) appears during the last week of October, or when crabs start to appear at the foot of the mountain trail. However, these indicators are no longer reliable.
Change in mean temperature	Increase in temperature fluctuation Higher temperature than in previous years, even extreme heat in mornings, causing changes in flowering. For example, in low-elevation areas, fruit trees start to flower as early as January, instead of the usual May or June. In the medium-elevation areas, sunflowers that used to bloom in summer are no longer flowering. Spread of new insect pests and diseases: banana pests at low-elevation areas, poultry disease in medium-elevation areas, brown and green grasshoppers in rice fields in high-elevation areas Changes in habitat: lowland fruit trees such as mango now grow and bear fruit in the highlands, animals from low-lying areas can now adapt in the highlands (e.g., cobra snake), *sayote* (chayote) and tomatoes bear fruit in the highlands (rather than in the lowlands) due to the warmer weather; and migration of non-highland insect species Increase in health problems: skin diseases for humans and animals resulting in reduced labor productivity Lower temperature than in previous years, which causes frost in new locations

ACKNOWLEDGMENTS

The development of this paper was made possible through the initiatives and efforts of vital experts, individuals, and institutions. The initiative was spearheaded by the Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA) out of the leadership of its Director, Dr. Gil C. Saguiguit, Jr., in cooperation with the Oscar M. Lopez Center for Climate Change Adaptation and Disaster Risk Management Foundation Inc. through a Regional Knowledge Sharing Writeshop on Climate Change Adaptation in Inclusive and Sustainable Agricultural and Rural Development held on 15–17 April 2015 at SEARCA, College, Los Baños, Laguna, for which the author was provided an opportunity to be a participant (presenter-writer).

The author is very much indebted and thankful to FAO, in partnership with the Philippine DA, particularly to Mr. Aristeo Portugal and Dr. Roberto Sandoval, for sharing the published report of the joint MDG-F 1656 programme: Strengthening the Philippines' Institutional Capacity to Adapt to Climate Change, Outcome 3.1 project "Enhanced Climate Change Adaptation Capacity of Communities in Contiguous Fragile Ecosystems in the Cordilleras," which was extensively used as reference.

Likewise, the author wishes to acknowledge the officials and experts of DA-RFO-CAR: Dr. Magdalena T. Wanawan (Chief of Research Division) and Ms. Marilyn V. Sta. Catalina (former Regional Executive Director) for their unwavering support and recommendation to participate in this undertaking.

REFERENCES

DA (Philippine Department of Agriculture) and FAO. 2012. *Compendium of Good Practice: Climate Change Adaptation Options in Agriculture*. Manila, Philippines: DA and FAO.

——. 2012. *Implementation Process for Community-Based Climate Change Adaptation in Agriculture: Experiences from the Cordillera Region*. Manila, Philippines: DA and FAO.

——. 2012. *Farm Operations Monitoring Manual to Support Monitoring and Evaluation of Good Practice Options for Climate Change Adaptation in Agriculture: Theory, Monitoring Forms and Instructions*. Manila, Philippines: DA and FAO.

PSA-NSCB (Philippine Statistics Agency-National Statistical Coordination Board). 2014. *Compendium of Philippine Environment Statistics 2014*. Quezon City, Philippines: PSA.

Sandoval, R., Jr. Undated. "A Framework for Monitoring and Evaluation of Good Practice Climate Change Adaptation Options in Agriculture: M&E Design, Methods and Analysis." Unpublished Report. Manila: FAO Philippines.

Farmers in the Mekong River Delta face extremes from climate change; they need CSA to ensure that rice production can increase in the face of climate change in a way that is sustainable and addresses mitigation where possible.
Photo by Georgina Smith, courtesy of CIAT

CASE STORY 8

Multi-stakeholder Prioritization Approach for Climate-Smart Agriculture Planning and Investment in Vietnam

Caitlin Corner-Dolloff[1], Andreea-Cristina Nowak[1], Miguel Lizarazo[1], Louis Parker[1], Mai Van Trinh[2], and Tran Dai Nghia[3]

ABSTRACT

This case story outlines the results of a national research initiative that utilized the Climate-Smart Agriculture Prioritization Framework (CSA-PF) to inventory, assess, and prioritize CSA options with stakeholders for various subnational regions. The CSA-PF is a four-phase process, which was implemented in Vietnam under the direction of the Ministry of Agriculture and Rural Development. In the first phase, a compendium of CSA practices was created, characterizing over 807 farms using 111 categories of practices across Vietnam. The practices were then analyzed twice using a set of CSA indicators, at first rapidly by experts to select 13 promising practices (11 crop, 2 livestock), and the second time through detailed surveys to better understand the trade-offs (Phase 2). Eight practices were selected for detailed cost-benefit analyses, which were carried out in Phase 3 by the Institute of Policy and Strategy for Agriculture and Rural Development. Economic evaluations were conducted in specific productions systems in regions of high importance to the agriculture sector and vulnerable to climate change (Red River Delta, Mekong River Delta, and South Central Coast). It was found that rice-shrimp rotations, integrated crop management in rice, and mixing rice crops and mushroom growing were some of the most profitable and low-risk options. The fourth phase, which is ongoing, will bring stakeholders together to establish investment portfolios of CSA priorities and action plans. All previous analyses will be utilized to prioritize and discuss strategies for minimizing trade-offs, increasing synergies between practices, avoiding or overcoming barriers to adoption, and linking with end user priorities.

---

1 International Center for Tropical Agriculture
2 Institute of Policy and Strategy for Agriculture and Rural Development, Ministry of Agriculture and Rural Development, Vietnam
3 Institute for Agricultural Environment, Vietnam Academy of Agricultural Sciences

The CSA-PF has been utilized by decision makers in Guatemala, Mali, Colombia, Ethiopia, and Ghana, but a broad national-level assessment, such as the one conducted in Vietnam, had never been attempted. The case story closes by outlining key lessons learned from the utilization of the CSA-PF in Vietnam, highlighting lessons around adapting prioritization processes to user needs, engaging stakeholder and establishing ownership, linking science and policy, building the CSA knowledge base, and utilizing prioritization processes to enable both short- and long-term action. Vietnam is well positioned to take concrete science-based action on CSA, and the outcomes of this process can inform the development of national CSA frameworks that guide iterative planning, research, and prioritization into the future, transforming the way Vietnamese agriculture addresses food security and development goals in the face of climate change.

INTRODUCTION

The goal of achieving global food security is facing unprecedented challenges, particularly since population growth and consumption patterns are increasing global food demand. Research has shown that even equitable redistribution of resources among the world population would not solve the global food insecurity problem. A combination of changing food diets and increasing agricultural production is needed to meet future demand. It has been estimated that crop production would have to increase by 69 percent[1] to address current undernourishment and feed a potential population of 9.6 billion by 2050 (UNDESA 2013; WRI 2013).

Climate change will exacerbate food insecurity challenges by constraining future agricultural production levels. A meta-analysis of crop models shows that overall decreases in crop yield are more likely to happen than increases by 2030; and by 2050, roughly 50 percent of the projections demonstrate that yield losses will be greater than 10 percent (Challinor et al. 2014). High temperatures, drought, and changes in rainfall patterns are currently affecting millions of smallholder farmers, and the intensity and frequency of these phenomena is expected to increase in the future. At the same time, the agricultural sector has expanded and intensified at the expense of ecosystem health, biodiversity, forests, soil and water quality and availability (Foley et al. 2011; Tilman et al. 2011), decreasing resilience of agro-ecosystems, and decreasing access to natural resources. Additionally, agriculture and related land-use change accounts for about 24 percent of total global greenhouse gas emissions (GHG), mostly through livestock and fertilizer production and use (WRI 2013).

These current and future trends highlight the need to rethink how agriculture is being practiced and how global future food demand can be met through sustainable, eco-efficient, and equitable means. Complementing this discourse on socioeconomic

1 Compared to 2006 levels

and environmental sustainability, the Climate-Smart Agriculture (CSA) approach is reflective of this new line of thinking, recognizing that agriculture, livelihoods, and climate change need to be considered as components of an interdependent food system. The solutions that emerge from the CSA approach aim to increase productivity, build resilience, and decrease agricultural emissions where possible and appropriate (Lipper et al. 2014).

Given the complexity in understanding the best pathways toward CSA systems, scientists at the International Center for Tropical Agriculture (CIAT) and the CGIAR Research Program on Climate Change, Food Security, and Agriculture (CCAFS) have been developing and implementing tools to support decision makers across levels (national, regional, local/farm) to define, analyze, and prioritize CSA options (Campbell et al. 2016). One of these decision-support tools is the Climate-Smart Agriculture Prioritization Framework (CSA-PF), which engages stakeholders in identifying cost-effective CSA investment options that are aligned to their needs (Corner-Dolloff et al. 2014). Prioritization is based on comprehensive assessments of cost and benefits, specifically the trade-offs between the CSA pillars (i.e., productivity increase, resilience building, and emissions reduction).

This chapter discusses the application of the CSA-PF in Vietnam where the Institute of Policy and Strategy for Agriculture and Rural Development (IPSARD) and the Institute for Agricultural Environment (IAE), under the Vietnam Ministry of Agriculture and Rural Development (MARD), led the process of prioritizing CSA options for future investments in Vietnam. The following sections present the context of the case story; describe the CSA-PF process; and outline key preliminary achievements, challenges, and lessons learned from the initiative applicable to future users.

Agriculture and Climate Change in Vietnam

The agriculture sector contributes approximately 18 percent to Vietnam's total GDP[2] (World Bank 2016a), and provides employment for about 47 percent of the country's labor force (FAO 2016).[3] A relative decline in the sector's contribution to household income has been observed in the past few years, yet this trend vary across the country's regions, and many households continue to rely on farming for food security (World Bank 2016b).[4]

---

2 Based on 2014 data

3 Based on 2012–2013 data. Agricultural employment in Vietnam has declined dramatically in the last few decades, from 65 percent in 2000 to 47 percent in 2013 as a consequence of the growth in the service sector and driven by the structural transformation of the country s economy.

4 The declining trends have been more pronounced in the Red River Delta, Northwest, Northeast, and North Central Coast regions and almost unnoticed in the Mekong River Delta and Central Highlands regions where agriculture has remained a major source of household incomes.

Agricultural land represents 35 percent of the country's total land area (FAO 2016),[5] with rice, maize, cassava, peanut, soybean, and sweet potato being the most important food crops (Ha et al. 2013). Most farming occurs on landholdings that average less than 0.5 hectares (ha), spread across various plots. These farmlands are mostly located in the northern provinces of Vietnam, which is home to around 85 percent of the farm population. Although Vietnam is the second largest rice exporter in the world, therefore contributing to global and national food security, many rural people in Vietnam are still net buyers of food. This means that their food security and livelihoods are directly affected by food price fluctuations (Rutten et al. 2014).

Vietnam is divided into eight main agro-ecological zones (AEZ): Northwest (NW), Northeast (NE), Red River Delta (RRD), North Central Coast (NCC), South Central Coast (SCC), Central Highlands (CH,) Southeast (SE), and Mekong River Delta (MRD). Each zone is characterized by different climate, soil, land cover, and topographic conditions (Ha et al. 2013; World Bank 2010). The MRD has the second largest population density and is the main agricultural region in terms of output value. It is also the most threatened region in terms of sea level rise and its corresponding impacts on agricultural production. The RRD is another key region for rice production due to its fertile soils. The SE region, with lower agricultural productivity levels due to more degraded soils, has been a hub for livestock industrial development (Ha et al. 2013).

Due to its exposure to extreme weather events, Vietnam is highly vulnerable to climate change. Sea level rise and salinity intrusion in coastal areas, frequent flooding and periods of drought, and increased water temperatures are some of the main climate threats that affect crops and fisheries. In light of these threats, crop yields (especially rice, maize, and cassava) are expected to decline significantly by 2030 and 2050 under a dry, wet, or intermediate scenario (World Bank 2010).[6] By 2050, rice yields are expected to decrease by 10%–20% (without CO_2 fertilization). Declines are expected especially in the NW and CH regions, but also to a lesser extent in the SCC, RRD, and NCC regions. Research has shown that the absence of adaptation measures in agriculture would cause significant economic losses in terms of GDP (about 2% lower by 2050 compared to baseline), in value-added in agriculture (about 13% lower by 2050 compared to baseline), as well as in household incomes, which would be more pronounced for economically vulnerable populations in rural and urban areas (World Bank 2010).

5 Based on 2011 data. This includes arable land under permanent crops and under permanent pastures.

6 The World Bank study *Economics of Adaptation to Climate Change* uses three main types of scenarios: (1) the one developed by the Ministry of Natural Resources and Environment of Vietnam, which uses the Scenario B2 (medium-emissions) of the Intergovernmental Panel on Climate Change, (2) the dry scenario CM4 model developed by The Institut Pierre Simon Laplac, and (3) the wet scenario GISS-ER model developed by the Goddard Institute for Space Studies (GISS). For more information see World Bank (2010).

At the same time, agricultural activities are also the second largest source of GHG emissions in Vietnam, next to energy, contributing 33.24 percent to the total emissions released (excluding land-use change and forestry; this account for approximately 48.5 million tons of carbon dioxide equivalent) (UNFCCC 2010). Half of the agricultural emissions come from rice cultivation, which indicates the important role of the agriculture sector as an entry point for action to reduce national and global GHG emissions.

These characteristics and threats to and from the agriculture sector in Vietnam highlight the need for immediate action from actors across sectors to provide integrated solutions to the climatic conditions that affect the population and their livelihoods. Strengthening farmers' capacity to respond to shifting weather patterns and increasing their resilience to the new conditions is a priority that government actors and implementers are interested in highlighting in the public policy and research agendas. By building on existing experience, expertise, capacity, and needs assessments, actors can channel their research, policy, and political efforts toward the promotion of an integrated agricultural development vision that builds on the objectives of increasing food security, building farmers' resilience and adaptive capacity, and developing a low carbon agricultural sector in Vietnam.

Climate-Smart Agriculture and Vietnam's Agricultural Development

The CSA approach is built around both well-established agricultural practices that farmers have been adopting for years to increase productivity and new innovative technologies. It highlights the importance of better understanding agricultural management practices through a climate lens, integrating agriculture development and climate change planning. The concept of CSA was coined in 2010, and is defined as agriculture that "sustainably increases productivity, enhances resilience, reduces/removes greenhouse gas emissions, and enhances achievement of national food security and development goals" (FAO 2010). In Vietnam, farmers have been implementing practices such as conservation agriculture techniques (e.g., minimum or no-till, mulching, crop rotations); use of climate-resistant and -tolerant crop varieties; and silvo-pastoral systems (to name a few), which can all be considered CSA practices. Often, these climate-smart efforts have remained undocumented or lacked continuity in implementation, which makes it challenging to take them to scale.

At the policy level, government initiatives recognize the importance of building links between climate change adaptation action, sustainable development, a low-carbon economy, and agricultural development. Numerous policies and strategies have been implemented to address these issues at the national, subnational, and local levels. Although these policy efforts have stressed the need to bring disaster prevention and mitigation to the forefront of debate and action, more efforts are needed to build medium- and long-term adaptation strategies that can help build resilience of the food system over time. The majority of climate change adaptation action has been through the establishment of large-scale costly infrastructure projects that do not necessarily target small-scale farmers. One of the latest policy documents, the *Intended Nationally Determined Contribution* submitted in 2015 to the United Nations Framework Convention on Climate Change, outlines actions and tangible achievements that Vietnam plans to make on both adaptation and mitigation, and also highlights the role of agriculture (SRV 2015).

In 2015, scientists and experts at MARD (led by IPSARD, IAE), CIAT, and CCAFS joined efforts to conduct a comprehensive assessment of potential CSA investment opportunities in order to maximize adaptation, productivity, and mitigation benefits for the farmers, while contributing to their food security under adverse climate conditions. The research initiatives utilized the CSA-PF process, aiming to inform farmers, implementers, decision makers, and donors at the local, national, and international levels about potential CSA investment options across the country and the trade-offs and costs and benefits of these options. The CSA-PF is currently being implemented in Vietnam, engaging with national and regional stakeholder groups throughout the process to ensure relevance, quality, and rigor of the process and related findings.

DESCRIPTION OF THE METHOD

Climate-Smart Agriculture Prioritization Framework

The CSA-PF was developed by researchers at CIAT and CCAFS in 2014 in response to the need of decision makers at various levels (from farm to policy) and across sectors (e.g., public, private, nongovernmental, academia) to identify best-bet cost-effective responses to short- and long-term climate change risks. The framework is a stakeholder-driven process[7] where actors analyze and select options based on (1) their ability to produce gains in productivity, adaptation, and mitigation where possible; (2) analyses of trade-offs between CSA options; and (3) assessments of economic costs and benefits. It ultimately leads stakeholders to develop CSA investment portfolios for specific production systems and AEZ. The CSA-PF offers methods for

1. identifying key agricultural crop and livestock systems for food security and their relation to climate vulnerabilities in the country/region;
2. identifying existing and promising CSA options (practices, technologies, services) in relation to key production systems and regions;

7 The selection of stakeholders is largely dependent upon the scale of the analysis. At the governmental level, stakeholders will be selected from the ministries and governmental bodies. If the framework is being implemented at the farm scale, then the stakeholders will be the farmers, local planners, and local decision makers.

3. evaluating context-specific outcomes of these practices in relation to productivity/food security, adaptation/resilience, and mitigation indicators;
4. analyzing the costs and benefits of implementation; and
5. identifying opportunities for and barriers to adoption and the enabling policies and strategies that support the implementation and/or expansion of CSA practices in the field (e.g., insurance and crediting schemes, early warning systems, etc.) (Corner-Dolloff et al. 2014).

The framework was designed as a set of guidelines and processes for stakeholders to use and modify given their needs at various scales (national to local) of decision making. Interested organizations can also conduct research components independently to contribute to the analyses. Likewise, the analytical phases can be modified to suit stakeholder needs and available resources. The process was designed to take six to eight months, and requires only United States Dollar (USD) 50,000–80,000; but often, the process is implemented for longer periods and with additional funds due to such factors as scope, number of participants, staffing support needs, and level of analysis required. Applying the CSA-PF requires utilization of expertise in coordination, participatory engagement, climate change, agronomy, and agricultural economics. It can further benefit from interdisciplinary expertise related to such areas as gender, system thinking, value chains, adoption, policy incentives, and others.

The CSA-PF was designed to have four additive phases, with the outputs of each phase acting as the inputs into the next. The phases alternate analyses with participatory decision making, allowing stakeholders to narrow a long list of possible CSA options step by step until portfolios of priority options are established.

Phase 1

The process usually begins by identifying the main partners and experts (also known as the "expert committee") who play an active role in facilitating contacts, establishing coordination and governance mechanisms, taking collective decisions on the design of the initiative, and sharing knowledge and information throughout the activities.

In previous iterations of the CSA-PF, partners have included national governments, NGOs, donors, local governments, and community-based organizations, depending on the scope of the process. Usually, there is one lead organization that has identified a need for use of the CSA-PF that then brings others onboard. The partners identify the objective and scope of the prioritization, such as the regional focus and production systems/value chains to link the CSA options with, and they establish the list of CSA options related to the scope. The team will also discuss and select CSA indicators (related to productivity, adaptation, and mitigation outcomes) to use in the trade-off analysis of the practices.[8] These initial assessments of potential outcomes of various practices are conducted in the first phase through surveys, expert interviews, and focus groups.

Phase 2

In Phase 2, a broad range of stakeholders are gathered to validate the findings from Phase 1. The indicator analysis is the basis for discussions regarding the trade-offs between the ability of different CSA options to achieve the three goals of CSA and stakeholder desired outcomes. The related barriers to adoption of specific practices are discussed to assess any practices that may need to be cut from the list based on the scope of the intended use of the CSA-PF outcomes, and if such barriers to adoption as basic infrastructure, policy, and culture can be tackled.

Stakeholders use these analyses and participatory decision-making techniques to select a shorter list of CSA options for further in-depth analysis. The number of options depends on the interests and resources available to carry out cost-benefit analysis (CBA). Long lists have ranged from tens to hundreds of practices, and short lists have tended to stay under 15 options.

Phase 3

The CBAs are conducted on each of the CSA options selected for the short list in Phase 2. The goal is to strengthen understanding of the profitability of practices based on scientific literature, national databases, expert knowledge, and primary data, as needed. A variety of techniques have been utilized in this phase, ranging in level of complexity from mostly simple financial CBAs, inclusion of social and financial externalities (Sogoba et al. 2016; Sain et al. 2016), to further detailed probabilistic scenarios in order to better understand adoption risk (Sain et al. 2016).

Phase 4

Stakeholders are reconvened in a participatory workshop in the final phase to analyze outputs from all previous phases in relation to the short list of options. This evidence is then used to develop portfolios (groups of CSA options) that maximize the desired benefits. Trade-offs between different CSA options and portfolios are then visualized and discussed, including synergies between practices, the aggregate benefits from different portfolios. Perceived constraints and barriers to adoption, along with ways to overcome them, are also explored.

---

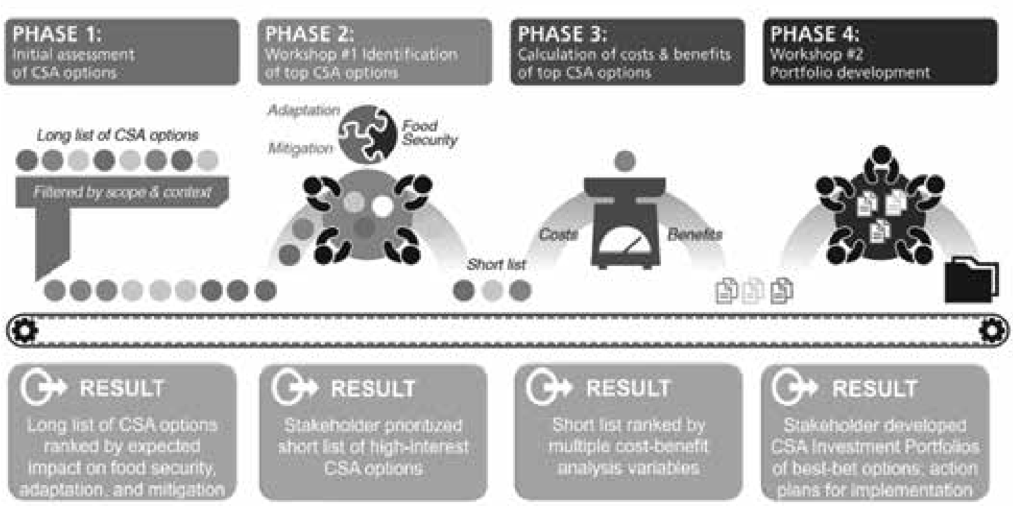
8 The framework includes a list of suggested indicators for evaluating practices linked with the CSA goals (productivity, adaptation and mitigation), such as yield, increased income, water use efficiency, emissions intensity, etc. The stakeholders select a subset of indicators that will enable the practices to be evaluated.

This flow of the framework is illustrated in Figure 8.1 although additional steps and activities can complement or replace those suggested in order to ensure that the framework suits the needs of users. Tools and processes aimed at addressing additional research questions or providing further in-depth analyses, such as crop modeling, participatory scenario development, and sustainable land management systems analyses, can be integrated into this approach. Likewise, since the main beneficiaries and implementers of CSA practices are at the community and farm levels, bottom-up processes (e.g., additional community-level dialogues, participatory surveys, etc.) can help to ensure equal representation, consideration of equity principles, and that the CSA options selected will match with local priorities and realities.

To date, the CSA-PF has been implemented fully in Colombia, Guatemala, and Mali (2014–2015). It is now being implemented in Ghana, Ethiopia, and Vietnam. Partners are using the CSA-PF for a number varying objectives including to

1. evaluate the current state of CSA and decide upon future strategies;
2. create a knowledge base for better integration of climate change into agriculture planning, beyond disaster risk reduction;
3. assess existing funding channels for agriculture;
4. search for new agricultural investment opportunities;
5. evaluate effectiveness and impact of existing policies that incentivize CSA; and
6. identify entry points and opportunities to expand CSA.

Figure 8.1. General components and suggested flow of the CSA-PF process and results



Prioritizing CSA Investments in Vietnam

The collaborative initiative between the MARD, CIAT, and CCAFS (with lead implementation by the IAE and IPSARD) aims to facilitate the generation and incorporation of expert knowledge and local information into the decision-making processes around national CSA investment priorities and evidence-based policy development in Vietnam. The initiative has enabled the engagement of national stakeholders in operationalizing the CSA-PF, combining mapping and analysis of CSA stakeholders and activities with participatory activities to jointly identify priorities for CSA investments in the country. The prioritization process takes into account a number of criteria for analyzing CSA options, such as relation to observed and expected climate threats, contributions to productivity, adaptation and mitigation, economic costs and benefits of CSA practices and services, and barriers to adoption.

In Phase 1, a national expert committee—involving experts from the MARD, IPSARD, and IAE, with technical support from the CIAT and the CCAFS—was constituted to jointly identify the objectives and activities of the analytical process. In June 2015, the committee conveyed a broader expert meeting to discuss the operationalization of CSA-PF activities, with participation from additional policy and research departments under the MARD, including the Department for Science, Technology, and Environment; National Agricultural Extension Centre; the Agricultural Genetics Institute; and Agricultural Science Institute of Southern Coastal Centre of Vietnam.

Given the high level of national interest in CSA and Vietnam's commitment to scaling-to-concept under existing climate change policies, the CSA-PF took on a national scope. This included a countrywide screening of existing CSA practices related to crop and livestock production. A main objective of Phase 1 is to establish a national database for decision makers and practitioners of existing CSA initiatives. Given that the database was geo-referenced, it could also serve to highlight adoption gaps of practices and categories of practices across provinces and districts. The subsequent phases of the CSA-PF narrowed the scope of analyses to priority regions, recognizing that additional research could be conducted in the future on remaining areas building on the new national CSA database. The short list of practices was compiled based on a ranking of the practices based on their overall contribution to the CSA pillars, estimated general cost-effectiveness, and alignment with local and sectoral plans and strategies.[9] These practices were then evaluated in-depth based on their economic costs and benefits (Phase 3) and based on barriers to adoption, for ultimate identification of investment portfolios that could then be included in future national planning processes (Phase 4).

9 Higher overall CSA score of a practice reflects higher contribution to the CSA pillars, and hence higher likelihood to be short listed.

OUTCOMES OF THE CSA-PF IN VIETNAM

The application of the CSA-PF in Vietnam is ongoing, and therefore the results of the final phase of the process is forthcoming. This section discusses the results of Phases 1–3, which includes the identification of the long and short lists of practices and expected outcomes from the process.

The countrywide screening of CSA initiatives[10] revealed 111 categories of CSA practices being carried out through 807 iterations of practices in various farming systems in 30 provinces (the majority are concentrated in the RRD, MRD, and SE regions). In the long list, practices conducted in different regions and with different productions systems were marked separately given that the impact of practices depends on their context, and should therefore have separate evaluation. The crop-related practices (around 95% of the total practices) identified in these provinces were mostly applied to rice, vegetables, and industrial crop production, and (to some extent) to fruit, potato, sugarcane, and maize production. Livestock CSA practices related to poultry, pig, and cow production.[11] Results also indicated that, in general, practices have been adopted as a means to diversify and intensify production, improve use of inputs (water and land) obtain higher yields, improve incomes on a day-to-day basis, and improve livelihoods and poverty alleviation over the long-term.

The long list of practices[12] identified across Vietnam was longer than those created for any other CSA-PF initiative. Given this, an additional filter was added to the CSA-PF process before a short list was identified for in-depth analysis. Practices were first grouped into 22 types to simplify analyses. These were then assessed using surveys and expert evaluation for benefits of practices to the three CSA pillars and relevance to local development strategies. Indicators were selected from a long list of CSA components based on stakeholder priorities and preferences for the desired impact that CSA practices would have if scaled out. The indicator list was agreed upon by the expert committee, and included evaluations of practices ability to achieve the following:

- *Productivity* – suitability to the agro-ecology analyzed, reduced input use, and facilitation of the production of a marketable output

10 The screening exercise was based on a comprehensive literature review on CSA practices currently being implemented and on surveys sent out to the country's provincial authorities. This was conducted in collaboration with the MARD Department of Crop Production. Out of the 63 provinces reached, 30 responded to the surveys. Appendix Table 8.1. lists the number of practices that have been identified by region.

11 Practices related to rice-shrimp farming were counted as practices related to crop production.

12 This refers to the 807 practices mapped in 30 provinces in Vietnam.

- *Adaptation* – increase the system's climate change adaptive capacity, improve equitable participation of women and men in agricultural activities, improve sustainable use of natural resources, promote social sustainability (education and livelihoods), and enhance food security
- *Mitigation* – increase the sector's mitigation potential, and ensure economic effectiveness of mitigation efforts
- *Relevance* – link with and strengthen local and sectoral plans and strategies

The IAE and the IPSARD used the indicator analyses to rank the practices and identified 13 practices of high interest in the three AEZs and provinces. Note that in this context, a practice means an agricultural management technique conducted in relation to a specific production system (e.g., rice, maize, cattle, etc.) within a specific AEZ.

The in-depth analysis of the impacts and costs and benefits of practices required narrowing down the focus to selected regions of interest based on their importance to agricultural production[13] and vulnerability to climate variability and change. Three main AEZs and one focal point province in each AEZ were selected: Nam Dinh province in the RRD, Ninh Thuan province in the SCC region, and Soc Trang province in the MRD. These AEZs contain around 43 percent of the country's agricultural lands[14] and about 76 percent of the total ha of rice fields and tons of rice production in the country. Apart from rice cultivation, these zones are also known for cultivation of maize, soybean, and sugarcane; livestock raising (poultry, pigs, cattle, and buffalo); and aquaculture. Previous vulnerability assessments have shown that the MRD has high climate change vulnerability, whereas the SCC and the RRD have medium vulnerability levels (Ha et al. 2013).

CBAs were conducted on 8 of the 13 short-listed practices in the selected provinces due to time and resource limitations, which can be expanded in the future.[15] These eight practices were selected from the list of 13 after being considered for their potential to be scaled out, ability of the practice to build resilience against major regional climate

13 See Appendix Table 8.2 for detailed information on the major crops and livestock by region.

14 0.8 million ha of agricultural land in the RRD, 2.6 million ha in the MRD, and 1.9 million ha in the SCC

15 In general, due to the extent and the resources (time, human, and financial) that a CBA requires, a shorter list of practices (8–10) is recommended for use in the economic assessment. If the resources are enough, then the CBA could also be run on the intermediate list (in this case, the 19 practices). This decision is usually taken by the expert committee, who can estimate the scope and length of the process as well as the stakeholders' interest and resources available.

change impacts, and the practical consideration to avoid assessments on similar practices in different regions at this time.

Data was gathered for the CBA of practices through literature review, key informant interviews, and semi-structured interviews with farmers and local experts. Information was also gathered on different aspects related to the adoption of the 13 CSA practices and climate change. Specifically, data was collected on

1. the implementers and location of the CSA practice (gender and education level of farmer, crops cultivated/livestock on the farm, seasonal calendar, income sources);
2. climate change perceptions (changes in rainfall, temperature, sea level rise, extreme climate events, etc.);
3. types of CSA practices adopted (technical description, justification of adoption, input use, soil and water management for practices' implementation);
4. practices' observed/expected impacts on CSA pillars: productivity (harvested yields, residues); adaptation (risk management, food security, gender equity, ecological and environmental sustainability, social sustainability); and mitigation (carbon sequestration, emissions reduction);
5. economic costs and benefits of practices and their environmental and social benefits (e.g., soil, water and air quality, labor for men and women, mitigation potential); and
6. enabling environment for CSA adoption (type of technical capacity, policies, and financial support available and needed).[16]

This information served as input for characterizing the priority CSA practices and for better understanding the barriers and opportunities for scaling out CSA for different actors (Table 8.1).

16 A detailed list of the indicators in the survey can be found in Appendix Table 8.3.

Table 8.1. Results from expert ranking of the short list of 13 high-interest CSA practices in Vietnam

No.	Name of CSA Practice	Average Points from Expert Ranking					Rank
		Production	Adaptation	Mitigation	Relevance	Total	
Crop Production							
1	ICM in rice using 1M5R*	20.83	26.77	22.30	11.80	81.67	1
	Soc Trang province	21.40	26.80	22.90	13.10	84.10	1
	Nam Dinh province	20.80	27.00	22.50	12.30	82.50	2
	Ninh Thuan province	20.30	26.50	21.50	10.10	78.40	3
2	Saving water irrigation for upland crop in Ninh Thuan province	21.00	25.40	21.00	11.30	78.60	2
3	Mushroom from rice straw in Soc Trang province	20.00	24.10	21.90	12.30	78.30	3
4	Shifting early sowing in summer season in Soc Trang province	20.40	25.10	19.40	12.30	77.10	4
5	Rice-shrimp rotation in Soc Trang province	19.60	24.30	20.30	12.10	76.30	5
6	ICM in rice using 3G3R	19.75	25.21	20.45	10.21	75.60	6
	Soc Trang province	20.60	26.50	22.00	12.30	81.40	1
	Ninh Thuan province	18.90	23.90	18.90	8.10	69.80	2
7	Two rice and one upland crop (*jujube*) in Soc Trang province	18.90	23.10	21.00	12.40	75.40	7
8	Salt-tolerant rice variety in Nam Dinh province	18.90	25.40	18.10	11.60	74.00	8
9	Shifting rice to Vietnamese apple in Ninh Thuan province	18.60	23.30	20.10	11.60	73.60	9
10	Shifting two-rice seasons to one rice and fish in Nam Dinh province**	18.10	24.30	18.50	11.00	71.90	10
11	Shifting tobacco to Vietnamese apple and sheep/goat raising in Ninh Thuan province	15.50	20.80	14.70	10.30	61.30	11

Table 8.1. (continued)

	Name of CSA Practice	Average Points from Expert Ranking					Rank
		Production	Adaptation	Mitigation	Relevance	Total	
Livestock							
12	Biogas from swine	21.60	26.16	25.43	12.57	85.73	1
	Nam Dinh province	22.40	26.60	25.60	12.80	87.40	1
	Soc Trang province	22.10	26.50	25.40	12.90	86.90	2
	Ninh Thuan province	20.30	25.40	25.30	12.00	82.90	3
13	Biological bed for chicken	19.25	25.35	22.95	12.20	79.75	2
	Nam Dinh province	19.40	26.10	22.80	11.90	80.10	1
	Ninh Thuan province	19.10	24.60	23.10	12.50	79.40	2

Notes: (1) * The practice, applied as a means to improve the overall sustainability of rice production, represents a combination of actions referring to the use of certified seed ("must do") and reductions in the amount of seed, fertilizer use, frequency of pesticide application, water use through alternative wetting and drying, and postharvest losses ("five reductions"). (2) ** This refers to cultivating rice in one season and fish in the next season, instead of rice in both seasons, to diversify production. (3) 1M5R = One Must Do and Five Reductions (also known as 1P5G); 3G3R = Three Gains and Three Reductions (also known as 3G3T); ICM = integrated crop management

The costs and benefits of adopting (implementating and maintaining) the eight selected CSA practices in the three target provinces were assessed using traditional CBA analyses. Economic costs and benefits were assessed from the perspective of a farmer if changing from their current practices to implementing CSA practices. The analyses were quantitative evaluations of variables that could be monetized either directly or by using shadow pricing or assigning proxy values to various environmental or social benefits. The CBAs produced net present value (NPV) and internal rate of return (IRR) values for the various practices, which are indicators used to assess the desirability of a given intervention based on the overall profitability (discounted into the future) or ability to provide returns on initial investments. Practices were then ranked by their NPV, IRR, and initial investment values and were given scores associated with the ranking. The practices were also scored for their risk tolerance based on sensitivity analyses (1 = low, 3 = high). The scores were combined to create a final ranking of practices based on these various outputs from the CBA studies (Table 8.2) for use by stakeholders to discuss priorities.

Table 8.2. Ranking of eight high-interest CSA options based on the CBA analysis

CSA Option	NPV	IRR	Initial investment	Risk tolerance	Total score	CBA Ranking
Rice-shrimp rotation in coastal area	7	6	5	3	21	1
Applying ICM in rice production (1M5R)	6	4	6	1	17	2
Rice-mushroom from rice straws	5	3	8	1	17	2
Water-saving irrigation for upland crop	3	8	3	2	16	4
Applying saline-tolerant rice variety	4	1	7	3	15	5
Biogas digester in pig production	1	5	4	3	13	6
Two rice and upland crop (jujube)	2	7	2	2	13	6
Shifting two-rice seasons to one-rice season and one-fish season	8	2	1	1	12	8

The CBA assessment demonstrated that most of the short-listed practices were profitable and relatively risk-adverse options. Shifting from two-rice seasons to one-rice season and one-fish season in the MRD was the most profitable in terms of overall NPV, whereas the water-saving irrigation project for upland crops in Central Vietnam had the largest IRR. When the multiple criteria for prioritization were combined, the rice-shrimp rotation in the MRD emerged as the most favorable with regard to profitability and risk tolerance.

A participatory assessment of barriers and opportunities for implementation was also conducted to complement the CSA indicators assessment and the CBA results. The constraints identified at the farm level were related to limited knowledge, high upfront costs for technologies that have greatest mitigation potential, and poor access to financing. At levels beyond the farm, the constraints identified were related to limited market accessibility and elevated risk, insufficient extension services and support, unsystematic supporting policies, limited finance mechanisms, and institutional governance.

The final stage of the CSA-PF is forthcoming and will bring stakeholders together to discuss the results of the study, including the analyses from different angles developed throughout prioritization phases. Under the leadership of the IPSARD and the IAE, stakeholders will define portfolios of CSA options for specific regions and production systems that could be included in future planning processes in the country's target provinces.

LESSONS LEARNED AND WAY FORWARD

The implementation of the CSA-PF in Vietnam provided important lessons for policy makers, researchers, and implementing organizations that aim to address CSA given the national scope of the discussion and diversity of CSA options identified. This section outlines five key lessons that span suggestions for future iterations of the CSA-PF and broader considerations for effective CSA out-scaling.

Tailor CSA Assessments to the Context

In Vietnam, addressing climate change issues in the agriculture sector is an area of high interest to policy makers and farmers alike. Due to this high demand, the scope of the CSA-PF initiative was broadened to ensure that the results were nationally relevant and could support a countrywide discussion on CSA. That said, mapping CSA practices across the entire country is a lengthy process. In order to have analyses with enough detail for action, each specific practices must be assessed in the various contexts were it can be applicable. This requires considerable resources and unwavering commitment from implementers and key informants. Other countries aiming to use CSA-PF may not be able to initially dedicate time and resources to a national study. Each iteration of the CSA-PF, or any analysis of CSA options, must be tailored to the specific objectives, needs, and interest of the implementers. This includes considering both the scope and the components of the actual analyses conducted, such as the indicators used and the externalities included in the CBAs.

Foster Stakeholder Inclusion and Ownership

Establishing CSA priorities and action plans requires strong commitment from the interested parties and bold leadership to plan, execute, and monitor the complex and interdisciplinary activities and to accomplish the expected results. Sustained involvement from stakeholders such as national/regional/local policy makers, development organizations, NGOs, farmers, academe and scientists, and the private sector must be cultivated from the onset of the process. A transparent and inclusive stakeholder engagement plan that allows space for codesign of the intervention and setting of the objectives and priorities was seen here as critical to the success of the CSA-PF in Vietnam.

The CSA-PF also generates valuable information on enabling environments for CSA, impacts and benefits of CSA investment, and gaps and barriers to adoption through exchanges with experts, farmers, and decision makers. It is critical to ensure that those involved in providing information have access to the data generated, and that there are opportunities for broader validation of findings. Stakeholders should also be involved in determining the analyses needed. It is important to remember that although analysis contributes to the identification of priorities, analytical results or rankings of practices, on their own, are not considered prioritization. While these analyses help to simplify the complexities of the trade-offs between investing in one CSA practice vs. another, such as a CBA, decisions are made in a political and cultural spaces; these tools cannot distill all criteria for prioritization together. It is up to the decision makers to ultimately clarify what matters in each context. Discussion, debate, and collective decision making are needed for priority setting. Strategies for building joint action are needed not only at the implementation phase, but also at the monitoring and evaluation stages of the prioritization process to ensure ownership of results and next steps.

Link Science and Policy

There is an evident knowledge gap related to CSA, both globally and nationally, between those who coined the concept and conduct CSA research and those in charge of operationalizing the concept and of using research results. While there is increasing understanding of the objectives that CSA actions aim to achieve, and although scientists from various disciplines have developed frameworks and analytical approaches to help mainstream CSA into action, decision makers often do not have substantial awareness of the importance, benefits, and impacts of CSA activities. They limit their ability to just either helping to enable policy creation or ensuring that policy design is evidence-based. Even when there is evidence available and political will, CSA decisions often lack an integrative approach to weighing trade-offs and accounting for the context specific impact of practices.

The CSA-PF pilots have demonstrated that the process itself has a strong capacity-building component for the stakeholders actively engaged in the process. It offers an opportunity to take a critical view of the CSA approach, to identify how the concept links ongoing and historic practices with new technologies and climate change challenges, and to codevelop pathways for tailoring agricultural investments so that they bring multiple benefits to the society and future generations. The CSA-PF aims to build momentum for science-policy integration, offering tools to link expert knowledge with the pragmatism of policy and decision makers. In Vietnam, the process provided opportunities to identify the need for a roadmap or National CSA Framework in order to guide the integration of CSA into various government actions such as the Vision 2050 or National Determined Contribution. The next step in this endeavor is to provide continuity to this dialogue. By keeping research and decision making closely together when collecting data, conducting analyses, and validating results, scientific efforts will be made more relevant to policy making; decision making can then draw from a rigorous and adequate information base.

Build the CSA Knowledge Base

It is clear from the Vietnam case, as well as from previous uses of the CSA-PF, that CSA practices lack documentation—both in terms of where practices are applicable and the impact that such practices have on the CSA pillars in various contexts. Researchers have found that even when data is available on practices, rarely do the same studies look at the multiple trade-offs across productivity, adaptation, and mitigation, with data on mitigation being especially limited (Rosenstock et al. 2015). Information on business cases for adopting CSA practices is also needed. In Vietnam, it was seen that most of the CSA practices assessed were profitable when compared to business as usual, but studies are needed to further explore the economic profitability and co-benefits of these practices under various contexts in order to improve understanding of how to promote or incentivize uptake by farmers.

The lack of comprehensive data on CSA makes it challenging to conduct detailed analyses for enabling action. This requires data collection from multiple sources and in different formats (qualitative, quantitative, and mixed). The CSA-PF therefore creates space for building the CSA knowledge base; however, it also recognizes that due to resources, each study can only do in-depth analyses on a few practices. Therefore, multiple ways of using available information on CSA practices is needed to assess practices of high interest. CSA-PF implementers must factor in time and resources for rapid rural appraisal methods, surveys, focus groups, and workshops. Ideally, these types of processes will lead to the development of a comprehensive database of CSA practices and impacts accessible to decision makers for future planning processes.

Enable Short- and Long-Term Action

Prioritizing CSA practices is only the first step in achieving the impact needed at scale to move food systems toward being climate-smart. Establishing enabling environments and comprehensive funding mechanisms is critical such that long-term CSA action can take place. Although barriers to adoption and potential solutions were explored in the CSA-PF process, further work is needed to validate solutions and to enact them. As seen in Vietnam, this could mean exploring incentive programs, private sector involvement to create transformative shifts in markets, establishing crosscutting CSA advisory boards, etc. Beyond these programs, a number of actions in Vietnam is needed to sustain CSA action, and could be applicable to other countries, including

1. capacity strengthening related to improving quality and timeliness of information system (climate, weather, market) and services (extension);
2. improving interinstitutional coordination to bridge climate change planning with environment, agriculture, economic, and social consideration; and
3. development of and extending access to financing mechanisms from national to farm levels.

It is important therefore to plan beyond the identified priority practices with highest CSA benefits toward policies and actions that need to be adjusted or developed in order to make sure that barriers to adoption are overcome. Establishing mechanisms for iterative planning is key to ensuring planning processes can build on the newest data and that the practices being promoted actually achieve the desired outcomes.

CONCLUSION

All in all, the complexity of the CSA concept, its various interpretations and forms of operationalization, and the broad array of investment interests belonging to different stakeholder groups turn the prioritization process into an ambitious agenda. Yet this is by no means unattainable, provided that there is general interest in collaboration and solid stakeholders' commitment to the process and the subsequent action to invest in implementation. Use of mixed scientific and political prioritization processes for CSA can provide forums to improve evidence-based decision making and better link agriculture and climate change policies and bring in additional critical actors across sectors and levels of governance.

ACKNOWLEDGMENTS

Funding for this initiative was provided by the CGIAR Research Program on CCAFS. The authors are greatly appreciative of the leadership of Leocadio Sebastian and Andy Jarvis and the assistance of Osana Bonilla-Findji, Bui Tan Yen, and Duc Ming Ngo from CCAFS in setting up and implementing the project. The in-country implementing partners were critical throughout all stages of the project from codesign through implementation. The key actors, in addition to the authors, included Le Hoang Anh and Bui My Binh (MARD), Tran Van The (IAE), and Le Trong Hai and Doan Minh Thu (IAE). Rauf Prasodjo, Nora Guerten, and Godefroy Grosjean (CIAT) provided technical and managerial support that was critical to the initiative. The authors also acknowledge the local government authorities and communities where the research took place, and thank them for contributing their time, knowledge, and energy to the process.

REFERENCES

Campbell, B.M., S.J. Vermeulen, P.K. Aggarwal, C. Corner-Dolloff, E. Girvetz, A.M. Loboguerrero, J. Ramirez-Villegas, T. Rosenstock, L. Sebastian, P. Thornton, E. Wollenberg. 2016. "Reducing Risks to Food Security from Climate Change." http://doi.org/10.1016/j.gfs.2016.06.002

Challinor A.J., J. Watson, D.B. Lobell, S.M. Howden, D.R. Smith, N. Chhetri. 2014. "A Meta-analysis of Crop Yield under Climate Change and Adaptation." *Nature Climate Change* 4: 287–291.

Corner-Dolloff, C., A.M. Loboguerrero, M. Lizarazo, A.C. Nowak, F. Howland, N. Andrieu, and A. Jarvis. 2014. *Climate-Smart Agriculture Investment Prioritization Framework*. Cali, Colombia: CIAT.

Corner-Dolloff, C., A. Jarvis, A.M. Loboguerrero, M. Lizarazo, A. Nowak, N. Andrieu, F. Howland, C. Smith, J. Maldonado, J. Gomez, O. Bonilla, T. Rosenstock, D. Martinez-Baron, and E. Girvetz. 2015. *Climate-Smart Agriculture Prioritization Framework*. Palmira, Colombia: CIAT.

FAO. 2010. *"Climate-Smart" Agriculture: Policies, Practices and Financing for Food Security, Adaptation and Mitigation*. Rome, Italy: FAO.

FAOStat. 2016. "Vietnam Agriculture Sector." Accessed on 13 May 2016. http://faostat3.fao.org/

Foley, J.A., N. Ramankutty, K.A. Brauman, E.S. Cassidy, J.S. Gerber, M. Johnston, N.D. Mueller, C. O'Connell, D.K. Ray, P.C. West, C. Balzer, E.M. Bennett, S.R. Carpenter, J. Hill, C. Monfreda, S. Polasky, J. Rockström, J. Sheehan, S. Siebert, D. Tilman, and D.P.M. Zaks. 2011. "Solutions for a Cultivated Planet." *Nature* 478(7369): 337–42.

GSO (General Statistics Office of Vietnam). 2014. "Agriculture, Forestry, and Fishery." Accessed 13 May 2016. https://www.gso.gov.vn

Ha, P.Q., M.V. Trinh, T.V. The, H.H. Cuong, D.T. Hien, N.T. Hue, N.P. Singh, and C. Bantilan. 2013. "Vulnerability to Climate Change: Adaptation Strategies and Layers of Resilience, Quantifying Vulnerability to Climate Change in Vietnam." *ICRISAT Research Report* No. 25. Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

Lipper, L., P. Thornton, B.M. Campbell, T. Baedeker, A. Braimoh, M. Bwalya, P. Caron, A. Cattaneo, D. Garrity, K. Henry, R. Hottle, L. Jackson, A. Jarvis, F. Kossam, W. Mann, N. McCarthy, A. Meybeck, H. Neufeldt, T. Remington, P.T. Sen, R. Sessa, R. Shula, A. Tibu, and E.F. Torquebiau. 2014. "Climate-Smart Agriculture for Food Security." *Nature Climate Change* 4(12): 1068–1072.

Rosenstock, T.S., C. Lamanna, A. Arslan, and M.B. Richards. 2015. "What is the Scientific Basis for Climate-Smart Agriculture? Preliminary Findings from a Quantitative Synthesis of What Works." *Info Note Series*. Cali, Colombia: CGIAR Research Program on Climate Change, Agriculture, and Food Security.

Rutten, M., M. van Dijk, W. van Rooij, and H. Hilderink. 2014. "Land Use Dynamics, Climate Change, and Food Security in Vietnam: A Global-to-Local Modeling Approach." *World Development* 59: 29–46.

Sain, G., A.M. Loboguerrero, C. Corner-Dolloff, M. Lizarazo, A.C. Nowak, N. Andrieu, and D. Martinez. 2016. "Costs and Benefits of Climate-Smart Agriculture: The Case of the Dry Corridor in Guatemala." *Agricultural Systems* http://dx.doi.org/10.1016/j.agsy.2016.05.004.

SRV (Socialist Republic of Vietnam). 2015. *Intended Nationally Determined Contribution of Vietnam*. Bonn, Germany: United Nations Convention on Climate Change.

Sogoba, B., N. Andrieu, F. Howland, O. Samake, C. Corner-Dolloff, O. Bonilla-Findji, and R. Zougmore. 2016. *Climate-Smart Solutions for Mali: Findings from Implementing the Climate-Smart Agriculture Prioritization Framework*. Cali, Colombia: CIAT.

Tilman, D., C. Balzer, J. Hill, and B.L. Befort. 2011. "Global Food Demand and the Sustainable Intensification of Agriculture." *Proceedings of the National Academy of Sciences of the United States of America* 108(50): 20260–20264.

UNDESA (United Nations Department of Economic and Social Affairs). 2013. *World Population Prospects: The 2012 Revision, Highlights and Advance Tables*. New York: United Nations.

UNFCCC (United Nations Framework Convention on Climate Change). 2010. *Emissions Summary for Vietnam*. Bonn, Germany: UN Climate Change Secretariat.

World Bank. 2010. *Economics of Adaptation to Climate Change: Vietnam*. Washington D.C., VA: The World Bank.

World Bank. 2016a. "World Development Indicators." Accessed 13 May 2016. http://data.worldbank.org/indicator/NV.AGR.TOTL.ZS

World Bank. 2016b. *Transforming Vietnamese Agriculture: Gaining More from Less: Vietnam Development Report*. 2016. Washington, D.C., VA: The World Bank.

WRI (World Resources Institute). 2013. *Creating a Sustainable Food Future: A Menu of Solutions to Sustainably Feed More Than 9 Billion People by 2050*. Washington, D.C., VA: World Resources Institute.

APPENDIX

Appendix Table 8.1. List of existing CSA plots in 2015, by agricultural production system, by region, Vietnam

Description	NM	RRD	MRD	SCC	NCC	CH	SE	Total
Main Crops	142	106	213	52	57	147	59	776
Rice	63	33	133	28	20	24	19	320
Maize	16	3	–	–	–	1	–	20
Soybean	–	–	–	–	–	2	–	2
Sugarcane	10	–	–	4	1	15	–	30
Potato	6	19	–	–	–	3	–	28
Vegetable	14	16	11	9	22	48	5	125
Fruit	12	10	18	7	–	–	11	58
Industrial plants	11	–	–	–	5	50	18	84
Others	10	25	51	4	9	4	6	109
Animal Livestock	4	9	4	4	3	4	3	31
Pig	2	2	2	2	3	1	–	12
Cow	–	1	–	–	–	1	3	5
Poultry	2	6	2	2	–	2	–	14
Fishery and Aquaculture	–	–	–	–	–	–	–	–
Total	146	115	217	56	60	151	62	807

Notes: (1) The data presented in this table were gathered from literature and survey results from 30 provinces in Vietnam in 2015. (2) The Northern Mountainous (NM) region comprises the Northeast (NE) and Northwest (NW) subregions of Vietnam. (3) CH = Central Highlands, MRD = Mekong River Delta, NCC = North Central Coast, RRD = Red River Delta, SCC = South Central Coast, SE = Southeast

Appendix Table 8.2. Key rural development and agriculture indicators, by population, by region, and by agricultural commodity

Item	Vietnam	RRD	MRD	SCC
Agricultural land areas (per '000 ha)	10,231.7	769.3	2,607.1	1,009.5
Total population (per '000 person)	90,728.9	20,705.2	17,517.6	9,117.5
Main Crops				
Rice				
Area (per '000 ha)	7,655.4	1,144.5	4,093.9	537.9
Quantity (per '000 ton)	44,975.0	6,756.8	25,244.2	3,166.4
Maize				
Area (per '000 ha)	1,177.5	88.7	38.0	79.3
Quantity (per '000 ton)	5,191.7	418.9	226.6	383.0
Soybean				
Area (per '000 ha)	110.2	38.1	0.8	–
Quantity (per '000 ton)	157.9	60.7	1.5	–
Sugarcane				
Area (per '000 ha)	305.0	1.0	54.5	58.9
Quantity (per '000 ton)	19,927.5	64.5	4,786.4	3,334.4
Animal livestock				
Pig (per '000 head)	26,761.6	6,824.8	3,470.4	2,246.3
Buffalo (per '000 head)	2,511.9	134.3	35.0	173.6
Cow (per '000 head)	5,234.3	492.8	677.9	1,185.5
Poultry (per '000 head)	327,746.0	89,028.0	58,246.0	25,499.0
Fishery				
Area (per '000 ha)	1,053.9	128.8	756.3	27.9
Quantity (per '000 ton)	2,919.2	229.2	1,216.9	845.7

Source: GSO (2014)

Note: (1)These indicators were identified to assist in establishing the scope of the study after the national survey of CSA practice had been conducted. (2) MRD = Mekong River Delta; SCC = South Central Coast

Appendix Table 8.3. List of indicators used in the surveys of CSA practices

No	Identifying Indicator
A.	General Information
A1.	Name of farmer, address, gender, and educational level
A2.	Name of investigator and date of survey
A3.	Main crops and cultivated areas
A4.	Seasonal calendar (different crops in different type of soil from January to December)
A5.	Main animal types and type of raising
A7.	Income sources
B.	Perceptions of Climate Change
B1.	Change in temperature
B2.	Change in rainfall
B3.	Change in sea level rise
B4.	Change in extreme climate events
B5.	Other related sign
C.	Climate-Smart Agriculture: Current vs. Historic Comparison, Reason for Change
C1.	General information
C1.1.	Name of CSA
C1.2.	Type of CSA application
C1.3.	Started year of application
C1.4.	Source of induced CSA
C1.5.	Description of main technical of CSA
C1.6.	Applied area of CSA
C1.7.	Land type of applied CSA
C1.8.	Rotation system with CSA
C2.	Production pillar
C2.1.	Basic technical package
1.	Description of levelling soil of CSA application
2.	Description of soil type of CSA application
3.	Land preparation practices
C2.2.	Input in use
1.	Seeds (name, amount)
2.	Sowing/transplanting practices
3.	Fertilizer in use (types and amount)
4.	Pesticide in use (main of pest and disease, type of pesticide, amount, times)
5.	Irrigation (skill, times, amount, period)
6.	Labor in use (type, number of working days)

Appendix Table 8.3 (continued)

No.	Identifying Indicator
C2.3.	Output
1.	Harvested yield
2.	Residues (type, amount in use)
C3.	Climate change adaptation pillar
C3.1.	Adaptation capacity
1.	Drought tolerance capacity (high, medium, low)
2.	Flooded resistance capacity (high, medium, low)
3.	Extreme climate capacity (high, medium, low)
4.	Risk-averting capacity to climate change (high, medium, low)
C3.2.	Food security ensure
1.	Food security support (kg/HH/year)
2.	Proportion of food expenditure in income
C3.3.	Gender balance
1.	Change in women share in working days
2.	Improved income for women
3.	Improved role for women
C3.4.	Ecological and environmental impact
1.	Improve effectiveness of water in use
2.	Improve effectiveness of fertilizer in use
3.	Improve chemical content in use
4.	Restore biodiversity
5.	Reduce pest and disease catching
6.	Improve underground water
7.	Prevent and reduce soil erosion
8.	Improve soil quality
C3.5.	Social effectiveness
1.	Relevance to farmer's awareness
2.	Relevance to local officers' and extension worker awareness
3.	Relevance to economic conditions, and investment and infrastructure capacities
4.	Relevance to marketable organization
C4.	Mitigation pillar
C4.1.	Opportunities for carbon balance in soil and biomass
C4.2.	Opportunities for N_2O reduction
C4.3.	Opportunities for CH_4 reduction
C4.4.	Potential other GHG emission reduction

Appendix Table 8.3 (continued)

No	Identifying Indicator
D.	Suggestions and Recommendations
D1.	Supportive policies for agricultural development in general
D2.	Supportive policies for climate change adaptation
D3.	Supportive policies for climate change mitigation
D4.	Technical supports of CSA mitigation (economic, adaptation, and mitigation measures)
D5.	Other suggestions and recommendations (financial, organization, communication, trainings, and education)

Hierarchical Level Linkages to Pilot Application:

City Level

Calumpang River, Batangas City
Photo by Pol Veluz

CASE STORY 9

How a City Gears for Climate Change

The Case of Batangas City, Philippines

Marisa J. Sobremisana[1], Decibel F. Eslava[1], Ma. Victoria O. Espaldon[1], Leonardo M. Florece[1], Alma Lorelei Abejero[1], Oliver Gonzales[2], Antonio J. Alcantara[1], Sofia A. Alaira[1], Simplicio Q. Veluz[1], and Luningning R. Morales[3]

ABSTRACT

This case story emphasizes the role of local government and the importance of strengthening the links among the industrial, civil society, and academic sectors in crafting and implementing a holistic plan for the environment using climate change adaptation strategies. The strategies deal with problems encountered by an agricultural community that has become urbanized, such as issues in land-use changes, flooding, and pollution. In order to institute a sound environmental plan, data that will enable planners to account and profile existing resources is highly important; however, such data are always lacking in developing countries. This case also highlights the importance of establishing good rapport between and among collaborating institutions such that plans can materialize. This case story recommends managing water resources and adopting green technologies in order to achieve sustainable climate change adaptation.

INTRODUCTION

Many urban areas in the Philippines have been expanding into the adjacent agricultural and forest areas. Due to the fast-paced urbanization and industrialization, these areas are unprepared for the associated consequences of urbanization, such as population growth and increased waste generation. This often results in environmental pollution, food and water insecurity, among others. The City of Batangas in the Philippines is not unique to this trend.

---

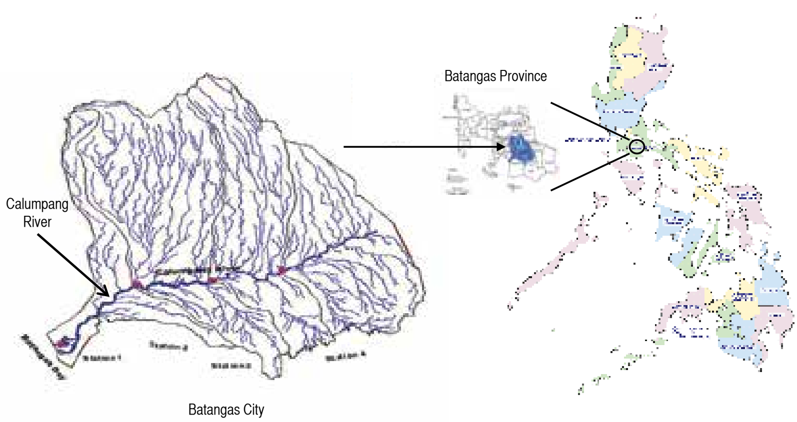
1 School of Environmental Science and Management, University of the Philippines Los Baños
2 Office of the City Mayor, Batangas City, Philippines
3 Provincial Environment and Natural Resources Office, Department of Environment and Natural Resources, Batangas City, Philippines

Batangas City has a major role in national development. It has been identified as the regional hub of CALABARZON.[1] Within the region, the city has become the accelerating point of commercial and industrial activities because of the Batangas Port, which is the alternate port to the Manila port. Hence, the city continues to grow economically, which has led to the city's population to grow due to the number of migrant workers and transients from neighboring provinces that come to the city.

Batangas City is located 112 kilometers (km) south of Manila (Figure 9.1) with a population of about 280,000 individuals. The total land area is about 27,600 hectares (ha), consisting of 24 urban and 81 rural *barangays* (villages). With this distribution, the city can be considered as an agricultural community; although in recent years, the total area planted to crops has reduced from 13,447.69 ha to only 6,496.35 ha due to the conversion of agricultural lands for residential, industrial, and institutional purposes.

Although the city produces rice, its production is not sufficient to supply the city populace. Thus, nearby rice-producing provinces (i.e., Mindoro Occidental, Mindoro Oriental, and Central Luzon provinces) supply the additional requirement of the city. However, other crops such as vegetables; root crops; corn; and fruits (e.g., mangoes, *atis* or sugar apple, tamarind, and bananas) are highly produced in the area. The city government, through the Office of the City Veterinary and Agricultural Services, has also launched a massive program on yellow corn production to its identified beneficiary farmers. Yellow corn is a high-value crop used as a major ingredient in the livestock feed-processing industry (feed millers). Moreover, livestock and poultry production is a flourishing industry in the city; thus, Batangas City is a major meat supplier of Metro Manila and other provinces. Different types of livestock raisers are present in the city, such as backyard, small-, medium-, and large-scale livestock raisers.

Figure 9.1. Location map of Batangas City and Calumpang River



1 CALABARZON is an administrative region in the Philippines located in southwestern Luzon. It is composed of the provinces Cavite, Laguna, Batangas, Rizal, and Quezon.

At present, only about 7,250 ha of the city's land area can be considered as forestlands. Meanwhile, the coastline of the city is currently used for industrial, residential, commercial, and transportation purposes. A total of 15 heavy industries engaged in power generation, oil refinery, and chemical and food processing are all located in the coastal area of Batangas City.

These kinds of opportunities have made Batangas City into a major player in the economic development of the Philippines. However, alongside this development are the negative environmental impacts, which can be exacerbated by the effects of climate change. The investments and gains made by Batangas City in agriculture, infrastructure, tourism, and other amenities can be lost in a single flood event. If not, it may be corroded by the disruption of cycles of the equally important water resources due to pollution and greenhouse gas (GHG) emissions. Therefore, the city government of Batangas aims to be proactive by engaging its citizen to observe and do what is right for the environment.

The Driving Challenge of the Batangas City Government

Working with local governments in the Philippines is a challenge by itself. This has been the common thinking among those who have had the chance to engage with them, particularly in implementing projects even when the beneficiaries are their constituents.

In 2010, the Government of the Philippines, through the Department of Interior and Local Government (DILG), challenged the local government units (LGUs) of the Philippines—from the provincial level down to the barangay level—to improve their quality of governance by launching a program on transparency and accountability called the Seal of Good Housekeeping and the Performance Challenge Fund. The Seal of Good Housekeeping assesses LGUs on their performance based on minimum governance standards:

1. The LGU must adhere to the full disclosure and transparency policy by posting its budgetary documents online and on their bulletin boards.
2. The LGU must have no serious negative findings in its annual audit report published by the Commission on Audit.

As a means of providing monetary incentives for LGUs, LGUs must be conferred with the seal in order to receive a grant from the Performance Challenge Fund (PCF). In addition to the PCF, the national government provides a performance-based grant, which the LGUs can use to supplement their funds for local development projects. Close to 84 percent of the total LGUs in the Philippines have taken the challenge to meet the minimum requirements for good housekeeping. Thus, to encourage local governments to continue their good governance practices while providing better services, the DILG again launched the Seal of Good Local Governance (SGLG) on 15 January 2014.

According to the then DILG Secretary Mar Roxas, the SGLG aims to motivate LGUs to

1. sustain the practice of accountability and transparency (good financial housekeeping),
2. to prepare for the challenges posed by disasters (disaster preparedness),
3. to be sensitive to the needs of vulnerable and marginalized sectors of the society (social protection),
4. to encourage investment and employment (business-friendliness and competitiveness),
5. to protect the constituents from threats to life and security (peace and order), and
6. to safeguard the integrity of the environment (environmental management).

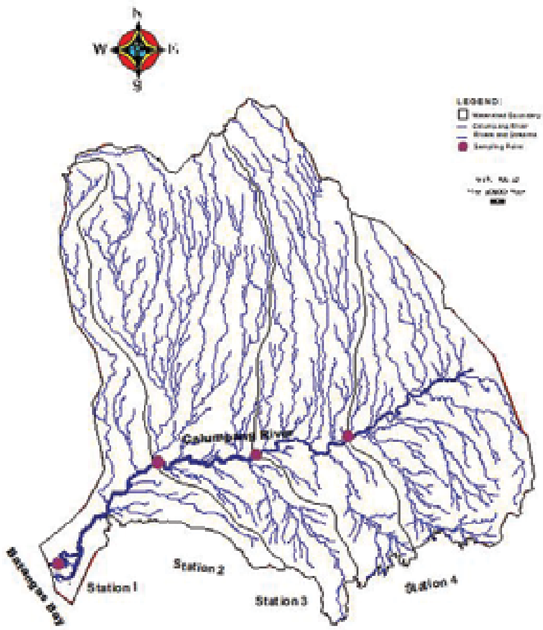
Having conferred with the SGLG can make any LGU proud. Accordingly, this challenge has opened the opportunity for LGUs to forge a strong collaboration with the academe. The desire of Batangas City to achieve exemplary distinction for the benefit of its constituents, in addition to being a model of good governance, paved the way for the city to establish its agenda for climate change and environmental stewardship.

CCA METHODS AND APPROACHES

One significant geographical feature of Batangas City that is naturally hazard-prone (particularly to floods) is the Calumpang River (Figure 9.2). Calumpang River is a major perennial river system with a catchment area of approximately 472 square kilometers (km^2) covering the municipalities of Ibaan, San Jose, Taysan, Rosario, Padre Garcia, and a part of Lipa City. It meanders at a length approximately 27.5 km from the mouth in Wawa, Batangas City up to the southern part of Lipa City with an average elevation of 4 meters above sea level (masl). The two mouths opening to Batangas Bay are located between Cuta and Wawa, whereas the other is between Wawa and Malitam, which is about 2 km from the Batangas port. From its mouth in Malitam up to the boundary of the municipality of Ibaan, the river is approximately 8 km in length, with an average width of about 90 meters (m). The Calumpang River basin is 43 percent agricultural land, 26 percent forest/watershed/grassland, and 31 percent built-up in actual land uses (Endonela et al. 2013). However, data is still lacking with regard to the hydro-geology and other physio-chemical characteristics of the river.

Thus, through the initiative of the Batangas City government, various surveys (including an accounting of previous flood disasters that have happened due to river overflow) were carried out to establish the baseline characteristics of Calumpang River. The data generated were accordingly utilized in the design of disaster risk reduction and mitigation (DRRM) and adaptation plans of the city.

Figure 9.2. Calumpang River watershed, 2011



Source: Morales (2011)

Flood-Proofing

The Philippines, being an archipelago, has many cities that are situated along the coast or along a river system. Flooding along rivers and streams are common. Climate change, manifested through more severe and frequent occurrence of typhoons, has therefore made these cities more vulnerable to flooding and storm surges.

Due to the geography of Batangas City, it is less prone to disasters caused by extreme weather events as compared to the other cities in the Philippines. The city is on the western side of the country, facing the West Philippine Sea, and is shielded by several mountains, which lessen the impact of typhoons. Despite this, the city has actively engaged in DRRM programs to minimize the probability that calamities would occur that would consequently put the city at risk in the face of climate change. Along this line, the characterization of the Calumpang River is an important step in establishing reliable and robust field data. The lack of such data has remained an obstacle in the modeling of many of the country's rivers and floodplains.

In the project, the researchers and the local government surveyed Calumpang River using an echo sounder for depth characterization and ground-penetrating radar (GPR) for shallow subsurface configuration. The echo sounder is a device that emits sound waves, which are then bounced back by the riverbed to the transducer. The depth of the riverbed can be calculated from the time it took for the sound to travel to the bed then back to the source. On the other hand, the GPR radiates electromagnetic waves (i.e., radio waves) through an antenna, and these electromagnetic waves are then reflected back to a receiver. The difference in the characteristics of the underlying materials influences the reflected signals. Natural and man-made features can be detected using this method. The GPR method has been employed in utility location, engineering assessment and monitoring, geological investigations, environmental assessment, and hydrogeophysical studies (Di Prinzio et al. 2013).

The data and information generated from the survey are important inputs to the flood-proofing plan of the city as they enable the researchers to determine the factors that can lead to flooding. For example, the degree by which the flood peak level can be reduced must be computed using real, ground-based data. Likewise, the conveyance capacity of Calumpang River needs to be assessed so researchers and local government planners can recommend possible solutions that are consistent with the policy of the Batangas City Government. Moreover, using sound and scientific data to design flood-proofing measures (e.g., temporary flood storage, constructed wetlands, and flood warning systems) would ensure that the proposed adaptation measures will be compatible with the river's natural processes. This would help minimize costs and the risks involved, and ensure that the measures are environmentally safe.

Multifunctional System

Like in many urban cities, conversion of lands from forestry and agricultural purposes to commercial, industrial, or residential uses is an ongoing trend. However, increasing the land area for construction will reduce the capacity of the soil to absorb rainfall runoff, which in turn reduces groundwater recharge. This condition can cause significant stream flow reduction during the dry season. The effects of urbanization (e.g., increase in construction of buildings, concrete roads, and other infrastructures) result in the decrease in infiltration and percolation of rainfall into the soil and increase in rainfall runoff, all of which eventually cause flooding. Compound this with the effect of climate change on water resources, urban areas that have ineffective urban planning are highly vulnerable to water shortages and flooding.

Land-use change is inevitable as urbanization and development progress. Thus, a policy that would integrate the different functions of the multifunctional systems existing in an urban community should be developed. In particular, the provision of multiple social, environmental, and economic functions in an urban community should be integrated. This can be done by adopting the concept of green technology and green building design and infrastructure in the midst of development and management of urban areas. The idea is to use technology and innovative strategies that harmonize agriculture with urbanization.

Pollution Prevention and Abatement

Calumpang River is used to be classified as Class C river in 1993 according to the Memorandum Circular No. 1993-07 of the Philippine Department of Environment and Natural Resources (DENR). Under the category, Calumpang River could be used for the propagation and growth of fish and other aquatic resources, for secondary recreation such as boating, and as industrial water supply for manufacturing processes after treatment. However, based on the water quality monitoring studies compiled by the Batangas City Government, Calumpang River has deteriorated over the years to the point that its classification has been downgraded to Class D. A Class-D classification means that Calumpang River can be used only for agricultural and manufacturing purposes after treatment. This prompted the city government to put the rehabilitation and restoration of Calumpang River into its Class C status (or better) as one of its top development priorities (Batangas City Government 2010). The city government then initiated projects to revitalize the river.

One of the identified major sources of pollutants in the river is the high density of swine population within the Calumpang River watershed. The water quality of the river will continue to deteriorate unless preventive and control measures as well as interventions from the LGU will be instituted. The fact that rivers flow makes them more resilient than other water bodies such as lakes. However, the degradation process of the organic pollutants under anaerobic condition, which usually occurs in the deeper areas of the river, produces GHG emissions (largely methane gas) in the watershed. Thus, helping the livestock farmers in the area install biogas digesters will reduce the amount of organic matter disposed to the Calumpang River, and thereby reduce methane emissions.

Another project that the local government has implemented is the adoption of constructed wetlands in suitable areas along the river in order to improve the water quality of the river. The constructed wetlands are designed to replicate natural wetlands, which utilize plants and its associated microorganisms for remediation. Natural wetlands filter water and trap sediments; hence, they are known as the "kidneys of the world." Under this technology, the polluted water that runs through the river will pass through strategically located constructed wetlands to be cleaned and filtered using water plants such as cattails, duckweed, bulruss, and water hyacinth. These plants are all available locally. Generally, wetlands are reliable systems with no need for energy and chemicals and have minimum operational requirements.

Revisiting and Establishing the Social and Institutional Links

An approach that has worked well and has become a pivotal force in Batangas City is the successful establishment of linkages and collaborations among the local government, industry sector, civil society, and academe (Yarime et al. 2012). In addition to the traditional roles of universities in fostering knowledge and education, more and more sectors are benefiting from its emergent third key function: linking knowledge generators in the academe to users of the created information in other sectors of society in order to facilitate technology and knowledge transfers (Etzkowitz et al. 2000; Florida and Cohen 1999; Gulbrandsen and Slipersæter 2007; Perkmann et al. 2013). These end users include local and national governments, policy makers, grassroots and mainstream communities, and economic actors (e.g., private companies and industry players). The earliest and more popular academe-industry connections are facilitated through commercialization of academic knowledge, such as patenting and licensing of inventions and academic entrepreneurship (O'Shea, Chugh, and Allen 2008; Rothaermel, Agung, and Jiang 2007).

Commercialization is viewed as the most effective means of generating academic impact due to the immediate and measurable market acceptance of the outputs of academic researches (Markman, Siegel, and Wright 2008). However, with emerging environmental, economic, and sociocultural sustainability issues, the codesign and coproduction of scientific knowledge for societal transformations are evolving as a new model of science (Future-Earth 2013; Mauser et al. 2013). Universities are well placed to influence societal transformations not only because they generate scientific, technological and social innovation, educate next generation leaders, and mediate across sectors and networks; they also enjoy the trust of various sectors of society due to their nonprofit status and history of commitment to public good (e.g., Stephens et al. 2008). Accordingly, this "trust" factor was the main reason that led to the collaboration between the City Government of Batangas and the University of the Philippines Los Baños-School of Environmental Science and Management (UPLB-SESAM). The alliance between the Batangas City Government and UPLB-SESAM started when the latter was commissioned to develop the Environmental Code (E-Code) of the former, which the city eventually enacted in 2010. The move made Batangas City one of the very few cities in the county that developed, endorsed, and enacted environmental policies that are tailor-made to suit their local conditions and requirements.

THE CCA STRATEGY

Codesigning for Sustainability: Crafting the E-Code

LGUs are becoming aware of the need to establish and implement stronger environment protection and conservation measures within their respective jurisdictions. The Local Government Code of 1991 (Republic Act No. 7160) delegates to the LGUs the responsibility to manage, to their fullest potential, all natural resource endowments they may have within their jurisdiction. In this respect, an E-Code is necessary in order to operationalize this responsibility correctly and efficiently.

An E-Code, in general, is a compilation, codification, and integration of existing municipal, provincial, and national laws and regulations on environmental protection. It serves as a guide to LGUs, government agencies, NGOs, business institutions, and other coordinating entities on how to plan and implement various environmental programs and policies. It also provides guidelines on how to regulate and manage the natural resources effectively. Accordingly, the E-Code can help local planners and policy makers to integrate specific regulations that are already in place and to introduce new unifying principles that may be needed. In general, the E-Code serves as a blueprint for protecting, conserving, and sustaining the environment and natural resources at the local level.

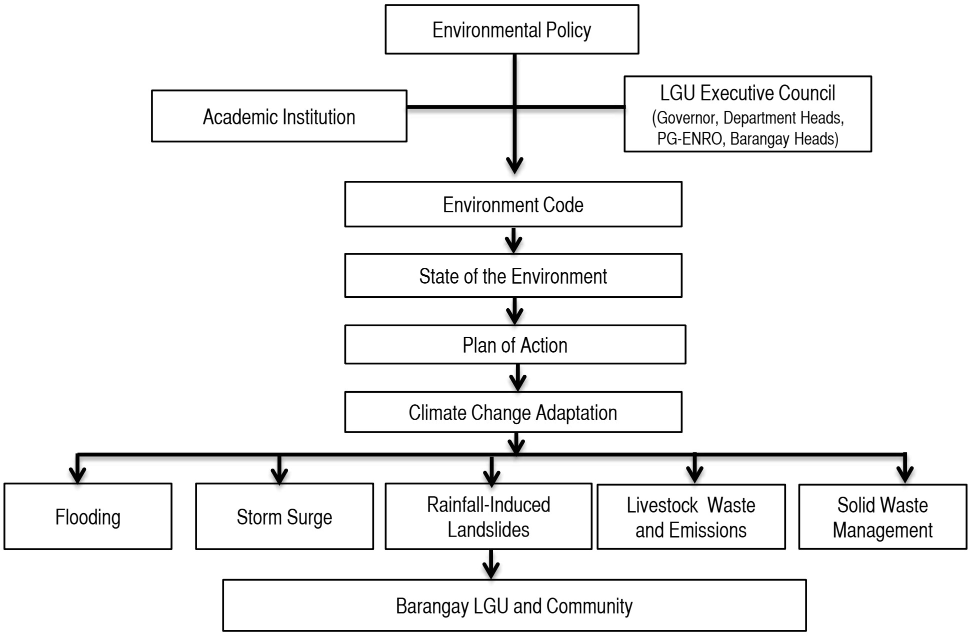
The activities that led to the development of the E-Code of Batangas City involved numerous societal engagement modes. The UPLB partnered with Batangas City in codesigning and coproducing the regulations that aim to ensure the sustainability of their urban environment. The articles in the Batangas City E-Code include provisions for the establishment of conservation areas; promotion of green designs and infrastructures; and management protocols for various natural resources, solid wastes, hazardous wastes, agricultural wastes, and air quality. The development of the city's E-Code also paved the way for the city to create the City Environment Council and to institutionalize the Community Environment and Natural Resources Office (CENRO).

Soon after the city government of Batangas enacted the E-Code and after the CENRO was institutionalized, it followed through by implementing the provisions stated in the E-Code. The *Filipino Connection* (22 January 2013), a local newspaper in Batangas, reported that as of January 2013, approximately 700 violators of the E-Code had been penalized, with total collected penalties amounting to Philippine Peso (PHP) 269,800. This shows that the environmental degradation being experienced by Batangas City, particularly on its land and water resources, is attributed to uncontrolled destructive human activities.

Subsequently, this activity of crafting and enacting the E-Code further diversified into numerous follow-up studies, which are all designed to ensure the sustainable development of the area. It has also made Batangas City recognize the link between the socioeconomic factors and the environment. Thereafter, the LGU did not waste time to materialize its desire toward a balanced life and economy in the face of the threats imposed by climate change. Figure 9.3 shows the processes that the city government and its partners went through to attain the desired output of instituting a plan of action for Batangas City.

One of the noteworthy achievements of the initiative is that each unit of the city government (down to the village level) had been highly engaged in the process of crafting their respective plans of action for CCA and sustainable development. This CCA strategy significantly contributes to inclusive and sustainable agricultural and rural development as it addresses the threats that climate change pose while preventing the damages to crop production and livestock-raising activities of farmers caused by drought and flooding.

Figure 9.3. Framework for developing the CCA strategy for Batangas City



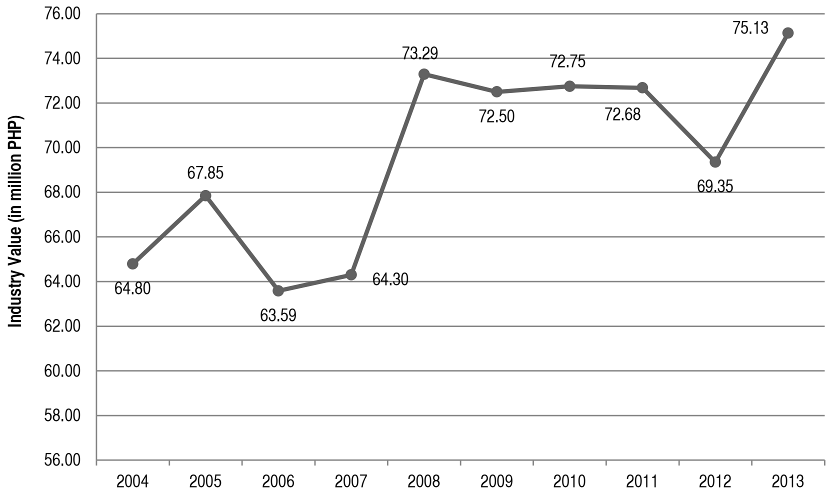
Notes: (1) LGU = local government unit; PG-ENRO = Provincial Government-Environment and Natural Resources Office; (2) *barangay* head = village head

OUTCOMES

The total economic values of swine and poultry industries in Batangas province substantiate their importance to the overall provincial and national economic development. The average mean economic value of the swine industry in Batangas City is estimated at PHP 69.6 million (Figure 9.4), whereas that of the poultry industry is at PHP 659.6 million (Figure 9.5) covering the period 2004–2013. However, the cost of the services that Calumpang River provides as a waste receptor of the productive activities of these industries is not yet included in the value estimation.

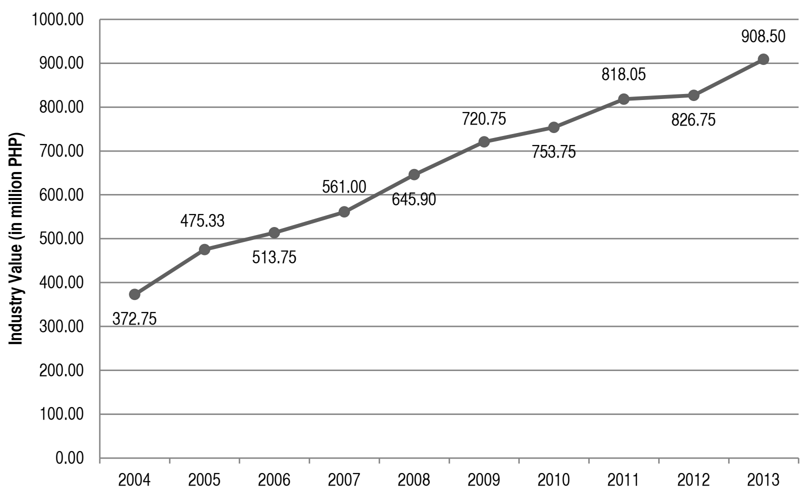
The continuous discharge of various types of effluents to Calumpang River has affected the assimilative capacity (the ability to degrade waste materials) of the whole river system. Its current condition has downgraded its long-term capacity to provide ecosystem services—particularly in its primary function as water source—for the livestock, poultry, and crop industries. In sum, the cost of rehabilitation will essentially offset the economic gains of the local government from these industries. Thus, setting up biogas digesters and developing constructed wetlands prior to farm operation can reduce the cost of its rehabilitation, and thus prevent further environmental degradation.

Figure 9.4. Economic value of swine industry, Batangas City, 2003–2014



Note: Mean = PHP 69.62 million

Figure 9.5. Economic value of poultry industry



Note: Mean = PHP 659.65 million

Six municipalities and two cities have jurisdiction over the watershed of Calumpang River. Table 9.1 shows that Batangas City has the most number of villages (33 villages) in the watershed and the highest swine population (14,322 animal units). Meanwhile, Ibaan has jurisdiction over the largest land area of the watershed (6,650.09 ha). The data also show that from 2005 to 2007, swine population in most municipalities in Batangas province have been consistently increasing (Table 9.2).

Table 9.1. Area covered by each city/municipality in the Calumpang River watershed and their swine production, 2011

City/ Municipality	Area (km^2)	Area (% of the Watershed)	No. of Barangays	AU
Taysan	52.46	16	18	5,969
Rosario	53.44	16	18	10,571
Lipa City	42.04	13	22	6,697
Padre Garcia	9.21	3	6	201
Ibaan	66.50	20	30	4,847
Cuenca	8.14	2	6	415
San Jose	45.55	14	26	10,318
Batangas City	56.69	17	33	14,322
TOTAL	334.04	100	159	53,340

Source: Morales (2011)

Note: AU = animal unit

Table 9.2. Swine population in Calumpang River watershed, 1997–2011

Municipality	1997	2005	2007	2008	2009	2011
Batangas City	24,750	46,502	62,685	62,163	62,163	65,498
Cuenca	7,500	21,780	24,447	2,720	2,720	2,720
Lipa City	216,890	92,496	184,007	93,452	93,452	93,452
San Jose	37,588	No data	29,293	18,112	No data	28,600
Ibaan	8,840	14,890	25,924	23,100	23,100	34,961
Taysan	28,280	12,278	45,051	21,023	15,645	17,722
Padre Garcia	5,312	15,280	17,153	1,082	7,981	7,981
Rosario	42,785	102,020	51,957	87,917	75,428	74,410

Source: Morales (2011)

According to the FAO (2005), pollution damage is especially harmful when large numbers of animals are concentrated in sensitive areas around cities or close to water resources. This is because effluents are commonly discharged into the environment or stored in vast “lagoons,” from which waste may spill or leak into nearby streams and groundwater supplies. Likewise, noxious gases emitted by these effluents escape into the atmosphere, and thus subject downwind neighbors to sickening odors. This condition also contributes to atmospheric aerosol formation, build-up of GHG, and formation of acid rain. An increase in swine AU means that swine wastes also increase. Accordingly, data show that a total of 9,451,113.90 kilograms per annum of waste have been generated within the Calumpang River watershed (Table 9.3).

Table 9.3. Estimated swine waste production (kg/ha) in Calumpang River watershed

Barangay	Area (km^2)	AU	AU/km^2	Annual Manure Production (kg/year)
Sabang Subwatershed				
Tingga Itaas	5.97	1,764.18	295.41	304,254.89
San Pedro	17.29	204.54	11.83	35,275.48
Mahacot Kanluran	15.94	357.57	22.43	61,667.42
Mahacot Silangan	19.65	166.30	8.46	28,680.51
Catandala	49.88	291.42	5.84	50,259.02
Paharang Silangan	23.54	152.31	6.47	26,267.76
Maapas	12.67	118.54	9.36	20,443.70
Bilogo	33.86	1,844.16	54.47	318,048.44
San Jose Sico	56.49	302.77	5.36	52,216.47
Soro-soro Ibaba	10.07	3,580.70	355.76	617,536.47
Soro-soro Ilaya	10.00	1,614.75	161.43	278,483.82
Mahabang Parang*	8.13	0.00	0.00	–
Bukal	24.44	233.55	9.55	40,278.62
Wawa Subwatershed				
Cuta	12.76	0.00	0.00	–
Wawa	7.22	7.05	0.98	1,215.86
Malitam	5.92	8.34	1.41	1,438.34
Pallocan Kanluran	6.44	0.30	0.05	51.74
Poblacion	0.00	0.00	0.00	–
Kumintang Ibaba	16.19	0.00	0.00	–
Gulod Itaas	13.61	88.54	6.50	–
Kumintang Ilaya	5.92	6.44	1.09	1,110.66
Dalig	20.53	153.42	7.47	26,459.20
Dumantay	18.56	156.97	8.45	27,071.44
Tingga Labac	28.29	568.93	20.11	98,119.09
Alangilan	9.90	29.45	2.97	5,079.02
Balagtas	14.16	177.41	12.53	30,596.57
Soro-soro Karsada	24.26	886.49	36.54	152,886.28
Banaba Kanluran	10.38	682.20	65.67	117,653.92
Balete	13.21	462.25	34.97	79,720.79
Mahabang Parang	16.24	347.08	21.37	59,858.28
Concepcion	12.21	115.92	9.49	19,991.85
Tingga Itaas	22.98	0.00	0.00	–
Natunuan	20.20	0.00	0.00	–
Bagong Pook	0.00	0.00	0.00	–
TOTAL				9,451,113.90

Source: Morales (2011)

The LGU's monitoring of the density of hogs per village has given the city government an overview of the hot spot villages and municipalities. The data on swine wastes generated from swine production within the watershed area have been the basis for computing the potential nutrient loading and hotspot area in terms of eutrophication and water pollution. Accordingly, the data on potential nutrient loading can be spatially located and displayed on geographic information system maps even at the barangay level. This information can help the city government to identify and monitor the hotspot areas, and plan out the most appropriate integrated farming system design.

Environmental damages such as water pollution and GHG emissions associated with livestock production can be managed and reduced using existing proven policies and technologies. Ideally, the best management practices must cover all aspects of farm operation, including farm siting and construction following the local government Comprehensive Land Use Plan. The main factor that should be considered when planning to reduce environmental and public health risks of feedlots and effluent lagoons is to ensure that farm operations are not located too close to each other, near streams and aquifers, and in densely populated communities.

Backyard raisers are not mandated to build waste treatment facilities; however, their common practice of constructing a simple open pit for waste management has proven to be ineffective in containing and managing the wastes produced from livestock farming. Thus, the generated wastes are inevitably disposed (directly or indirectly) into the rivers and creeks. Although the farms that compose these high-density areas are located in agricultural lands—hence, they are within their bounds to operate such farm activities—the air and water pollution that such ineffective waste management practices cause may incite conflicts with those residents and business operators located in nearby residential, industrial, and institutional areas.

Based on the lessons garnered by international communities (as summarized by the FAO), the adoption of environmentally sound practices depends on (1) the incentives that adopters will gain from the practice (e.g., financial assistance and training), (2) binding standards, and (3) enforcement and sanctions.

In successful programs, the financial incentives given to adopters for investing in technologies that reduce pollution in existing farms can reach as high as 75 percent of the cost of the recommended technology. New and expanding operations, on the other hand, can be expected to factor the cost of environmental controls into the overall costs of doing business. Incentives are not applied to them.

Certification programs can also be used to encourage livestock raisers to improve their husbandry practices. Farmers can be rewarded, for example, by offering price premiums or market access privileges for products that are certified as coming from code-compliant farms. Farmers may also require extension training and assistance to select and implement environmentally sound best management practices.

However, with all these on hand, the assessment of the best practices for swine farming in the Philippines is still inadequate. In most cases, the best practices are implemented by large corporations because they have adequate funds. It is still common for swine growers, regardless of its size, to consider pollution abatement technology as an additional investment cost.

The end goal, however, is for the agro-industries and farmers to eventually self-regulate with regard to their use of resources and waste management.

ACKNOWLEDGMENT

The project management and staff would like to acknowledge the full financial support of the Batangas City government in the conduct of this research. It has also been an engaging and fruitful research opportunity with the very cooperative and welcoming constituents of the city.

REFERENCES

Alcantara, A.J. 2010. *Enhancing Entrepreneurship for Organic Fertilizer and Compressed Biogas through Life Cycle Assessment and Environmental Audit for Biodigester-Based Swine Waste Management Systems*. Laguna, Philippines: University of the Philippines Los Baños.

Batangas City Government. "Batangas City Environment Code Ordinance No. 16: An Act Providing for the Environment Code of Batangas City." Batangas City: Batangas City Government, 2010.

Batangas City Planning and Development Office. 2011. "Socio-economics, Physical, and Political Profile of Batangas City CY 2011." Accessed 25 March 2013. http://www.batangascity.gov.ph/download/ 2011/seppp_(fy2011).pdf

Di Prinzio, M., M. Bitelli, A. Castellarin, and P.R. Pisa. 2013. "Application of GPR to the Monitoring of River Embankments." *Journal of Applied Geophysics* 71: 53–61.

DENR (Department of Environment and Natural Resources of the Philippines). "DENR Administrative Order 1990-34: Revised Water Usage and Classification/Water Quality Criteria amending section Nos. 68 and 69, Chapter III of the 1978 NPCC Rules and Regulations." Quezon City, Philippines: DENR, 1990.

———. "DENR Administrative Order 1990-35: Revised Effluent Regulations of 1990, Revising and Amending the Effluent Regulation." Quezon City, Philippines: DENR, 1990.

Endonela, L., J. Manilay, D. Anacio, H.A. Hoang, R.B. Capuno, S. Chanthavong, J.M. Encinares, D.C. Galias, S.S. Girsiang, K.M. Htut, M.W. Maung, N.F. Monserate, M.S. Muros, T.M. Nieva, O. Sabuga, S. Simondac, and S.M. Woi. 2013. "Calumpang River, Batangas City Flood Dredging Project: Environmental Impact Assessment." Unpublished ENS 296 AB-1L Class report. Laguna, Philippines: School of Environmental Science and Management, University of the Philippines Los Baños.

Etzkowitz, H., A. Webster, C. Gebhardt, and B.R.C. Terra. 2000. "The Future of the University and the University of the Future: Evolution of Ivory Tower to Entrepreneurial Paradigm." *Research Policy* 29(9): 313–330.

FAO. 2005. "Pollution from Industrialized Livestock Production." *FAO Livestock Policy Brief* No. 2. Rome, Italy: Livestock Information, Sector Analysis and Policy Branch, Animal Production and Health Division, FAO.

Florida, R., and W.M. Cohen. 1999. "Engine or Infrastructure? The University Role in Economic Development." In *Industrializing Knowledge: University–Industry Linkages in Japan and the United States* edited by L.M. Branscomb, F. Kodama, and R. Florida, 589–610. Cambridge, MA: MIT Press.

Future-Earth. 2013. *Future Earth Initial Design: Report of the Transition Team*. Paris, France: International Council for Science.

Grimm, N.B., S.H. Faeth, N.E. Golubiewski, C.L. Redman, J. Wu, X. Bai, and J.M. Briggs. 2008. "Global Change and the Ecology of Cities." *Science* 319(5864): 756–760.

Gulbrandsen, M., and S. Slipersæter. 2007. "The Third Mission and the Entrepreneurial University Model." In *Universities and Strategic Knowledge Creation: Specialization and Performance in Europe* edited by A. Bonaccorsi and C. Daraio, 112–143. Cheltenham, UK: Edward Elgar Publishing.

Kania, J., and M. Kramer. 2011. "Collective Impact: Stanford Social Innovation Reviews." *Stanford Social Innovation Review* Winter 2011 Issue. Stanford, CA: Stanford University.

Markman, G., D. Siegel, and M. Wright. 2008. "Research and Technology Commercialization." *Journal of Management Studies* 45(8): 1401–1423.

Mauser, W., G. Klepper, M. Rice, B.S. Schmalzbauer, H. Hackmann, R. Leemans, and H. Moore. 2013. "Transdisciplinary Global Change Research: The Co-creation of Knowledge for Sustainability." *Current Opinion in Environmental Sustainability* 5(3): 420–431.

Morales, L. 2011. "Effect of Swine Pollution on Water Quality and Fish Productivity of Calumpang River Watershed, Batangas City." Unpublished PhD Dissertation, University of the Philippines Los Baños.

O'Shea, R., H. Chugh, and T. Allen. 2008. "Determinants and Consequences of University Spinoff Activity: A Conceptual Framework." *Journal of Technology Transfer* 33(6): 653–666.

Padura, V.R.S., and A.J. Alcantara. 2014. "Environmental Audit for Swine Waste Management Systems in Lipa City, Philippines." Paper presented at the International Conference on Agriculture, Food, and Environmental Engineering (ICAFEE 2014), 15–16 January 2014, Kuala Lumpur, Malaysia.

Perkmann, M., V. Tartari, M. McKelvey, E. Autio, A. Broström, P. D'Este, R. Fini, A. Geuna, R. Grimaldi, A. Hughes, S. Krabel, M. Kitson, P. Llerena, F. Lissoni, A. Salter, and M. Sobrero. 2013. "Academic Engagement and Commercialisation: A Review of the Literature on University-Industry Relations." *Research Policy* 42(2): 423–442.

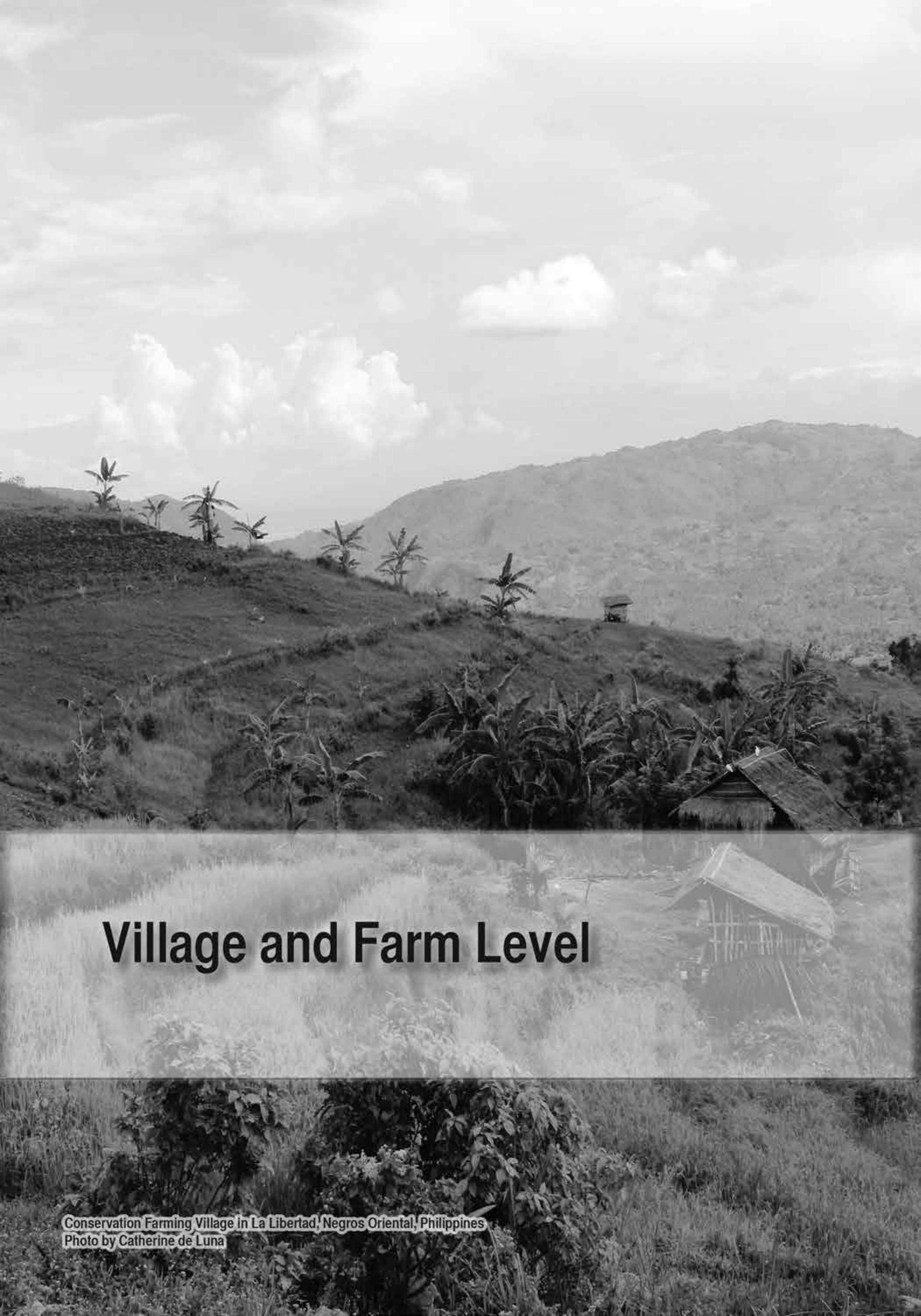
Rothaermel, F.T., A. Agung, and L. Jiang. 2007. "University Entrepreneurship: A Taxonomy of the Literature." *Industrial and Corporate Change* 16(4): 691–791.

Rotmans, J., and D. Loorbach. 2008. "Transition Management: Reflexive Governance of Societal Complexity through Searching, Learning, and Experimenting." In *Managing the Transition to Renewable Energy* edited by J.C.M van den Bergh, and F.R. Bruinsma, 15–46. Cheltenham, UK: Edward Elgar Publishing.

Stephens, J., G. Roman, A. Graham, and R. Scholz. 2008. "Education as a Change Agent for Sustainability in Different Cultures and Contexts." *International Journal of Sustainability in Higher Education* 9(3): 317–338.

Yarime, M., G. Trencher, T. Mino, R. Scholz, L. Olsson, B. Ness, N. Frantzeskaki, and J. Rotmans. 2012. "Establishing Sustainability Science in Higher Education Institutions: Towards an Integration of Academic Development, Institutionalization, and Stakeholder Collaborations." *Sustainability Science* 7(1): 101–113.

Village and Farm Level



Conservation Farming Village in La Libertad, Negros Oriental, Philippines
Photo by Catherine de Luna

CASE STORY 10

Climate Change Adaptation and Upland Development through Conservation Farming Villages

Rex Victor O. Cruz[1], Wilfredo M. Carandang[1], Catherine C. de Luna[1], Vida Q. Carandang[1], Dixon T. Gevaña[1], and Genevieve A. Galapia[1]

ABSTRACT

Conservation Farming Village (CFV) is a modality for transforming traditional upland farming systems into sustainable upland production systems. Not only does it address upland degradation, it also stimulates upland community development that is adaptive to climate changes. CFV aims to help upland farmers to improve their economic conditions by strengthening their capacities to manage natural resources, and thereby protect their communities against environmental degradation while sustaining their sources of livelihood. The program adopts (1) community-based participatory approach to technology development, promotion, and utilization; and (2) multilevel technology promotion mechanism that capacitates local extension/change agents. Such strategies ensure that the efforts in promoting upland farming technologies are sustained and strengthen the "multiplier effect" of existing technology diffusion processes at the local level.

Currently, five areas in the Philippines—representing five different bio-geophysical and social-economic-cultural environments—have adopted the CFV approach. The CFV program includes empowering farmer volunteers to become the vanguards of sloping land resources by providing them with skills and knowledge on food, wood, and fiber production, and on resource management. The program taps (1) the active leadership and participation of local government units (i.e., municipality and *barangay* [village]) in carrying out program activities down to the barangay level such as extension work, community organizing, and facilitating market linkages and other support services; and (2) technical expertise and guidance of a state university/college in the province or nearest to the site.

Owing to the establishment of S&T-based farms that showcases agroforestry and soil and water conservation technologies, the farmer-participants at the CFV sites now

1 College of Forestry and Natural Resources, University of the Philippines Los Baños

have diverse sources of income and increased farm productivity. Crop diversification allows farmers to have numerous income sources at different times of the year, making them resilient to climate changes. Also, rehabilitation of the degraded watersheds has been enhanced.

INTRODUCTION

The Philippines is highly vulnerable to the impacts of climate-related events, such as being hit by 19–20 tropical cyclones each year. Upland farmers have been identified as one of the most vulnerable groups to such events mainly because they have limited capital assets and depend on rain for their everyday living (Pulhin, Lasco, and Espaldon 2009).

The developing and poor countries are dependent on economic activities that are vulnerable to climate change, being heavily reliant on climate-sensitive natural resources for livelihood and income. For instance, agriculture, fisheries, and forestry activities are commonly exposed to climate variability and extremes that can directly influence production efficiency, reduce livelihood and employment opportunities, and can put at risk human health, households, and communities (IPCC 2001 as cited by Peras 2005; IPCC 2007).

According to Pulhin et al. (2006, 1–2),

> watershed areas in the Philippines are believed to be among those to be adversely affected by climate change. Watersheds are critical to the economic development and environmental protection, and therefore, they are key to the pursuit of sustainable development. More than 70 percent of the country's total land area lies within watersheds. Much of the remaining natural forests that provide a host of environmental services are located in these areas. Also, it is estimated that no less than 1.5 million hectares of agricultural lands presently derive irrigation water from these watersheds. Moreover, around 20–24 million people—close to one-third of the country's total population—inhabit the uplands of many watersheds, majority of whom depend on its resources for survival.

These 20–24 million people are mostly composed of lowland migrants who have brought improper farming technologies to the uplands or watershed areas, which have consequently accelerated soil erosion in the already-fragile upland. Almost 75 percent (22.88 million ha) of the total land area in the Philippines already suffers slight to severe erosion (BSWM 2010). The World Bank notes that soil erosion is the Philippines' worst environmental problem (World Bank 1989).

The estimated total annual soil loss in the Philippines varies from 74.5 million tons (DENR 1992) to 80.6 million tons (Francisco 1994). Although soil erosion is a natural process, human activities from destructive land-use practices and the generally steep slopes of many upland areas significantly accelerate soil erosion, especially in the highlands.

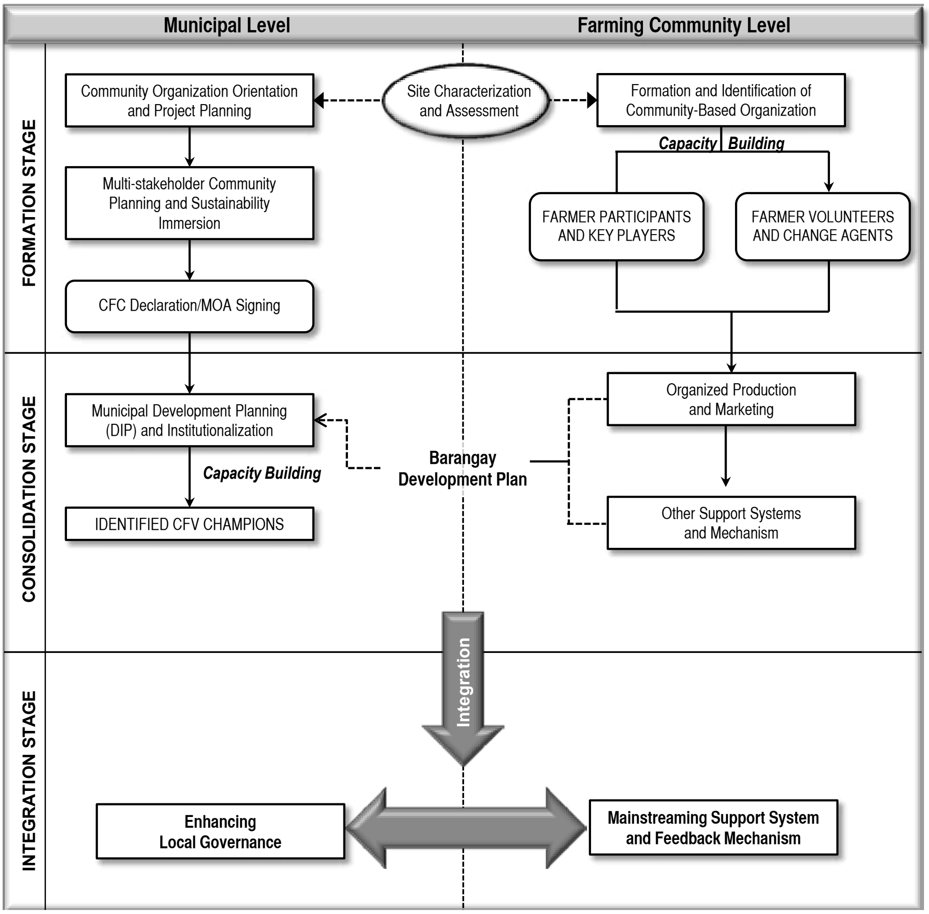
To date, farming technologies that can address problems of soil and water degradation and food insecurity in the upland areas have already been developed. However, these technologies remain inaccessible to poor upland farmers due to problems in extension and information dissemination. Recognizing this limitation, the Conservation Farming Village (CFV) strategy facilitates the adoption and implementation of S&T-based sloping land management and agroforestry systems in order to promote sustainable upland development and to help farming communities to adapt to climate change. CFV addresses climate change by introducing to farmers a number of soil and water conservation techniques that capture and store water, reduce soil erosion, and enhance soil diversity in order to improve crop production. Agroforestry increases farm resilience to climate variability by buffering crops to the effects of temperature and precipitation variability and to strong winds associated with storms.

CONSERVATION FARMING VILLAGE AS AN ADAPTATION STRATEGY

CFV is a strategy that enhances the transfer of conservation farming technologies and practices. Although CFV primarily focuses on addressing problems in sloping land management system, it can also be used as a climate change adaptation (CCA) strategy.

There are three active players in the implementation of CFV: the academic institution, municipal/city local government unit (LGU), and the farmers. The academic institution provides the technical knowledge about climate change and sloping land management. The municipal/city government downscales the implementation of the CCA strategy to the *barangays* (villages) under their jurisdiction. The farmers or farmer volunteers (FVs) then serve as the decision makers and implementers/adopters of sloping land management system and CCA strategies (Figure 10.1).

Figure 10.1. Framework for the implementation of CFV in the Philippines



Note: CFV = Conservation Farming Village/s; MOA = Memorandum of Agreement

CFV sites are chosen based on the following criteria:

1. The site should be an upland barangay.
2. The area should have reliable source of water.
3. The area has problems on soil erosion.
4. It is within a critical watershed.
5. It has active agricultural production.
6. It is accessible to land transportation.
7. It is within the covered areas of operation of respective universities.
8. It should have an LGU that supports the proposed technological interventions, and it should be willing to assist in the implementation of the CFV project.

LGUs and farmers in the Philippines are now recognizing the increasing denuded watershed areas and declining volume of water that can be extracted due to climate change. As such, the amount of water and soil conserved through the adoption of sloping land management technologies can contribute to the income and livelihood of the farmers as these technologies allow them to plant crops that can provide water for their short-, medium-, and long-term needs without being heavily distressed by climate changes.

On the other hand, FVs are selected based on the outcomes of the project implementers' consultation with either the barangay captain, LGU personnel assigned in the area, or members of the barangay council. The criteria for selecting the FVs are combination of the following:

1. The FV should have a large farm (> 2 ha) that is generally sloping, accessible, and easy for other farmers to view.
2. S/he should have strong leadership skills.
3. S/he must be willing to have his/her farm developed using conservation farming technology during and after the project duration.
4. S/he must be eager to learn.
5. S/he must be committed to be trained and to train other farmers thereafter on the farm technologies learned.
6. S/he should have good moral character.

In establishing CFVs, farmers undergo capability-building activities. At least five farmers who are willing to develop a portion of their farmland into a model farm that would demonstrate sloping land management in their locality are chosen as FVs. The physical attributes of the farm are then assessed using the Agroforestry Land Capability Mapping Scheme (ALCAMS). ALCAMS takes into consideration the slope of the area, vegetation, and soil fertility to enable the implementers to recommend an agroforestry system that is best-suited to the current condition of the land. The species to be planted, however, are chosen by the farmers based on their needs, skills, and knowledge on sustainable upland husbandry (both traditional and new knowledge) and on information regarding the market situation in their locality.

Small upland farmers are the most vulnerable to climate changes. They largely depend on degraded upland areas, which are vulnerable to the changing climate, for their production of food, wood, and livestock. Farmers need to schedule the various activities of the farm such that they can have steady source of food for the family. To augment their food and income requirements, they need to engage in other livelihood activities when farm activities are lean and as climate permits. Accordingly, a change in these climatic conditions can directly influence production efficiency and lessen livelihood and employment opportunities. Changes in the climate can also substantially damage human health, households, and communities (Olmos 2001; Ikeme 2003; IPCC 2001 as cited by Peras 2005; USAID 2007; Leary et al. 2008).

OUTCOMES OF THE INTERVENTION

The implementation of the CFV program in the Philippines started in five provinces: (1) Albay, (2) Ifugao, and (3) Quezon in Luzon region; (4) Negros Oriental in the Visayas region; and (5) Davao del Norte in Mindanao. Based on the criteria set by the National Economic and Development Agency of the Philippines, the following cities and municipalities were identified as project sites: (1) Ligao City in Albay, (2) Alfonso Lista in Ifugao, (3) General Nakar in Quezon, (4) La Libertad in Negros Oriental, and (5) Panabo City in Davao del Norte.

The implementation framework called for the participation of academic institutions who would partner with the identified LGUs in initiating the concept and practice of CFV. Thus, the following academic institutions and LGUs forged partnerships for the implementation of the CFV program:

1. Bicol University College of Agriculture and Forestry with City of Ligao,
2. Ifugao State University with the Municipality of Alfonso Lista,
3. University of the Philippines Los Baños with the Municipality of General Nakar,
4. Silliman University with the Municipality of La Libertad, and
5. University of Southeastern Philippines with the City of Panabo.

With the exception of Silliman University, which is a private institution, the remaining four academic institutions are state universities (Figure 10.2). The characteristics of the different sites are found in Table 10.1.

Figure 10.2. CFV locations in the Philippines

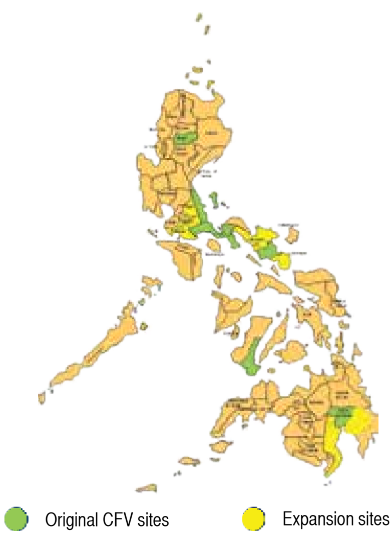


Table 10.1. Characteristics of the different CFV sites during the initial phase of implementation in 2009

Parameters	Ifugao (Alfonso Lista)	Quezon (General Nakar)	Albay (Ligao City)	Negros Oriental (La Libertad)	Davao del Norte (Panabo City)
Assisting university	IFSU	UPLB	BUCAF	SU	USeP
Number of CFVs	3	3	3	4	3
Slope range (%)	8–15	18–50	8–30	>18	18–50
Elevation (masl)	–	24–66	154–271	600–800	–
Average annual rainfall (mm)	3,454	4,105	3,432	1,218	1,759
Average annual temperature (°C)	24.9–35.0	26.8	–	–	33.0
Number of FVs	17	15	15	40	15
Number of female FVs	0	5	4	14	4
Number of adopters	9	11	137	193	90
Number of female adopters	0	1	66	82	50
Total area of model farms (ha)	17	50.25	49.00	93.00	40.30
Climate type	III	II, IV	II	II	IV

Notes: (1) Climate Type II = No dry season with a pronounced rainfall from November to January; Climate Type III = Seasons are not very pronounced, relatively dry from November to April, and wet during the rest of the year; Climate Type IV = Rainfall is more or less evenly distributed throughout the year (2) BUCAF = Bicol University College of Agriculture and Forestry; CFV = conservation farming village; FV = farmer volunteer; IFSU = Ifugao State University; SU = Silliman University; USeP = University of Southeastern Philippines; UPLB = University of the Philippines Los Baños; (3) Sites in ( ) are the specific municipalities or cities where the CFV sites were established. (4) "–" means no data available.

The strategies under the overall concept of CFV include the following:

1. Identification of sloping land farming models through participatory approaches;
2. Integrating on-farm research, training, capacity development, and technology diffusion; and
3. Incorporating profitability and environmental management strategies in farm planning.

The model farm was established through a simple process that started with the identification of the FV farm, followed by the identification and assessment of the interventions needed, the demonstration and testing of the CFV practices, and the promotion of CFV practice to adjacent farms once confidence on the positive performance of the interventions has been achieved.

A series of trainings and cross-site/farm visits were conducted through the course of the project implementation to enable FVs and the municipal/city local government to learn more about sloping land management (i.e., agroforestry) and all its supportive technologies. The most appropriate technology for each farm was selected based on a participatory and bottom-up selection system. Some of the technologies that were implemented include: alley-cropping/use of hedge rows; sloping agricultural land technologies including integration of livestock; contour farming; natural vegetative strips; contour composting/vermicomposting; conservation agriculture/farming systems in the sloping lands (multi-species cropping, conservation tillage, ground cover, pole barriers, and other physical barriers such as bench terraces, contour rock walls, canals and soil traps); water-saving technologies/water management; nitrogen-fixing trees; silviculture; and improved forage planting (Table 10.2).

The CFV is initially developed with the FVs organizing themselves into groups. These groups would then collectively lay out contours using the A-frame in all of the farms owned by the group members. Hedgerow species that had been initially used include rensonii (*Desmodium rensonii)*, flemengia (*Flemengia congesta*), calliandra (*Calliandra calothyrsus*), and madre de cacao (*Gliricidia sepium*). Eventually, food crops like pineapple (*Ananas comosus*) and banana (*Musa sapientum*) were also planted as vegetative contour strips.

As a result of the CFV implementation, the FVs were able to establish S&T-based farms that showcase conservation farming/sloping land management technologies. Such mechanism helped the farmers to gain steady income sources and enabled the rehabilitation of the degraded watershed that is adapted to the current climate conditions in the area.

Before the project was implemented, farmers had been practicing monocropping and cultivation had been parallel to the slope. Likewise, farmers highly depended on inorganic fertilizers and pesticides, and farm wastes were burned. These practices contribute to climate change, declining productivity, and deterioration of the fragile upland environment, including deforestation and loss of biodiversity.

Table 10.2. Number of FVs practicing sloping land management technologies in five provinces in the Philippines (as of 2012)

Sloping Land Management Technologies	Ifugao (Alfonso Lista)	Quezon (General Nakar)	Albay Ligao City	Negros Oriental (La Libertad)	Davao del Norte (Panabo City)	Total
Number of FVs						
Hedgerow planting	17	15	15	40	15	102
Mulching	12	15	6	2	0	35
Rock walls	1	0	1	5	0	7
Multi-storey agroforestry	0	4	4	40	0	48
Composting	17	15	15	20	0	67
Crop diversification	17	–	–	–	–	17
Crop rotation	17	–	–	0	0	17
Number of farmer-adopters						
Hedgerow planting	9	4	–	116	90	219
Mulching	0	15	–	0	0	15
Rock walls	0	0	–	8	0	8
Multi-storey agroforestry	0	0	–	193	0	193
Composting	9	0	–	33	0	42
Crop diversification	9	0	–	–	0	9

Note: Figures cited in this table are from multiple responses.

CFV is an approach that promotes the transfer of agroforestry and other conservation farming technologies and practices; thus, it banks on the tendency of people to copy what they see as good/successful initiatives. Hence, S&T-based "model farms" that showcase conservation farming technologies were established in at least 0.5 ha of land in a strategic location where they can be easily noticed. With these farms to copy, the establishment of CFVs or model villages is expected to produce farms where majority (if not all) of the farmers practice sustainable technologies, such as alley-cropping, bench terracing, minimum tillage, composting, nutrient recycling, and other sloping agricultural land technologies.

When farmers are tilling and making productive lands, their tendency to collect forest resources to augment their income decreases, thereby easing the pressure on the forest. As such, the forest is now valued as a shelter against extreme events and not as a resource to be depleted.

In the municipality of General Nakar in Quezon province, for example, farmers who were once dubbed as forest destroyers are now the vanguards of the forest due to their ability to produce enough food from their farms without the need to encroach and clear the forest to increase their farm area. The farmers of these lands are now employing land management technologies that are capable of conserving water and reducing soil erosion. Hence, farmers can plant and harvest all year round even with the threats posed by extreme climate events.

LGUs have also recognized the contribution of CFV to natural resource conservation and to increased farm productivity and incomes of the FVs. As such, the participating LGUs have enacted ordinances to ensure that CFVs are institutionalized in their locality. Such CFVs incorporate all the components of conservation farming such as no burning of farm wastes and using crop residues as mulch, which can later improve soil properties. As part of effecting change, the program is into making upland farming a local development issue, which is vital in the sustainable development of upland areas.

The establishment of S&T-based farms has also helped farmers to increase their household income. Before the project, farmers used to rely heavily on inorganic fertilizers. But with the implementation of the project, farmers are now shifting from inorganic to organic farming. They pile crop residues and weeds (minus the roots and seeds) in piles fenced by bamboo splits—a system of compost pile. Also, farmers have dug some holes where they can pile all the crop residues and cut grasses and other farm wastes, and then use this as fertilizer when decomposed—a system of compost pit. For example, in one farm in General Nakar, a farmer has been doing a form of compost compartment. He constructed two adjacent pits where the compost is alternately produced.

The various capacity-building sessions provided in the program and the cross visits to farms doing organic farming have been an eye opener to the FVs. Through these capacity-building activities, they learned how to reduce their production cost and to produce healthier products while contributing to the conservation and rehabilitation of the environment through organic farming. For example, in a village in the municipality of La Libertad, Negros Oriental province, a farmer had dug a series of pits in the alley, and then dumped all the crop residues and weeds from his farm. Although he was not able to plant on the alley for a season, he enriched the soil in his farm, which was ready for planting after six months. Likewise, several farmers who planted rensonii, flemengia, and indigofera hedgerows are now earning from the seeds of these crops.

In a farm in Ligao City in Albay province, Mrs. Veronica Yuson used to have coconut production as her sole source of income. When the CFV project was implemented, she learned the combination of crops that can be produced simultaneously; she also learned crop rotation in addition to composting, mulching, and alley-cropping. The hedgerow crops planted were *kakawate* (*Gliricidia sepium*), whereas the alley crops included upland rice, peanut, ginger, bush sitao, sweet pepper, and pineapple. An increase by as much as 634 percent was documented in her farm in 2014. Table 10.3 shows her farm productivity and net annual income in 2014.

Table 10.3. Farm productivity and net annual income of Veronica Yuson before and after employing conservation farming practices, 2014

Without CF Practices			With CF Practices		
Crops	Harvest (kg)	Net Income (PHP)	Crops	Harvest (kg)	Net Income (PHP)
Coconut (*copra*)	750*	5,495	Coconut (*copra*)	750*	5,495
			Upland rice	350	8,500
			Peanut	288	3,180
			Pineapple	110	875
			Ginger	150	16,050
			String beans	160	875
			Root crops	45	–150
TOTAL		5,495	TOTAL		34,825

Notes: (1) * 70% share of the farmer (2) CF = conservation farming

The improvement in the land management practices of the FVs lessened soil erosion in their farms and also increased their farm productivity (Figure 10.3). As such, this enhanced their ability to adapt to climate variability, thereby making them more resilient to the impacts of climate change. The shift from monocropping to diversified and scheduled planting brings about different products at different times of the year, making the farmers self-sufficient. The different crops integrated into the farm allow the farmers to harvest at different times, which make food sufficient for their families all year round, while the surplus farm products are sold in the market to augment their income. The increased number of crops planted in an area translates to increased output. The perennial crops planted will also provide for the environmental services needed in the degraded watersheds. The practice of alley-cropping has reduced soil erosion due to the presence of obstructions piled on alleys and because the live plants prevent the top soil from eroding. The reduction in soil erosion has also minimized the use of inorganic fertilizers while teaching farmers to utilize their crop residues as source of nutrients.

With these visible benefits, LGUs have now incorporated CFVs into their barangay development plans. The support for the wider adoption of CFV in the locality paved the way for local executives to have better governance over their existing resources. There is an appreciation of maintaining natural resources, especially the forest, as this is their life support system.

Figure 10.3. Before and after CFV

Note: The photo on the left shows the monocrop maize and peanut without soil and water conservation measures before the CFV program was implemented in 2009 in Ligao City, Albay. The right photo shows an integrated farm with conservation farming practices in 2013 or five years after CFV was implemented.

SUMMARY OF LESSONS AND WAY FORWARD

Conservation Farming Village is a modality to make communities more productive, to reduce pressures on forests, and to make communities more resilient to the impacts of climate change. The CFVs established in the five sites in the Philippines paved the way for the implementation of sloping land management practices. This enabled farmers to diversify their crop production, thereby helping them to produce different farm products at different times of the year. Accordingly, the capacitated farmer-adopters have become multipliers of the CFV knowledge by spreading the CFV concept to other farmers. Likewise, the capacity-building activities of the CFV program in all of the project sites have undoubtedly equipped the FVs and CFV adopters with the skills toward sustainable farming in sloping lands. As a result of the success witnessed in the FV farms, other farmers have been encouraged to emulate the cropping system adopted by the FVs.

The tripartite collaboration among SUCs, LGUs, and farmers enhanced the adoption of sustainable farming system, thereby reducing the pressure on the remaining forest as the local communities have become less reliant on extracting forest products as a livelihood source. Likewise, the CFV collaborations at all levels enabled the agriculture and forestry schools to impart technical knowledge and skills to the LGUs and communities. In particular, through the establishment of model farms, the project implementers were able to demonstrate to farmers the available planting materials and sloping land management technologies that are appropriate to the biophysical conditions of their locality. Meanwhile, the local government served as the bridge between the project implementers and the local communities, which enabled the effective implementation of the different project activities at the local sites. In sum, the LGUs' participation imparted the "local flavor" of the program.

The model farm development addressed the need for soil and water conservation, increased farm diversity and income, and promoted *bayanihan* (cooperative undertaking) among the participants. Also, the model farms served as venue for experiential learning among the farmers as they were able to modify and improve the introduced CFV cropping system based on their available resources.

CFV is already included in the Barangay Development Plan and Annual Investment Plan of the project municipality sites. In these plans, funds from the local governments' Internal Revenue Allotment are allocated for the development and maintenance of CFV in order to sustain the benefits gained from the CFVs. The policies that have institutionalized the CFVs in these LGUs will ensure that CFV will continue to improve farmers' lives and contribute to the rehabilitation of the upland areas. These policies will also allow farmers to adapt to the changing climate due to their increased capacity to continually produce farm outputs all year round with lower production costs resulting from their use of organic farm residues.

ACKNOWLEDGMENT

The authors would like to acknowledge the Kennedy Round 2 Productivity Enhancement Program, through the Philippine National Economic and Development Authority and the Philippine Council for Agriculture, Aquatic, and Natural Resources Research and Development, for funding the implementation of CFV from 2009 to 2011. Likewise, the authors would like to thank the Department of Agriculture-Bureau of Agricultural Research for funding the research and development program for CFV from 2011 to 2015.

REFERENCES

BSWM (Bureau of Soils and Water Management). 2010. *The Updated Philippine National Action Plan to Combat Desertification, Land Degradation, and Drought (DLDD) FY 2010–2020*. Manila, Philippines: BSWM-DA, DAR, DENR, and DOST.

Carandang, A.P. 2012. "Assessment of the Contribution of Forestry to Poverty Alleviation in the Philippines." In *Making Forestry Work for the Poor: Assessment of the Contribution of Forestry to Poverty Alleviation in Asia and the Pacific*, 267–292. Bangkok, Thailand: UN-FAO Regional Office for Asia and the Pacific.

DENR (Department of Environment and Natural Resources of the Philippines). 1992. *A Report on Philippine Environment and Development Issues and Strategies*. Quezon City, Philippines: DENR.

Francisco, H.A. 1994. "Upland Soil Resources of the Philippines: Resource Assessment and Accounting for Soil Depreciation. " *Innotech Workshop Paper* No. 6. Quezon City, Philippines: Innotech.

Ikeme, J. 2003. "Climate Change Adaptation Deficiencies in Developing Countries: The Case of Sub-Saharan Africa." *Mitigation and Adaptation Strategies for Global Change* 8(1): 29–52.

IPCC (Intergovernmental Panel for Climate Change). 2001. *Climate Change 2001: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK: Cambridge University Press.

———. 2007. *Climate Change 2007: Synthesis Report*. Cambridge, UK: Cambridge University Press.

Leary, N., J. Adejuwon, V. Barros, P. Batima, B. Biagini, I. Burton, S. Chinvano, R.V.O. Cruz, D. Dabi, A. De Comarmond, B. Dougherty, P. Dube, A. Githeco, A.A. Hadid, M. Hellmuth, R. Kangalawe, J. Kulkarni, M. Kumar, R.D. Lasco, M. Mataki, M. Medany, M. Mobsen, G. Nagy, M. Njie, J. Nkomo, A. Nyong, B. Osman-Elasha, E. Sanjak, R. Seiler, M. Taylor, M. Travasso, G. Von Maltitz, S. Wandiga, and M. Wehbe. 2008. "A Stitch in Time: General Lessons from Specific Cases." In *Climate Change Adaptation* edited by N. Leary, J. Adejuwon, V. Barros, I. Burton, J. Kulkarni, and R. Lasco, 1–27. Routledge: Earthscan.

Olmos, S. 2001. "Vulnerability and Adaptation to Climate Change: Concepts, Issues, Assessment Methods." Accessed 12 December 2009. http://www.start.org/Projects/AIACC_Project/meetings/Trieste_02/trieste_cd/Resource_Materials/CCKN.pdf

Pulhin, F.B., R.D. Lasco, and M.V.O. Espaldon. 2009. "Mainstreaming Climate Change Adaptation in Watershed Management and Upland Farming in the Philippines." In *Climate Change Adaptation and Natural Resources Management in the Philippines: Proceedings of the National Conference Workshop on Climate Change Practices in Natural Resources Management* edited by R.D. Lasco, B. dela Cruz, and F.B. Pulhin. Laguna, Philippines: FORESPI.

Pulhin, J.M., R.J.J. Peras, R.V.O. Cruz, R.D. Lasco, F.B. Pulhin, and M.A. Tapia. 2006. "Vulnerability of Communities to Climate Variability and Extremes: Pantabangan-Carrangalan Watershed in the Philippines." *AIACC Working Paper* No. 44. Washington, D.C.: International START Secretariat.

Peras, R.J.J. 2005. "Vulnerability and Adaptation Strategies of Pantabangan-Carranglan Watershed Communities to Climate Variability and Extremes." Unpublished MS thesis, University of the Philippines Los Baños, Laguna, Philippines.

USAID (United States Agency For International Development). 2007. "Adapting to Climate Variability and Change." Accessed 14 December 2009. https://www.usgcrp.gov/library/2008/Adaptating-to-Climate-Variability-and-Change-English.pdf

PCAARRD (Philippine Council for Agriculture, Aquatic, and Natural Resources Research and Development). 2011. "The National Program on Sustainable Upland Farming through the Establishment of Barangay Sagip-Saka or Conservation Farming Villages (CFV)." Unpublished PCAARRD program report. Laguna, Philippines: PCAARRD.

World Bank. 1989. *Philippine Environment and Natural Resource Management Study*. Washington, D.C.: World Bank.

Farmer harvests *Arachis pintoi* from conservation agriculture with trees on sloping farm for animal feed
Photo by Agustin R. Mercado, Jr.

CASE STORY 11

How Filipino Farmers Cope with Climate Change through Conservation Agriculture with Trees

Agustin R. Mercado, Jr.*[1]*, Rodel D. Lasco*[1]*,
***and Manuel R. Reyes*[2]**

ABSTRACT

The areas with degraded landscapes in Southeast Asia are expanding rapidly. The conservation agriculture with trees (CAT) strategy is the best "tool box" for sustainable crop production intensification. CAT follows the Landcare approach, with principles and practices founded on minimal soil disturbance, continuous mulching, pests and nutrients management, species rotations, integration of trees, and rainwater harvesting.

This case story presents the outcomes of a project conducted in the municipality of Claveria in Misamis Oriental province, Philippines. Specifically, this chapter presents how the interplanting of maize with cowpea and then relayed with upland rice has ensured the food and nutritional security and has improved the incomes of smallholder upland farmers in the municipality.

Arachis pintoi grown with maize has provided farmers with the inputs to produce feeds for livestock. Likewise, the cropping system has provided better groundcover for protecting soil against erosion, eliminated the use of herbicides, and increased farmers' crop yields. The project also identified promising varieties of maize, upland rice, cowpea, forage grasses, forage legumes, sweet potato, cassava, and sorghum that provide better economic and biomass yield. These crops produced higher yields than the locally grown varieties and are also suitable for conservation agriculture production systems.

The project implementers also identified a cost-effective way of creating rainwater-harvesting system through animal-built embankment. Establishing a series

---

1 World Agroforestry Centre, Claveria, Misamis Oriental, Philippines
2 North Carolina Agricultural and Technical State University

of ponds can mitigate severe runoff during heavy rainfall events by increasing water infiltration, and thus mitigate flooding. Accordingly, rainwater-harvesting ponds has provided the farmers with an opportunity to grow fish, ducks, and other aquatic animals, which enhanced household food and nutritional security of farm households. The pond water enriched with nutrients could also be used to irrigate trees and crops during dry spells.

The research results of the project have been extrapolated to other upland areas in the Philippines through the Landcare approach. Through the active participation of farmer groups, local government units, and technical facilitators that constitute the Landcare approach, farmers were able to achieve rapid and inexpensive method of expanding the use of technologies in the Philippine uplands. These technologies can also be used in other areas in Southeast Asia with similar biophysical and socioeconomic environments.

INTRODUCTION

It is estimated that 40 percent of the Philippine population (approximately 40 million people) live on less than United States Dollar (USD) 2 per day, with the poorest areas of the country concentrated in the uplands (USAID 2009). Rural poverty increases pressure on natural resources like forest, soil, and water, which are considered as the last "capitals" of the poor. Thus, these resources must be managed sustainably.

Losses in agricultural productivity will lead to food insecurity, which will then compel the Philippine government to import food. Furthermore, market distribution networks that supply food to distant food-poor communities are vulnerable to natural calamities, conflict, and other factors related to climate change. If these networks collapse, communities dependent on imported food will become more food insecure.

Currently, conservation agriculture (CA) is being successfully implemented in the United States, Canada, Brazil, Argentina, Australia, Paraguay, and in the Indo-Gangetic Plains. About 95.8 million hectares (ha) (Derpsch 2008) are being used for conservation agriculture; however, only about half a million hectares were planted on small farms in 2002 (Wall 2007 and Ekboir 2003, as reported by Derpsch 2008). Only few countries (e.g., Brazil) have invested in CA research and have developed technologies for small farmers. Brazil is among the few countries that manufacture equipment for small farmers (Derpsch 2008).

In the Philippines, CA has not yet established a foothold, although there are some promising sustainable agriculture activities in the region. In 1996, the World Agroforestry Centre initiated the Landcare project in Claveria, which is a small farming community in the province of Misamis Oriental in the Philippines (Mercado et al. 2001). With the support from the Australian Centre for International Agricultural Research and Agencia Española Cooperacion Internacionale, these Landcare initiatives have expanded to other municipalities and provinces in Mindanao.

There are about 10,000 farmers in many communities in Mindanao who are members of Landcare groups. These groups practice conservation farming; they establish natural vegetative filter strips (NVS) along the contour, and practice agroforestry technologies to control soil erosion (Mercado and Cadisch 2004). The World Agroforestry Centre facilitates the formation and continuation of Landcare groups in many areas in Mindanao. “Landcare” is a community-driven approach where various stakeholders in local upland communities work together to address community natural resource degradation problems (Mercado et al. 2001).

DESCRIPTION OF THE ADAPTATION

The resource-poor upland farmers are highly vulnerable to the impacts of climate change, and their miseries are exacerbated due to erratic rainfall patterns, more frequent occurrence of extreme weather events, and other resource-degrading events that always stretch their carrying capacities. Many of them have migrated to urban areas in the hope of better opportunities, thereby overstretching the resources available in those areas. For example, 40 percent of the Philippines’ domestic food requirements and 30 percent of the country’s food exports come from Mindanao (the southernmost main island of the Philippines); yet in 2011, Typhoon Sendong (international name: Washi) damaged an estimated USD 48.4 million worth of properties and livelihoods in the area. The following year, Typhoon Pablo (international name: Bopha) devastated Mindanao again, affecting 6.3 million people, with more than 200,000 homes damaged or destroyed. Major sources of income, like production of banana, coconut, corn, and rice, were devastated as plantations had been flattened to the ground. Mindanao suffered an estimated loss of USD 780 million due to the typhoon. Many people who had migrated to urban areas became informal settlers who live along river banks, which are more prone to flooding or surges of water levels.

By planting more crops in one area, as in conservation agriculture with trees (CAT), farmers can rely on several streams of income and food sources. If one kind of crop gets damaged by a strong typhoon, then farmers practicing CAT will still have other crops to fall back on and sell. This method is also more environment-friendly since it fosters a more diverse ecosystem that has little reliance on external inputs like expensive fertilizers. It also attracts different forms of wildlife that cannot be found in monoculture plantations.

Upland farmers are typically smallholders who practice diverse integrated production systems. They are primarily interested in adopting systems that cater to their interests of diversification as a risk-aversion mechanism and as a way to ensure household food and money. Thus, CAT is a promising option relevant to their context.

Specifically, CAT is defined as the integration of trees into annual food crop systems by employing the following principles: minimal soil disturbance; diverse crop species; continuous ground cover; judicious integration of trees; and integrated water, nutrient, and pest management.

Depending on what kind of woody species is used and how the trees are managed, incorporating the planting of woody plants into crop fields and agricultural landscapes can help

- maintain vegetative soil cover year-round;
- bolster nutrient supply through nitrogen fixation and nutrient cycling;
- suppress insect pests and weeds;
- improve soil structure and water infiltration;
- enhance greater direct production of food, fodder, fuel, fiber, and income from products produced by the intercropped trees;
- enhance carbon storage both aboveground and below-ground;
- enhance formation of greater quantities of organic matter in soil surface residues; and
- promote more effective conservation of above- and below-ground biodiversity.

There are two CAT pathways, namely, the *annual-based system* and the *perennial-based system*. The *annual-based system* involves growing the annual food crops in between rows of trees that are particularly planted along the contour of sloping lands. Crops are planted in plots that are usually spaced 20–30 meters apart. One example of this system is planting maize intercropped with cowpea between rows of rubber trees + bananas + forages (Figure 11.1). The combination of rubber trees, bananas, and forages as contour hedgerows provide soil binding and anchorage that reduces—if not eliminate—soil erosion and landslides during extreme rainfall events.

On the other hand, the *perennial-based system* involves planting trees and annual crops through a multi-strata system. In the first 2–3 years before the tree canopy closes, annual food crops can be planted with trees similar to the practice of "taungya" system.[2] One example is the multi-strata of rubber + cacao + *Arachis pintoi* (Figure 11.2). This multi-strata system enhances the growth of resources aboveground and below-ground. The presence of rubber trees in cacao production will improve cacao's productivity; cacao requires shade, which the rubber trees can accordingly provide. Meanwhile, *Arachis pintoi* fixes nitrogen from the air, which complements the fertilizer requirement of cacao and rubber trees; it also provides good ground cover, which can suppress weeds and fodder for livestock.

2 "Taungya" means growing food crops in between rows of newly planted or young trees.

Figure 11.1. Annual-based system, Claveria, Misamis Oriental, Philippines

Note: Maize intercropped with cowpea between rows of rubber trees + bananas + forages

Figure 11.2. CAT perennial-based system

Notes: (1) Multi-strata of rubber trees + bananas + forages
(2) CAT = conservation agriculture with trees

CAT Project in Claveria, Misamis Oriental

The CAT concept was first tested in the municipality of Claveria, Misamis Oriental province, Philippines. Claveria is located 42 kilometers (km) northeast of Cagayan de Oro City with a total land area of 82,475 hectares (ha). Claveria lies on an undulating plateau, with elevation ranging from 350 to 950 meters above sea level (masl). The soils in the municipality are classified as acid upland soils with fine mixed isohyperthermic, Ultic Haplorthox (Mercado 2007). About 62 percent of the total land area is rolling and very steep. On average, the annual soil erosion in the municipality is between 200 and 350 megagram per hectare (Fujisaka et al. 1995; Mercado 2007). The average annual rainfall in Claveria is 3,000 millimeters, which is distributed throughout the year with peak months in June and October. The dominant crops planted in the municipality are maize, upland rice, sweet potato, vegetables, and cassava. Claveria serves as the upper watershed area of 13 other municipalities located along the coastline.

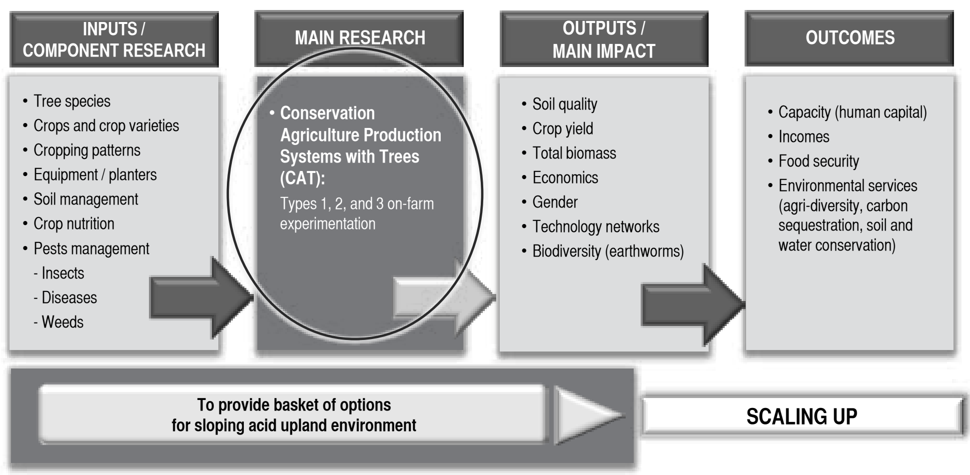
The current land use in Claveria is loosely differentiated into upper and lower elevation zones by agro-ecosystem characteristics, which determine the cropping and vegetation patterns. Land use in lower Claveria (400–600 masl) is dominated by the cultivation of maize, upland rice, and cassava. Upland rice is more common in lower Claveria. Upper Claveria (>600 masl) has more flatlands, cooler temperatures, and longer rainy seasons than the lower areas. The vegetable production on the flatter landforms in upper Claveria makes it the primary vegetable-growing region in Northern Mindanao.

Farmers in Claveria are generally poor, with 60 percent of the households earning below the food threshold level (USD 215 per month), and 70 percent earning below the poverty threshold level (USD 290 per month). These environments represent most of the acid upland areas in Southeast Asia, which consist of about 181 million ha. Hence, the technologies generated from Claveria can be potentially extrapolated to many parts of Southeast Asia.

The participatory research project on CAT implemented by different Landcare groups in Claveria used on-farm research methodologies based on the following:

1. Researcher-designed and managed trials;
2. Researcher-designed and farmer-managed trials; and
3. Farmer-designed and farmer-managed trials, particularly in the long-term research on CAT (Figure 11.3).

Figure 11.3. Conceptual framework of CAT research project in Claveria, Misamis Oriental, Philippines



CAT Treatments

The researcher-designed and -managed trials and the farmer-designed and -managed trials conducted in Claveria were composed of (1) five CAT treatments and (2) conventional farmer's practice, which served as the control treatment. These six treatments were treated with two fertility levels; they served as the subtreatments (subplots). Table 11.1 details the different treatments done in Claveria.

Table 11.1. Different CAT treatments tested in Claveria, Misamis Oriental

Treatment	Description
Treatment 1 (T1)	Maize + *Arachis pintoi* – maize + *Arachis pintoi*
Treatment 2 (T2)	Maize + *Stylosanthes guianensis* – fallow
Treatment 3 (T3)	Maize + cowpea – upland rice + cowpea
Treatment 4 (T4)	Maize + rice beans – maize + rice beans
Treatment 5 (T5)	Cassava + *Stylosanthes* – land preparation similar to that in T1
Treatment 6 (T6)	Farmer's practice: Two plowings and two harrowings using animal-drawn moldboard plow and spike-toothed harrow, respectively

Treatment 1

Two weeks before maize was planted, weeds had been sprayed with glyphosate (Brand name: Roundup) at the rate of 1.5 liters per hectare with a total of 720 grams active ingredient. The maize seeds were then dibble-planted using sticks, spaced at 70 centimeters (cm) × 20 cm, to make 72,000 plants per hectare. *Arachis pintoi* cuttings were planted in single rows in the middle of the maize rows spaced at 2 meters (m) apart. Two fertility levels were used: (1) 0-30-0 $NP_2O_5K_2$ (low-fertility level as F0) and 60-30-30 (moderate-fertility level as F1) during the first cropping.

Due to the poor performance of F0 during the first cropping, it was modified into high-fertility level with 120-60-60. All phosphorus (P) and potassium (K) were applied as basal. Nitrogen (N) was applied 30 days after crop emergence. A second maize crop was planted by furrowing using small double-moldboard plow drawn by carabao. This furrowing created a 10-centimeter open strip where the maize were seeded. After 30 days, the *A. pintoi* recolonized the opened space. At harvest, the maize stalks were cut at ground level to enable the project researchers to determine the biomass and grain yield of the planted maize. *Arachis pintoi* biomass was sampled after maize had been harvested. *Arachis pintoi* biomass was determined by sampling a 1 m × 1 m plot. Biomass was weighed, and subsamples were then taken for moisture determination.

Treatment 2

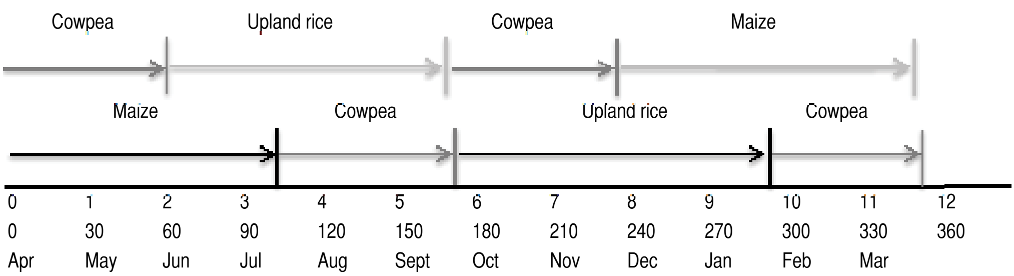
The maize was established and managed similar to how it was in T1. *Stylosanthes guianensis* seeds had been drilled in between rows of maize and then thinned to 10–15 plants per linear meter. Maize and *Stylosanthes* were sampled similar to how it was in T1. The sampling of maize and *Stylosanthes* were similar to that in T1.

Treatment 3

The land was prepared similar to how it was in T1. The maize was established in double rows at 35- and 20-centimeter spacing between plants to make a plant population of 72,000 plants per hectare. This was alternated by two rows of cowpea at 35-centimeter row spacing, with 10–15 plants per linear meter. After the cowpea had been harvested, upland rice was planted. After maize had been harvested, cowpea was planted. This planting scheme is shown in Figure 11.4.

Based on the schedule shown in Figure 11.4, in 340 days, farmers would have two full-crops of maize, two half-crops of upland rice, and four half-crops of cowpea. This intensive system can serve as the bridging harvest before the main crops are planted, and can thus provide farmers with harvests every 60 days. This would then help ensure their household food requirements and also augment household income.

Figure 11.4. Phenology of maize + cowpea/upland rice + cowpea cropping pattern



Treatment 4

The land preparation and planting of maize was similar to how it was in T1. Production of rice beans were established two weeks prior to maize harvest.

Treatment 5

Furrows were spaced at 100-centimeter intervals, and cassava cuttings were planted 50 cm apart to make 20,000 plants per hectare. The cassava was harvested approximately 10 months after planting. *Stylosanthes* was established by seeds in between rows of cassava.

Treatment 6

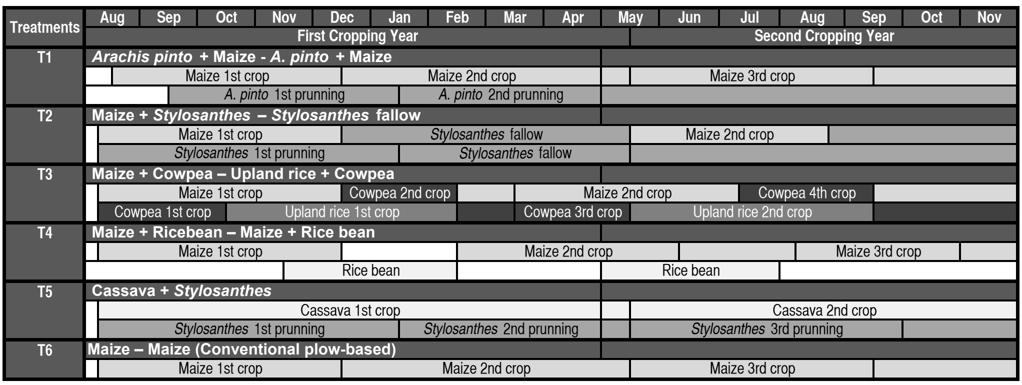
Rows were furrowed using animal-drawn moldboard plow. Maize was managed and harvested similar to that in T1, T2, and T3. In the second cropping, the stalks were spread uniformly and plowed under. The planting, management, and harvesting were similar to that in the first cropping.

Field Implementation

These five conservation agriculture production system (CAPS) treatments and farmers' practice of maize monoculture at two fertility levels were laid out and replicated four times. A total of 25 farmers tested the CAT treatment at the farmer-managed experiments, which were located across several villages in Claveria. Each farmer tested one CAT treatment in a 1,000-square-meter plot located in the middle of their traditional maize system.

Component researches like tree species, crops and crop varieties, soil management, and crop nutrition were also conducted to complement the main CAT research. The results of the component studies were fed back to the CAT system (Figure 11.5).

Figure 11.5. Crop phenology of six different conservation agriculture production systems

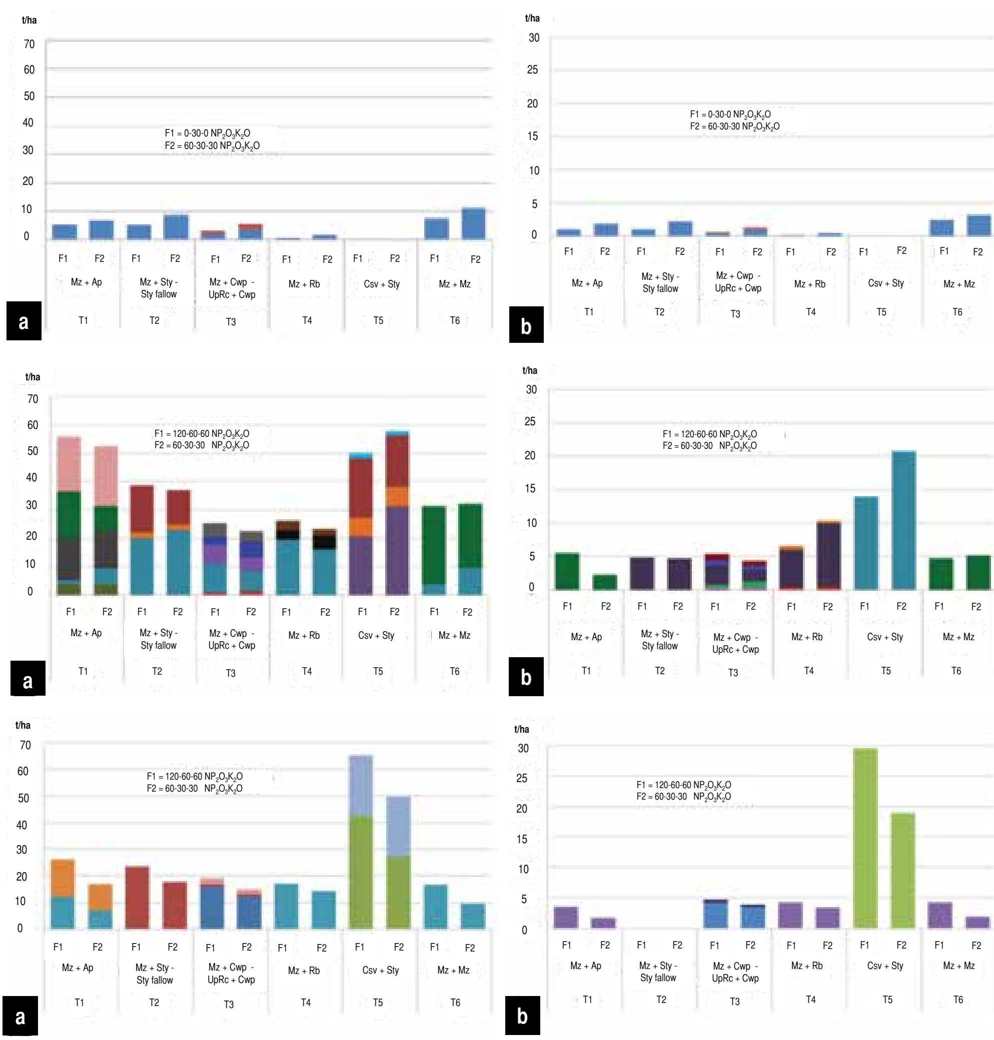


OUTCOMES OF THE ADAPTATION

Conservation Agriculture Production Systems

The results of the research project in Claveria showed that the conventional maize system had better yields than the other CAPS in terms of total biomass and grain yield during the first cropping experimentation in 2010. Maize with rice bean had the lowest yields among all cropping patterns. The moderate-fertility level (60-30-30) had higher yield across all CAPS as compared to that of the low-fertility level (0-30-0). In the subsequent year in 2011, cassava + *Stylosanthes* had the highest total biomass. This was followed by maize + *Arachis pintoi*, then by maize + *Stylosanthes*. A similar trend was observed in 2012. Still, cassava ranked first in total biomass, whereas the rest of the cropping patterns were comparable with one another, except for the traditional monoculture maize which had the lowest yield (Figure 11.6).

Figure 11.6. Annual productivity of different conservation agriculture production systems



The researchers found that cassava + *Stylosanthes* had the highest total system productivity among all of the CAPS treatments tested. Maize + *Arachis pintoi* had the highest total biomass and grain yield among all of CAPS treatments with maize. This may be due to the higher N_2-fixing capacity of *A. pintoi* that supplemented additional N to the soil, thus providing N to both crops. Meanwhile, the productivity of the conventional maize monocropping system declined in the subsequent years.

The results of the partial gross analysis indicated that in the first cropping, the annual total system profitability of the CAT treatments ranged between 7 percent and 20 percent; meanwhile, the conventional maize system was 123 percent higher than the CAT treatments (except in cassava + *Stylosanthes*). The reasons are two-folds: (1) CAT entailed higher initial land preparation costs, and (2) low crop productivity.

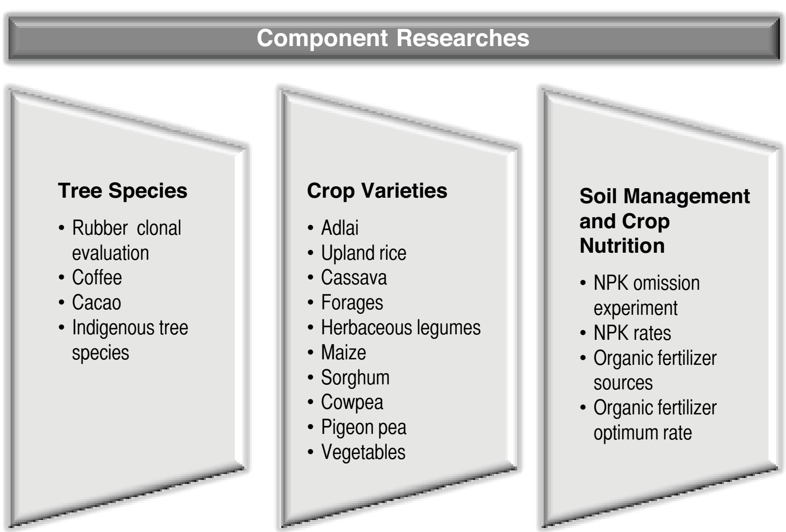
After four years of experimentation, the CAT systems increased the annual system profitability of the tested crops from 492 percent (cassava + *A. pintoi*) to 863 percent (maize + cowpea). The yield of maize + *A. pintoi* was 778 percent higher than that of the conventional maize (excluding the value of *A. pintoi* herbage harvest) at 5,250 kg/ha at 21-day clipping interval, which should be accounted for. Grain legumes (like cowpea and rice beans) integrated systems had higher total system profitability than the other systems due to higher bean price.

Stylosanthes grown with cassava and with maize yielded significantly better than the *A. pintoi* planted in association with maize. *Arachis pintoi* is usually a low-starter forage legume. *Stylosanthes* planted with cassava grew better than *Stylosanthes* with maize. This was due to slower growth of cassava that would allow *Stylosanthes* to get established and grew along with it as opposed to the fast-growing maize.

Component Research to Support CAT

The researchers also determined which crop varieties are best-suited for CA. Specifically, the researchers looked at different crops and crop varieties that have both high biomass production and economic crop yield and are also suitable for CA systems. These include adlai (Job's Tears), forage grasses, sorghum, cassava, and open-pollinated maize (Figure 11.7). The following subsections describe the different crops and varieties evaluated in the project.

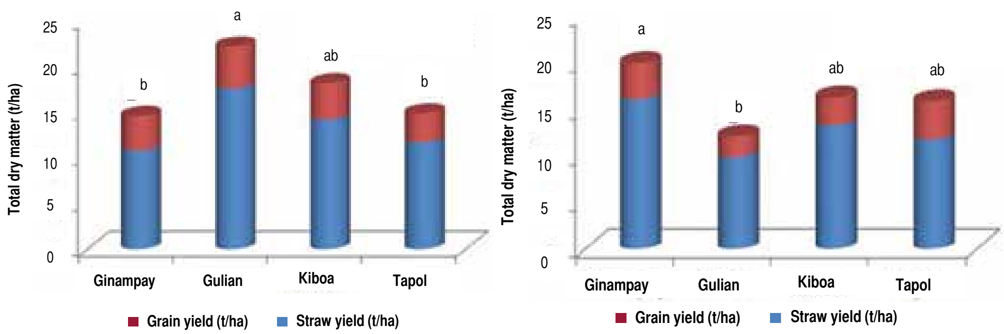
Figure 11.7. Component researches to support the main CAT research



Varietal trial of adlai (Coix lacryma-jobi L.)

Gulian, an adlai variety, performed well in an acid upland condition; it superseded other adlai varieties like Kiboa, Ginampay, and Tapol. Ginampay performed best at rationed crop (Figure 11.8). The results imply that Gulian and Ginampay can be good sources of organic matter (OM) for the soil; these varieties also promise higher yield and income for farmers in an integrated CAPS. The slow-degrading biomass due to the wide carbon-nitrogen ratio can be used as mulch to control weeds and to preserve soil moisture. The roots of adlai can grow up to 3 m into the subsoil, which enable the plant to withstand dry spells.

Figure 11.8. Performance of adlai varieties as first and rationed crops



Open-pollinated maize varietal evaluation

The maize varieties IPB-13 and IPB-6 outyielded the traditional varieties such as Tinigib and Seniorita (Figure 11.9). These open-pollinated maize varieties are suitable for upland maize farmers because they can collect seeds for the subsequent cropping. Choosing maize varieties that have both high grain yield and stalks will provide benefits to the soil and to the farmers. These top two varieties are included in the seed production for future distribution to farmers.

Sorghum varietal evaluation

ICSU-93034 and IC-93046 sorghum varieties showed better adaptation in acid soils as opposed to other entries (Figure 11.10). At present, farmers in Claveria are using these two cultivars in the farmer-managed plots.

Figure 11.9. Relationship between grain yield and biomass yield of open-pollinated corn varieties for CAPS

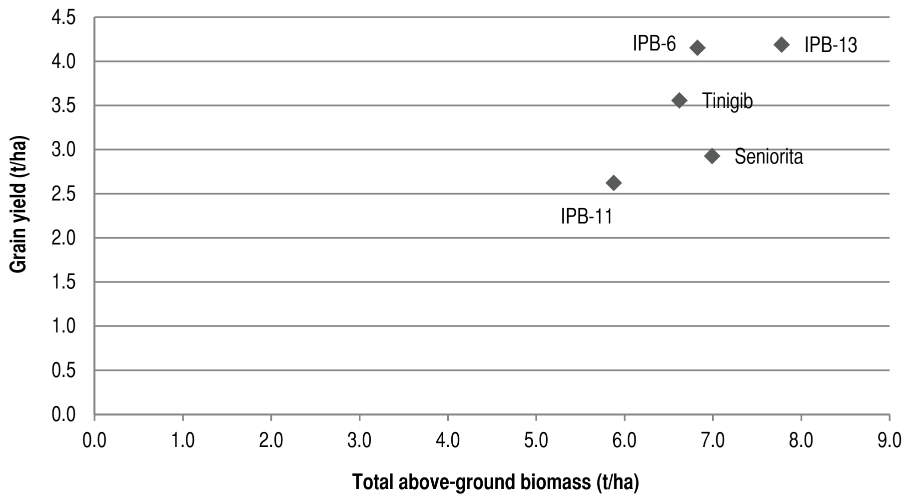
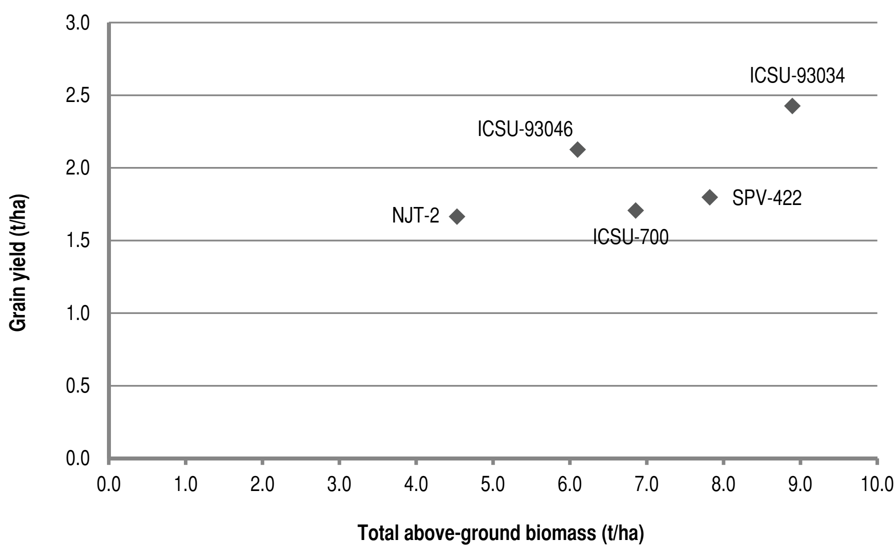


Figure 11.10. Relationship between grain yield and biomass yield of sorghum varieties



Forage species evaluation

Seven collections of six different fodder grasses from different sources in the provinces of Bukidnon and Misamis Oriental in the Philippines were evaluated for biomass production for possible inclusion in CAPS. These fodder grasses were *Bracharia rhuzinensis*, *Bracharia decumbens*, *Setaria sphacelata* (var. splendida), *Setaria sphacelata* (var. nandi), *Pennisetum purpureum*, and *Panicum maximum*.

In terms of plant height and total aboveground biomass, *Pennisetum purpureum* was the top performer, followed by *Setaria* (var. splendida) (Table 11.2). These two forage grasses are the erect type and are suitable for a cut-and-carry system or to be planted as grass strips for soil conservation measures in sloping lands. *Brachiaria rhuzinensis* is another alternative forage grass, which is a creeping type of grass and adapts well to acidic soils. These promising forage grasses could be integrated into CAPS, which would generate high biomass for soil fertility regeneration.

Table 11.2. Biomass and plant height of forage grass cultivars three months after pruning, evaluated for CAPS

Forage Grasses	Biomass (t/ha)	Plant Height (cm)
Brachiaria decumbens	1.15c	73.80c
Brachiaria rhuzinensis	5.05abc	68.20c
Panicum maximum	3.13bc	95.80c
Pennisetum purpureum	9.12a	160.75a
Setaria (var. nandi)	4.23abc	61.47c
Setaria (var. splendida)	7.97ab	106.15b
Mean	5.13	94.36
CV (%)	62.89	22.24
SED	2.15	13.99

Notes: (1) Means having the same letters are not significantly different from each other by DMRT at 5% level. (2) CV = coefficient of variation; SED = standard error of the mean difference

Forage herbaceous legumes evaluation

Stylosanthes guianensis and *Crotolaria juncea* outperformed the rest of the herbaceous legumes evaluated (Table 11.3). *Arachis pintoi* yielded approximately three times lower than *Stylosanthes* did five months after planting. Both *Stylosanthes* and *Arachis* have already been integrated into the wider evaluation in both the farmer-managed and researcher-managed trials. *Crotolaria juncea* has not yet been integrated, but the crop also performed well under acidic soil environment. This could also be integrated into wider experimentation so that its potential can be realized.

Table 11.3. Aboveground biomass of herbaceous legumes five months after planting

Herbaceous Legumes Species	Biomass (t/ha)
Arachis pintoi	1.38b
Calopogonium mucunoides	0.33b
Centrosema pubescens	0.71b
Crotolaria juncea	3.82a
Stylosanthes guianensis	4.64a
Mean	2.05
SED	0.43
CV (%)	42.00

Note: Means having the same letter are not significantly different from each other by DMRT at 5% level.

Sweet potato varietal evaluation

The newly introduced PSB-16 and Lingatos yielded better than the local varieties Ka Alma and Miracle in both aboveground biomass and roots (Figure 11.11). These four varieties are now planted in a wider scale to be able to produce cutting planting materials for possible inclusion in the CAPS experimentation.

Figure 11.11. Relationship between sweet potato root weight and total biomass

Upland rice cultivar evaluation

Under acid-poor soil, IR-55419-04 and NCIRC-9 had comparable grain yield and total dry matter yield with IR-30716, which is currently used in CAPS experiments (Figure 11.12).

Cowpea cultivar evaluation

The variety IT82D-889 outyielded the cultivar taken from the Northern Mindanao Integrated Agricultural Research Center. IT82D-889 matures 60 days after sowing (Figure 11.13). It has shown good adaptation to acidic soils, and is now integrated into the researcher- and farmer-managed experiment in combination with maize and upland rice.

Figure 11.12. Relationship between total biomass and grain yield of different upland rice varieties

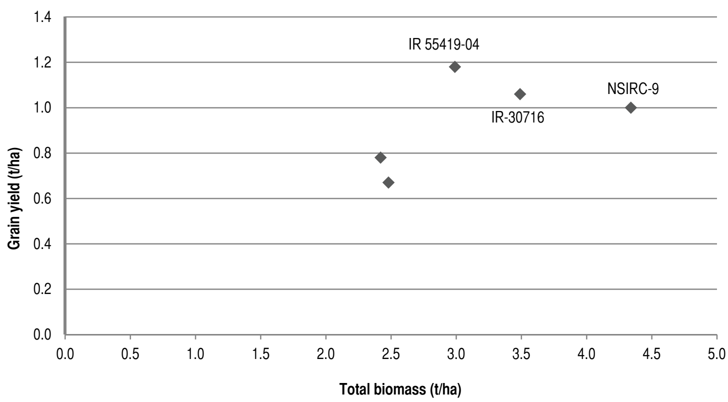
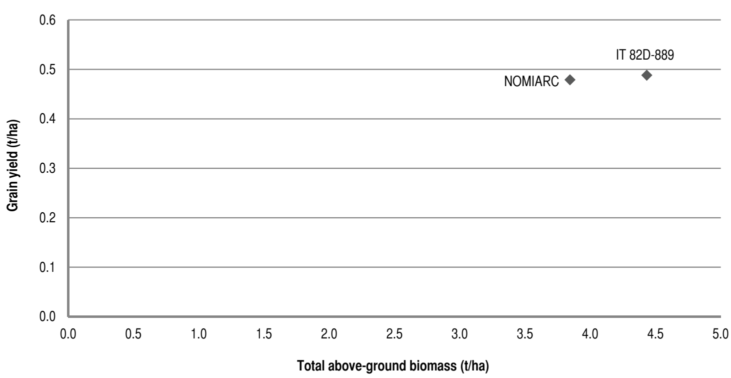


Figure 11.13. Relationship between grain yield and total biomass of different cowpea varieties



Other Components of CAT Good Innovation for Climate Change Adaptation

Natural vegetative filter strips establishment

Establishing natural vegetative filter strips along contour lines is the initial and simple, low-cost conservation measure that will allow natural vegetation to grow at 50-centimeter width strips spaced at 8–10 m apart. This will effectively protect the soil from erosion (Figure 11.14). NVS systems provide foundation for establishing cash perennials on the contour strips.

Rainwater harvesting through animal-built embankment

Meanwhile, rainwater harvesting addresses rainfall variability, thus making water available to crops and livestock during dry spells (Figure 11.15). It increases water infiltration to provide subsurface irrigation to perennial crops. It also provides additional income to farmers as it allows them to culture fish, frogs, and ducks. Such activities will increase farmers' income while improving the nutrient load of the pond water, which will accordingly improve crop growth if used for irrigation.

Figure 11.14. Natural vegetative filter strips for effective soil erosion control

Figure 11.15. Animal-built rainwater harvesting as climate change adaptation strategy against drought

Organic fertilizer production at the farm level

Organic fertilizer production at the farm level (e.g., vermicomposting) is important in addressing farmers' fertilizer requirements. Using organic fertilizers increases soil OM, which improves soil structure and soil moisture holding capacity. Water then becomes available to crops during dry spells, thus making a suitable growing environment for crops. Its use also mitigates climate change as the practice prevents CO_2 emission through fertilizer substitution from the use of inorganic fertilizers and from injection of carbon into the soil that enhances its sequestration. This low-cost technology has the potential for mass participation of smallholders to climate change mitigation.

Vegetable agroforestry

Integrating properly managed trees into an intensive vegetable production system can improve vegetable yields up to 40 percent. This is because trees provide desirable microclimate for vegetable production as they reduce wind speed and temperature, increase relative humidity, provide high soil moisture, and improve soil organic matter content. Trees also provide environmental services such as habitat for wildlife, soil erosion control, and carbon sequestration. Lastly, trees provide additional nutrients to crops (through N_2-fixation) and additional income to farmers coming from timber harvests.

SUMMARY OF LESSONS AND WAY FORWARD

The body of evidence showing that CAT innovations improve agricultural activities is apparent. The CAT strategy helps increase crop yields, soil OM, and soil moisture; and helps improve the income and resilience of farmers to environmental stresses (e.g., drought, intense rainfall, typhoons) while reducing labor and capital costs. Currently, many farmers in Mindanao are adopting the strategy.

Given these benefits, government, NGOs, private companies, and other stakeholders should then address the barriers to CAT research and development by providing funds and subsidies, by investing on CA machinery and equipment, and by strengthening linkages between research and development activities.

The researchers' and farmers' experiences in Claveria, Misamis Oriental provided the foundation for the expansion of CAT innovations in the Philippines. This system can also be used in other countries in the humid tropics with similar biophysical and socioeconomic environments as the Philippines.

Accordingly, the following activities should be done to provide an enabling environment for the expansion and acceptance of the CAT strategy:

1. Massive information dissemination about conservation agriculture, its principles and benefits;
2. Establishing demonstration/model sites (cum experimental fields) at strategic locations;
3. Development of appropriate CAT tools and equipment relevant to smallholder farmers and sloping lands;
4. Provision of planting materials at the early stage of adoption;
5. Provision of initial capital, particularly to smallholders;
6. Adequate institutional support through suitable policy formulation that will include CAT in the projects and programs of line agencies; and
7. Provision of technical capacities at the local level to promote and facilitate the adoption of CAT.

The project proponents/implementers established a CAT center in Claveria, Misamis Oriental in order address the need for CAT information dissemination. At the center, interested individuals can come, see, learn, and discuss the various issues, facets, and components of CAT relevant to their specific context.

Scaling Out and Up through Landcare Approach

The Landcare approach is based on effective community groups being in partnership with the local government. Such groups respond to the issues affecting them, and they are more likely to find and implement solutions independently rather than just follow those imposed by external agencies. Landcare is about people; the key to its success is based on a mature social capital and a close bond between and among farmer "communities" and governments. The success of scaling out technologies through Landcare is dependent on how these three key actors interact and work together:

1. Concerned citizens in the community who are
   - willing to share their talents, skills, and other resources;
   - usually resource poor who want to improve their livelihoods;
   - willing to learn, share experiences, and employ new sustainable farming techniques;
   - committed to resource conservation and protection and the creation of work groups for that purpose; and
   - tillers, non-tillers, owners, or tenants of the land.

2. Local government units who can provide
    - policy support to institutionalize conservation farming, agroforestry, and other practices for sound environment and natural resource management;
    - budget allocations through the creation of local ordinances;
    - leadership in facilitating Landcare groups and related activities;
    - capacity-building programs for the overall development of Landcare; and
    - financial support for Landcare activities.
3. Technical facilitators (i.e., World Agroforestry Centre and other line agencies) who can provide
    - appropriate technologies for sustainable agriculture and natural resource management;
    - facilitation for Landcare group formation and their activities;
    - information, communication, and education programs; and
    - network support for Landcare groups

Meanwhile, the different modalities for expanding the CAT strategy through the Landcare approach can be

1. through the local development planning process, which will require an engagement with LGUs in their local development planning process, resulting in the institutionalization of the project at the planning stage;
2. through integrating the strategy into the conventional extension program of local government line agency;
3. through the local development planning process and integration of CAT into existing local programs;
4. through province-wide expansion by integrating CAT into the programs implemented by government line agencies and special local warm bodies at the provincial level; and
5. through integrating CAT at the national level by including it in the programs, projects, workshops, and planning process of the national government's line agencies.

The Landcare approach may be suited to scale out and scale up CAT in other locations in the Philippines and elsewhere in Southeast Asia. Landcare can provide a national focus for the sustained management of farm and other natural resources by farmers, with minimal local government support in the context of climate change and in the process of adapting to it.

ACKNOWLEDGMENT

This project was made possible through the support provided by the United States Agency for International Development and the generous support of the US for the Sustainable Agriculture and Natural Resources Management Collaborative Research Support Program under the terms of the Cooperative Agreement Award No. EPP-A-00-04-00013-00 to the Office of International Research and Development at Virginia Polytechnic Institute and State University (Virginia Tech), Blackburg, Virginia, USA.

The authors would like to acknowledge the strong collaboration with the Claveria Research and Development Foundation Inc., Misamis Oriental, Philippines; the North Carolina Agriculture and Technical State University, Greensboro, North Carolina; the University of the Philippines Los Baños, Laguna, Philippines; and the Misamis Oriental State College of Agriculture and Technology, Claveria, Misamis Oriental, Philippines.

REFERENCES

Derpsch, R. 2008. "No-Tillage and Conservation Agriculture: A Progress Report." In *No-Till Farming Systems* edited by T. Goddard, M.A. Zoebisch, Y.T. Gan, W. Ellis, A. Watson, and S. Sombatpanit, 7–39. Bangkok, Thailand: World Association of Soil and Water Conservation.

Ekboir, J.M. 2003. "Research and Technology Policies in Innovative Systems: Zero Tillage in Brazil." *Research Policy* 32(4): 573–586.

Fujisaka S., A.A. Mercado, and D. Garrity. 1995. *Farmer Adaptation and Adoption of Contour Hedgerows for Soil Conservation*. Manila, Philippines: International Rice Research Institute.

Mercado, A.R., Jr. 2007. *Potential of Timber-Based Hedgerow Intercropping for Smallholder Agroforestry Option on Degraded Soils in the Humid Tropics of Southeast*. Bogor, Indonesia: World Agroforestry Centre, Southeast Asia Regional Research Programme.

Mercado, A.R., Jr., and G. Cadisch. 2004. "Soil Conservation and Social Capital Formation: The Landcare Experience in the Philippines." Paper presented at the 6th National Watershed Summit, 18–21 November 2004, Malaybalay City, Philippines.

Mercado, A.R., Jr., D.P. Garrity, and M. Patindol. 2001. "The Landcare Experience in the Philippines: Technical and Institutional Innovations for Conservation Farming." In *Development in Practice*, Vol. 12 edited by S. Franzel, Denning, G.L. and P. Cooper, 495–508. Florida: Routledge and Taylor and Francis Group.

USAID (United States Agency for International Development). 2009. "Country Assistance Strategy Philippines: 2009–2013." Accessed 30 November 2009. http://pdf.usaid.gov/pdf_docs/Pdacn452.pdf

Wall, P.C. 2007. "Tailoring Conservation Agriculture to the Needs of Small Farmers in Developing Countries: An Analysis of Issues." *Journal of Crop Improvement* 19(1/2): 137–155.

Cassava shoot infested by exotic mealybugs
Photo by Phanuwat Moonjuntha, courtesy of Department of Agriculture of Thailand

CASE STORY 12

Diversity and Resilience in the Context of Climate Change

The Case of Invasive Pests in Cassava in Southeast Asia

Kris A.G. Wyckhuys[1] and Erik Delaquis[1]

ABSTRACT

Throughout the developing world, the effects of climate change, the far-reaching degradation of land resources, and agricultural intensification are putting considerable pressure on agro-production systems. This situation has become particularly acute in Southeast Asian cassava, a crop that is regionally grown by 8 million smallholder farmers on more than 4 million hectares of land area in the region. In many parts of Southeast Asia, this prime food, cash, and bio-energy crop is largely grown under monoculture, which is a system that is fraught with a worrisome record of accelerating soil erosion, stagnating yields, and mounting plant health problems. Thus, agricultural researchers and experts in the region are now considering the application of within-field crop diversification in order to step away from this unsustainable crop management scheme. Adding diversity to cropping systems can boost production efficacy while conferring system stability, resilience, and overall ecological sustainability. Crop diversification schemes can contribute to pest control through herbivore suppression, natural enemy enhancement, and improve the overall resilience of crops to pest or disease attack. Furthermore, companion crops can greatly improve water infiltration and storage as well as actively prevent soil erosion and runoff, and thus reduce the vulnerability of crops to climate change. However, to date, there is no science-based decision-making structure that can help farmers to select efficiently the right type of companion crop or to devise proper diversification schemes. Ultimately, developing such "expert systems" could be an important step toward the development of highly productive, resilient, and pest-suppressive cassava cropping systems.

1 International Center for Tropical Agriculture

INTRODUCTION

Cassava (*Manihot esculenta*) is the fourth most important agricultural commodity after rice, wheat, and maize as it features prominently in the diet of millions of people throughout the tropics. Cassava is grown on more than 18 million hectares (ha) worldwide, which sustains the livelihoods of countless smallholder farmers, many of whom operate in degraded environments. As one of the signature smallholder crops in Southeast Asia (SEA), cassava plays a pivotal role in sustaining rural livelihoods and (small-scale) agro-industries (Howeler 2010). Regionally, cassava cultivation directly sustains approximately 8 million smallholder farm households, and supports countless rural processing plants and a wide-range of cassava-based industries. In the meantime, cassava continues to be a chief food security crop in Indonesia and Southern Philippines, where approximately 1.0–1.5 million ha of this crop is grown, and 50 percent of locally cultivated cassava is directly used for human consumption.

Throughout the world, cassava crops are affected by myriad of arthropod pests, such as whiteflies, mealybugs, mites, and limiting diseases (Figure 12.1) (Graziosi et al. 2015). Until the turn of the century, cassava in SEA was virtually free from noteworthy pests or diseases. However, the recent appearance of invasive mealybug pests and emerging diseases have greatly altered this situation, and farmers throughout SEA now face mounting difficulties in sustaining their yields and in safeguarding their harvests. The appearance of these novel plant health threats is directly related to increased global trade and associated movements of infested planting material, deficient quarantine systems, pervasive crop expansion, and the ever-more-pronounced climate change (and climate variability) (e.g., Muniappan et al. 2009; Parsa, Kondo, and Winotai 2012).

The cassava mealybug (*Phenacoccus manihoti*) is one of the world's most destructive cassava pests. The cassava mealybug is originally from South America; it invaded the African continent in the late 1970s, subsequently impacting cassava production throughout Central and Sub-Saharan Africa. In some areas, this tiny insect has caused yield losses of up to 84 percent, affecting the livelihoods of 20 million people and compromising regional food security.

In 2008, the pestiferous mealybug arrived in SEA, which is a region where approximately 35 percent of the global cassava production is concentrated. By 2010, *P. manihoti* has caused a 30-percent annual crop loss in Thailand. It aggressively spread to key cassava growing areas in Cambodia, Lao PDR, Vietnam, Malaysia, and Indonesia (Sartiami et al. 2015). In Indonesia, the pest was first detected in 2010 and has since made its way to East Java and Southern Sumatra. In the Philippines, *P. manihoti* was first detected on the island of Bohol in late January 2015, and is thought to be present in other parts of the country. Although there are no official estimates of mealybug-inflicted yield losses, the current impact of *P. manihoti* on both countries is expected to be particularly high.

Figure 12.1. Cassava affected by crop disease and pest

Leaf proliferation as an unmistakable symptom of cassava witches' broom disease

Photo by Georgina Smith, courtesy of CIAT Asia

Cassava shoot infested by exotic mealybugs

Photo by Phanuwat Moonjuntha, courtesy of Department of Agriculture of Thailand

In recent years, several other invasive mealybugs (i.e., the papaya mealybug, *Paracoccus marginatus*; the striped mealybug, *Ferrisa virgata*; the jackbeardsleyi mealybug, *Pseudococcus jackbeardsleyi*) have affected local cassava crops, with estimated yield losses ranging from 40%–80% in certain areas (Bellotti, Herrera, and Hyman 2012; Myrick et al. 2014). Aside from cassava, most of these mealybug invaders are affecting a number of other important agricultural and horticultural crops. In Indonesia, the long-term impact of invasive mealybugs on national welfare is estimated to be more than United States Dollar (USD) 3 billion if the spread of this pest is not controlled. Many local smallholder farmers are increasingly resorting to pesticide use to tackle mealybug invaders, thus reducing their already-slim profit margin.

Aside from the complex effects of the spread of mealybug pests, (novel) plant diseases have equally impacted cassava production in SEA. The cassava witches' broom (CWB) is a systemic disease caused by phytoplasmas and was initially reported in the region in 1993 (Alvarez et al. 2013). CWB causes 30%–35% yield losses, and can also significantly reduce cassava starch content. In early 2014, CWB was reported from all major cassava-cropping areas in the Greater Mekong River subregion. In some countries, 80 percent of the fields are affected by this disease, with average field-level incidence estimated at an astonishing 30%–50% (Table 12.1). Hence, these problems of emerging diseases and spread of invasive pests need to be immediately addressed in order to safeguard the livelihoods of the countless small-scale cassava producers throughout rural SEA.

The outbreaks of cassava mealybug and CWB are inherently tied to the overall climate and local weather conditions; *P. manihoti* reached high population levels under conditions of extended drought and high temperatures. Populations of cassava mealybug (and other limiting pests such as mites) are typically enhanced by high temperatures, and tend to reach outbreak levels when evaporation exceeds precipitation for prolonged periods of time.

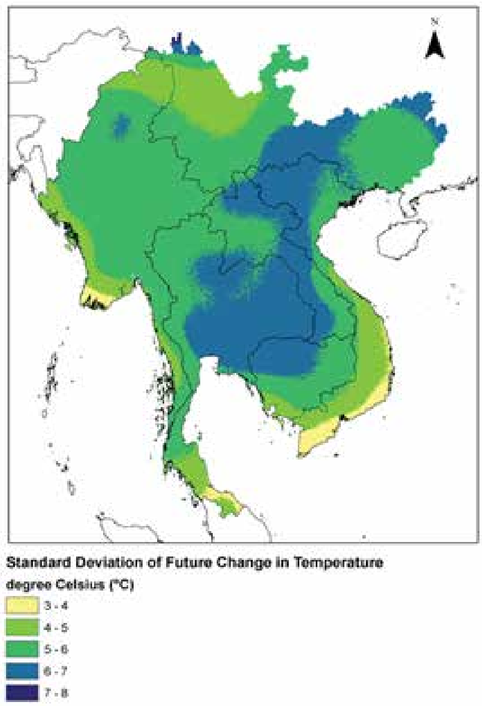
On the other hand, mealybug populations rapidly decline once precipitation increases; heavy rainfall is largely considered to be the major determinant in mealybug population dynamics. Prolonged drought periods paired with rapidly increasing mealybug infestations, especially in young cassava crops, inflict tangible yield. Moreover, under current climate change projections, the climatic conditions of several key cassava-growing areas in SEA (e.g., Eastern Thailand, Central Cambodia, Eastern Indonesia) are becoming increasingly suitable for mealybug development (Figure 12.2).

Table 12.1. Occurrence and incidence of the main (non-native) mealybug species and CWB disease in cassava fields within the different GMS countries (Graziosi et al. 2015)

Location	Cassava Mealybug[a]		Short-Tailed Mealybug[b]		Long-Tailed Mealybug[c]		CWB	
	Occur	Inc	Occur	Inc	Occur	Inc	Occur	Inc
Thailand	0.63	0.19	1.00	0.48	0.98	0.37	0.37	0.15
Laos	0.28	0.13	0.49	0.20	0.34	0.11	0.67	0.29
Cambodia	0.82	0.19	0.76	0.18	0.82	0.31	0.78	0.47
Myanmar	0.00	0.00	0.95	0.21	0.45	0.04	0.00	0.00
Vietnam	0.34	0.37	0.38	0.25	0.23	0.18	0.35	0.24
GMS	0.41	0.18	0.72	0.26	0.56	0.20	0.44	0.23

Notes: (1) a = *Phenacoccus manihoti*, b = *Paracoccus marginatus* and *Phenacoccus madeirensis*, c = *Pseudococcus jackbeardsleyi* and *Ferrisia virgate*. (2) Occur = Occurrence, Inc = Incidence. *Occurrence* and *incidence* pertain to the population of the main (non-native) mealybug species and CWS disease in infested/monitored cassava fields within the different GMS countries. *Occurrence* indicates the proportion of infested fields per country; *incidence* refers to the proportion of infested plants per affected field. (3) CWB = cassava witches' broom disease; GMS = Greater Mekong Subregion.

Figure 12.2. Extent of variability in projected temperature increases in major Southeast Asian cassava-growing areas



Source: CCAFS (2015)

Notes: (1) Eastern Thailand, Central Cambodia, and Eastern Indonesia are the major cassava-growing areas in Southeast Asia. (2) The map shows the extent and location where the anticipated extreme weather events would likely occur in the broader Southeast Asia. Areas such as Eastern Thailand, Central Cambodia, and Central Lao PDR are expected to have more frequent extreme weather events.

In a similar fashion, heightened temperatures and increased drought may very well lie at the basis of regionwide outbreaks of CWB. Higher temperatures can dramatically accelerate the development and reproduction of the insect vectors of this disease, whereas prolonged drought can cause additional stress to cassava plants and make them far more susceptible to CWB infection.

Although both mealybug pests and CWB diseases are relatively new to cassava crops in SEA, the plant health situation is greatly aggravated by climate change. Moreover, cassava crops with suboptimal soil fertility levels, improper rotation schemes, and monocropping arrangements are proving to be particularly vulnerable to the attacks of climate-triggered pests and diseases. Although the current plant health emergency is reflective of global climate change, it is also an unmistakable symptom of defunct cassava production systems. In summary, cassava is grown in a most inadequate manner in many parts of SEA, and climate-induced insect pests and diseases are telling us so.

DESCRIPTION OF THE ADAPTATION

In many parts of SEA, cassava is largely grown under monoculture, which is a cropping system fraught with a worrisome record of accelerating soil erosion, stagnating yields, and mounting plant health problems. It is only in selected areas of North Vietnam, South China, Southern Philippines, and Indonesia that intercropping practices are widely adopted. The most intensive intercropping systems are found in the wetter parts of West Java and Sumatra, where cassava is grown together with upland rice, maize, mungbean, soybean, cowpea, or peanut. In all other cropping areas in the region, cassava is predominantly grown under monoculture, with (almost) complete abandon of crop rotation, organic matter addition, or proper fertilization schemes. To step away from these defunct crop management schemes, researchers in SEA are increasingly considering promoting within-field crop diversification through using intercrops or cover crops. Well-designed polycultures can greatly contribute to soil conservation, and thus produce win-win outcomes between primary crop yield and pest or disease suppression.

Cover crops (or companion crops in general) are almost seemed to be tailor-made to address some of the most urgent issues in global agriculture and nature conservation. By adding diversity to cropping systems, cover crops can increase production efficacy, while conferring stability, resilience, and overall ecological sustainability. A “rotation effect” is frequently documented to explain the synergistic interactions of crops grown together or in sequence. These effects clearly benefit producers, but the underlying mechanisms are difficult to explain. Cover crops have proven highly effective in improving water infiltration and storage while increasing carbon sequestration, reducing soil erosion, and contributing to ecological weed management. Furthermore, cover crops have been shown to benefit pest management and to suppress diseases. Hence, it remains without doubt that cover crops can confer a multitude of benefits to the target crop and can make agricultural production more sustainable, efficient, and environmentally sound.

However, soil conservation strategies (in general) and intercropping schemes (in particular) continue to be plagued by anemically low levels of adoption. Many cassava farmers in SEA remain hesitant to adopt cover crops or intercrops, fearing that these techniques will spread pests or diseases, interfere with crop management, or prove to be costly. The recent apparition of multiple destructive pests and diseases as well as the expected benefit of crop diversification to tackle plant health problems provide a unique and unprecedented opportunity to bring the benefits of intercropping and cover cropping schemes to farmers’ attention and to further their adoption throughout the region. These novel, pest-suppressive cassava cropping systems can equally provide relief for other problems that continue to haunt cassava's reputation in SEA (i.e., as a crop that brings about soil erosion or causes soil nutrient depletion). Lastly, diversified cassava cropping systems not only resist climate-triggered pests and diseases, but they are also expected to be more resilient to broader climate change impacts.

Improving plant resilience to herbivory or disease attack may be one poorly explored mechanism that could drive synergisms between plants in polycultures. Crop diversification schemes can contribute to pest control through herbivore suppression, natural-enemy enhancement, and improvement in the overall resilience of crops to herbivory. Similarly, they can benefit disease control by slowing the development, fitness, and movement of disease vectors, or by boosting myriad of plant defense mechanisms. Direct bottom-up effects of plant diversity encompass the disruption of herbivores (including CWB vectors) from locating, accepting, feeding upon, and inflicting yield loss to a target crop. In the meantime, polycultures can boost indirect, top-down plant defenses by offering alternative, non-prey foods such as pollen and nectar or by providing host or prey items that enhance and sustain populations of natural control agents (i.e., so-called natural enemies). At present, the development of selection tools for companion crops is still in its infancy, and polycultures continue to be designed arbitrarily. Such hit-and-miss approaches are largely ineffective in supporting beneficial arthropods and in taking pest or disease control forward. The selection of appropriate companion crops that will maximize (primary) crop yield while controlling for pest or disease requires a sound understanding of the biology and ecology of the relevant species.

Multidisciplinary approaches have rarely been adopted. Cover crops continue to be solely selected based on their (often supposed) benefits in terms of soil nutrition, water conservation, or erosion prevention. A strategic selection of appropriate cover crops should underbuild the design of novel cropping systems, and novel research tools and methodologies continue to be underused in this process. Biochemical techniques (e.g., polymerase chain reaction-based gut-content analysis, anthrone analyses) can readily reveal the nutritional status of natural enemies and elucidate the trophic linkages in diversified cassava crops. Microcosm studies, info-chemical analysis, and wind-tunnel assays may shed light on the role of plant-produced volatiles of plant associations (versus single plants) and their underappreciated contribution to induced plant resistance or natural enemy recruitment. Lastly, cutting-edge science will prove obsolete if farmer perspectives and yield optimization do not receive the necessary attention from the start.

In conclusion, a science-based selection of companion crops is central in the development of novel cropping systems. It is a complex exercise in which farmers, agronomists, soil/water scientists, entomologists, economists, modelers, crop physiologists, and breeders should join forces.

HYPOTHESIS

Associational resistance against insect herbivores and plant pathogens is not an evolved characteristic of individual plants, but are largely determined by the surrounding plant community. Neighboring plants do not necessarily need to be competitors (e.g., for nutrients, water, or space), but may instead facilitate plant performance by reducing pests and pathogen infestation. This can be due to mechanisms such as visual protection by tall associated plants, masking chemical cues used by herbivores, modified microclimate, or even changes in soil community structure and corresponding plant performance. Reduced herbivory (or vector-borne disease attack) may be driven by mechanisms affecting herbivores directly, or by mechanisms enhancing herbivore natural enemies (e.g., by providing alternative foods such as floral nectar). Through several of these mechanisms, cover crops can be highly effective in reducing pest populations or in suppressing (vector-borne) plant diseases within the target crop.

In cassava, research has shown far lower pest incidence in mixed crop systems (Thung and Cock 1979; Gold, Altieri, and Belloti 1989a, 1989b, 1990). Furthermore, intercropping and varietal mixtures have been embraced by cassava farmers in some parts of the developing world, such as eastern Africa or Indonesia.

The linkages between cropping systems diversification and pest suppression were first elucidated in the 1970s when sharply lowered whitefly pest populations in cassava/bean intercrops were compared to cassava monocrops. Other key cassava pests (e.g., burrower bug or stem-borer) equally reach lower infestation levels when cassava is grown in association with cowpea, sunnhemp, or maize. In maize, the most globally popular cassava intercropping system, there have also been reported instances of win-win interactions that reduce key pests of both crops. There is also a body of anecdotal evidence that points to the heightened abundance of the pest's natural enemies (e.g., voracious predators or parasitic wasps) in more diversified cassava crops versus cassava monocultures. Few studies have evaluated higher level interactions involving predators, a particularly promising approach due to cassava's long "undisturbed" growing period, which may provide stable habitat for predatory species. Thus, crop diversification strategies have the potential to reduce pest pressure while boosting (free) natural pest control. However, little is known about the extent by which polycultures can enhance the control of climate-triggered pests (e.g., cassava mealybugs) or the degree to which companion crops can enhance the abundance, fitness, and efficacy of the foremost natural enemies of the highly invasive mealybugs. Also, the relative contribution of one companion crop (versus another) in ensuring control of *P. manihoti* or other invasive mealybugs is poorly understood.

Intercropping schemes equally contribute to disease control (Boudreau 2013). African studies show that cassava fields intercropped with beans, maize, or sweet potato have far lower incidence of the limiting cassava mosaic disease. In some areas, disease pressure is reduced by 45%–50% when cassava crops are interplanted with sorghum. Intercrops have also been shown to slow the development and population build-up of insect vectors of cassava diseases, and may even interfere with the dispersal and feeding behavior of these agents. Under specific intercrop arrangements, cassava plants can better fight off diseases when conditions are far less suitable for diseases to spread and proliferate. Analyses at the landscape level are less common, but large-scale research in highly infected areas where intercropping is prevalent in Africa has identified that incidence and severity of mosaic disease was lower in intercropping systems and throughout the study area (Night et al. 2011). The same study indicated that virus dynamics differed depending on whether or not the neighboring fields also contained cassava. Although intercrops have been shown to help manage African cassava diseases, nothing is known with regard to the extent by which intercrops can interfere with CWB or mealybug invaders under the particular cropping conditions in SEA.

Nevertheless, these highly encouraging results should motivate scientists to conduct follow-up experiments to further improve the odds of designing diversification schemes that can contribute to pest and disease suppression or help stabilize crop yields. In the meantime, the current regionwide plant health situation provides a unique opportunity for devising a scientifically underbuilt decision-making structures that can help farmers in SEA to select the right kind of plant diversity strategy to apply to cassava production. Ultimately, this case story presents an example of the ongoing diversification efforts for other agricultural crops in the tropics.

SUMMARY OF LESSONS AND WAY FORWARD

This chapter exemplifies the urgent need for a science-based decision-making structure that would optimize pest and disease control, as delivered by companion crops, in smallholder-based cassava production in SEA. More specifically, mechanistic experiments still need to be implemented to elucidate the contribution of companion plants to top-down and bottom-up pest control (and disease suppression) in local cassava crops. By doing so, the appropriate companion plants could be identified to maximize pest suppression, and effective crop diversification schemes could be devised in order to improve pest regulation with minimal pesticide inputs while sustaining or improving crop yield. As a way forward, a multifunctional assessment of different types of crop and non-crop vegetation needs to be conducted. Likewise, an “expert system” that will allow efficient selection of the right type of companion crop for cassava production in SEA needs to be developed.

In particular, the novel research approaches that need to be adopted include the following:

1. Incorporate biochemical analyses, insect mouthpart, and floral architecture studies in order to elucidate the contribution of companion plants to natural enemy enhancement;

2. Adopt laboratory-based screening protocols for rapid assessment of the contribution of companion crops to pest/disease suppression and related crop morphological and chemical defenses;
3. Use microcosm studies to evaluate the effect of plant heterogeneity on volatile-mediated recruitment of natural enemies or priming (against pest or disease attack);
4. Use targeted screening protocols for rapid assessment of the contribution of cover crop to disease suppression or CWB vector interference; and
5. Work hand-in-hand with cassava growers in different SEA countries such that the attributes of candidate companion crops, cropping arrangements, polyculture management schemes, and plant production limitations can be considered carefully; thus planting the seed for future broad-scale adoption.

Such initiatives will reveal key mechanisms of plant-plant and plant-insect interactions within cassava-based intercropping systems. Associated findings could have important implications for scientists, farmers, policy makers, and society at large in the region. Also, these activities provide the necessary groundwork for developing highly productive, resilient, and pest-suppressive cassava cropping systems. Crop diversification also constitutes the cornerstone of sustainable intensification of cassava crops in SEA; cassava production is intensified while environmental impacts are minimized.

National partners and scientists from the International Center for Tropical Agriculture in Asia are steadily working toward this goal, with the hope of providing long-lasting relief to most pressing (climate-triggered) plant health problems and of securing the sustainability, productivity, and profitability of one of Southeast Asia's most important agricultural commodities.

REFERENCES

Alvarez, E., J.M. Pardo, J.F. Mejia, B. Assunta, N.D. Thanh, and T.X. Hoat. 2013. "Detection and Identification of '*Candidatus Phytoplasma asteris*'-related Phytoplasmas associated with a Witches' Broom Disease of Cassava in Vietnam." *Phytopathogenic Mollicutes* 3(2): 77–81.

Bellotti, A., B.V. Herrrera, and G. Hyman. 2012. "Cassava Production and Pest Management: Present and Potential Threats in a Changing Environment." *Tropical Plant Biology* 5(1): 39–72.

Boudreau, M.A. 2013. "Diseases in Intercropping Systems." *Annual Review of Phytopathology* 51: 499–519.

CCAFS (CGIAR Research Program on Climate Change, Agriculture and Food Security). 2015. "Climate Change and Food Security Data Portal." Accessed 25 May 2015. http://ccafs-climate.org/data/

Gold, C.S., M.A. Altieri, and A.C. Bellotti. 1989a. "Cassava Intercropping and Pest Incidence: A Review Illustrated with a Case Study from Colombia." *Tropical Pest Management* 35(4): 339–344.

——. 1989b. "Effects of Intercrop Competition and Differential Herbivore Numbers on Cassava Growth and Yields." *Agriculture Ecosystems & Environment* 26(2): 131–146.

——. 1990. "Effects of Intercropping and Varietal Mixtures on the Cassava Hornworm, *Erinnyis ello L.* (Lepidoptera: Sphingidae), and the Stemborer, *Chilomima clarkei* (Amsel) (Lepidoptera: Pyralidae), in Colombia." *Tropical Pest Management* 36(4): 362–367.

Graziosi, I., N. Minato, E. Alvarez, T.D. Ngo, T.X. Hoat, T.M. Aye, J.M. Pardo, P. Wongtiem, and K.A.G. Wyckhuys. 2015. "Emerging Pests and Diseases of Southeast Asian Cassava: A Comprehensive Evaluation of Geographic Priorities, Management Options, and Research Needs." *Pest Management Science* 72(6): 1071–1089.

Howeler, R.H. 2010. "Cassava in Asia: A Potential New Green Revolution in the Making." In *Proceedings of the 8th Regional Cassava Workshop: A New Future for Cassava in Asia - Its Use as Food, Feed and Fuel to Benefit the Poor* edited by R.H. Howeler, 34–65. Bangkok, Thailand: CIAT.

Muniappan, R., B.M. Shepard, G.W. Watson, G.R. Carner, A. Rauf, D. Sartiami, P. Hidayat, J.V.K. Afun, G. Goergen, and A.K.M. Ziaur Rahman. 2009. "New Records on Invasive Insects (Hemiptera: Sternorrhyncha) in Southeast Asia and West Africa." *Journal of Agricultural and Urban Entomology* 26(4): 167–174.

Myrick, S., G.W. Norton, K.N. Selvaraj, K. Natarajan, and R. Muniappan. 2014. "Economic Impact of Classical Biological Control of Papaya Mealybug in India." *Crop Protection* 56: 82–86.

Night, G., P. Asiimwe, G. Gashaka, D. Nkezabahizi, J.P. Legg, G. Okao-Okuja, R. Obonyo, C. Nyirahorana, C. Mukakanyana, F. Mukase, and I. Munyabarenzi. 2011. "Occurrence and Distribution of Cassava Pests and Diseases in Rwanda." *Agriculture, Ecosystems & Environment* 140(3): 492–7.

Parsa, S., T. Kondo, and A. Winotai. 2012. "The Cassava Mealybug (Phenacoccus manihoti) in Asia: First Records, Potential Distribution, and an Identification Key." *PlosOne* 7(10): e47675.

Sartiami, D., G.W. Watson, R.M.N. Mohamad, M.Y. Hanifah, and A.B. Idris. 2015. "First Record of Cassava Mealybug (Hemiptera: Pseudococcidae) in Malaysia." *Zootaxa* 3957(2): 235–238.

Thung, M., and J.J. Cock. 1979. "Multiple Cropping Cassava and Field Beans: Status of Present Work at the International Centre of Tropical Agriculture, CIAT." In *Proceedings of an International Workshop on Intercropping with Cassava* edited by E. Webel, B. Nestel, and M. Campbell, 7–16. Palmira, Colombia: CIAT.

Special Case

Animal genetic resources cryopreserved and submerged in liquid nitrogen in cryotanks for storage
Photo by Alexander M. Paraguas

CASE STORY 13

Conserving Animal Genetic Diversity to Adapt to Climate Change in the Philippines

Lilian P. Villamor

ABSTRACT

Buffaloes and other livestock animals play a significant role in maintaining the genetic diversity of an ecosystem. Likewise, these animals serve as the pride and symbol of the country where they originated from. In the Philippines, the upgraded genetic traits of modern buffalo breeds have significantly contributed to the country's high-quality produce of carabao milk and meat; this consequently improved the lives of the Filipino farmers and other stakeholders. However, the effects of climate change have resulted in environmental changes that now threaten the lives and genetic diversity of buffaloes and other livestock in the country.

In response to the threats posed by climate change, the Philippine government established a cryobank facility at the Philippine Carabao Center (PCC) through the financial and technical support of Korean International Cooperation Agency and the Philippine Department of Agriculture. The cryobank facility is in support of the PCC's existing genetic improvement program for livestock in the country, which is known as the Cryobanking of Animal Genetic Resources (AnGR) program.

The AnGR program does not preserve only the genetic sources of buffaloes, but of other domesticated animals as well. The strategy to run the cryobanking consists of various components, namely, collection of animal genetic resources, preservation, data banking, provision of access to stored samples, and implementation of information and dissemination campaign. To date, the collection and cryopreservation of semen and embryos, oocytes, and somatic cells from various species are mainly from buffaloes, cattle, and caprine.

The AnGR program aims to establish a national repository of germplasm and biological samples from livestock, poultry species, threatened and wild animals, and indigenous species that will sustain the genetic diversity of animals in the Philippines.

---

1 Philippine Carabao Center of the Philippine Department of Agriculture

INTRODUCTION

Buffaloes play an important role in any given location where they thrive best. In the Philippines, water buffaloes (Philippine Carabaos or native carabaos) are being used as draft labor for some of the back-breaking activities in farming—from the tedious land preparation, weeding of crops, to hauling of the harvested produce. Likewise, the manure of livestock is an excellent component of organic fertilizer that enhances the natural condition of the soil, which is considered as the backbone of a healthy environment and can lead to a sustainable status of agriculture in the general context.

The rural area in the Philippines, in its picturesque setup, is usually characterized by the presence of carabaos. In fact, famous annual festivities—such as the festivities in the municipalities of Talavera and San Isidro in Nueva Ecija province, Pulilan in Bulacan province, Angono in Rizal province, and San Agustin in Isabela province—cannot be completed without the carabao race or carabao parade.

Although various stories may explain the origins of these festivities, the common aim of these events is to pay homage to the patron saint of that particular town and to bring the Philippine carabao and upgraded carabaos at the center stage. This tradition began way back in the Hispanic era when the Spaniards ruled over the Philippines between 1565 and 1821. The locals have included carabao in the festivities since this animal species is vital to the lives of farmers. For instance, in the feast of San Isidro, farmers are highly involved in decorating and dressing up native carabaos such that they can be showcased at the big parade. Farmers are also involved in the "Kneeling Carabao Festival," where carabaos are made to kneel to be blessed by the priest in front of the church. Carabao races are also held during these festivities, in which the strongest and the most beautiful carabao will win the grand prize.

Another carabao festival celebrated during the month of September is the *Nuang* Festival in the municipality of San Agustin in Isabela province. This festivity gives tribute to farmers, wherein they showcase buffalo crossbreeds. *Nuang* is a generic name that the locals of San Agustin have coined for carabaos. During this festival, different contests are held, whereby the best animals are judged and selected under categories such as "Best Buffalo in Milk Production," "Best Dairy Buffalo," "Best Draft," and "Best Dressed Buffalo." The Nuang Festival is a special event in remembrance of the farmer's many dreams, which are accordingly fulfilled relative to their success in improving and upgrading the breed of Philippine national animal (PCC 2012a).

In traditional agricultural system, carabaos are the farmer's best helper in plowing the field. Their draft power is immensely impressive, as evidenced by the heavy load that these animals carry during land cultivation. Indeed, swamp buffaloes are known to be very hardworking. Swamp and riverine carabaos are the two main types of carabao species in the Philippines. The first type is primarily known for its draft power, its high adaptive capacity to environmental temperature, and for its work endurance. It is also known for its meat and milk. On the other hand, the riverine carabao (e.g., Murrah and Nili-Ravi Indian buffaloes) is a dairy breed; it is bigger and grows faster than the native carabao (Flores et al. 2007; Orville 2013). The male and female riverine buffalo can gain weight by as much as 360 grams and 400 grams a day, respectively, for the first 24 months of its life (Flores 2004). Due to the superior genetic traits of riverine buffaloes, genetic researchers prefer to use the semen of this breed in artificial insemination programs, with the aim of improving the milk production of other buffalo breeds such as the native Philippine carabaos (Flores et al. 2007). Accordingly, the Philippine Carabao Center of the Department of Agriculture (DA-PCC) implements the national crossbreeding program to improve the milk production of native carabaos. The PCC uses the processed semen of purebred dairy buffalo bulls in the artificial insemination of native female carabaos.

With the improved and upgraded genetic stock of carabaos in the country, crossbreds have the potential for increased growth, body size, and milk production. They can produce more milk than native carabaos. The former can produce an average of 8–10 kilograms (kg) of milk a day in a 305-day lactation period, whereas the latter produces only an average of 1.5 kg of milk per day. The hybrid vigor produced from such crossing expresses the complementary traits of the parental animals, which accordingly becomes traits in growth, reproductive performance, and disease resistance (Flores 2004).

According to the data from the Philippine Statistics Authority, the contribution of carabao milk to the milk output of the country increased from only 16 percent in 2003 to almost 47 percent in 2015. Moreover, the *Manila Bulletin* (3 May 2015) reported that local milk production had increased by 2.4 percent or 20.0119 million liters in 2014 compared with the yield of 19.53 million liters in 2013.

Carabaos are not only a good source of meat and milk in the Philippines; their manure is also a good main substrate of vermicomposting. The utility of carabao and cow manure is included in the organic fertilizer production project of the municipal government of Llanera, Nueva Ecija province, which was extended to the cooperative members of the municipality. According to Mayor Lorna Mae Vero, mayor of Llanera, the cooperative can produce 3,516 tons of manure per year, which is sold at Philippine Peso (PHP) 20 per kilo, with each bag of fertilizer containing 40 kg. She also noted that this project is an avenue for an average household to earn additional PHP 19,200 per year at modal average of two 1 meter × 4 meters beds with 4 kg of African night crawlers per bed. The income is collected every 45 days of production per cycle (PCC 2012).

Climate Change Issues

The economic and social importance of buffaloes and other livestock in the Philippines should be secured in the midst of the threats posed by climate change. The increasing incidents of animal heat stroke and proliferation of other pests and diseases brought by extreme weather events such as El Niño, La Niña, *habagat* (monsoon rain), super typhoons, and prolonged dry spells can be attributed to the effects of climate change. It is predicted that such events would be more frequent in the coming years, and such scenario imposes very alarming conditions.

As early as 2010, the Philippine Atmospheric Geophysical and Astronomical Services and Administration, the country's weather bureau, has warned that 16 provinces in the country would first experience the effects of severe heat or high temperature due to climate change. True enough, animal deaths (e.g., buffaloes, cattle, goats, and pigs) have been reported in the provinces of Ifugao, Benguet, and Kalinga due to heat stroke. *The Philippine Star* (7 March 2010) also reported that the economic loss in livestock have reached PHP 1,376,220,352. On 18 April 2015, *The Philippine Star* reported that a significant number of animals had died in Negros Occidental due to the dry spell. Damages to livestock was estimated at PHP 10 million. If this condition gets worse, then the situation will be very distressing to the health, nutrition, and lives of animals.

The detrimental effects of climate change are not limited to water supply shortage; the phenomena can also cause "super typhoons." For instance, the *Philippine News Agency* (2 February 2015) reported that the strongest typhoon Yolanda that had caused severe flooding in Northern Cebu in 2014 had wiped out all the carabaos, cattle, goats, pigs, and native chicken in the region.

In the global arena, the FAO reported in 2000 the status of the world's animal breeds that have suffered loss of genetic variation. According to the FAO report, 12 percent are extinct, 17 percent are endangered, 9 percent has crossed the critical condition, and 39 percent remains free from risk (Blackburn 2004). Moreover, it has been reported that livestock breeds have been disappearing at a rate of 5 percent annually in the United States, half of the breeds of domestic animals have also become extinct, and 43 percent of the remaining breeds are endangered in Europe (Shand 2000). If this pattern continues, then animal genetic diversity will be inevitably lost. The decreasing population and loss of domestic animal diversity in the Philippines signals the need for animal conservation in preparation to the detrimental effects of climate change.

Thus, a support tool for in-situ or field condition conservation of animal breeds is necessary. This can be done through establishing a backup facility that would enable the ex-situ or out-in-the-normal habitat conservation of a given species. In such facility, ultra-low temperature preservation (or cryobanking) and an ex-situ type conservation in-vitro (glass/laboratory condition) type of cryoconservation can be established to become a tool for preserving animal genetic resources for climate change preparedness. Accordingly, this needs proper handling and management of animal biological samples for future breeding and reconstruction of animal population.

THE CCA STRATEGY

Cryobanking of livestock in the Philippines started with buffaloes. In 2008, Administrative Order No. 9, Series of 2008, mandated the PCC to lead the Department of Agriculture Animal Biotechnology Program, particularly the reproduction, maintenance of the nutrition and physiology, breeding and genetics, and dairy and meat of large and small ruminants. Accordingly, a state-of-the-art cryobank facility was established in the Philippines through the financial assistance and technical support of the Korean International Cooperation Agency. This became the take-off point for the PCC to consolidate its program and to expand one of its mandates, which is to conserve live Philippine carabao and include it in in-vitro conservation (cryopreservation).

What is cryobanking? Cryobanking is an ex-situ type of conservation that manages animal genetic resources in external or artificial environment under low-temperature conditions. Cryobanking includes in-vitro cryoconservation of oocytes, semen embryos, somatic, or tissues. It serves as a backup for genetic stock management of animal genetic resources in support of the in-situ conservation of animals or conservation that implies constant use of the animal under its natural environment. Through the advent of cryopreservation technology, in-vitro cryoconservation has been made possible.

The word cryobiology is derived from three Greek words “kryos,” which means cold; “bios,” which means life; and “logos,” which means science. According to Fahy and Hirsh (1982), cryobiology is a technique that can be used to keep the unaltered state of the biological systems in a viable condition for several years at any temperature below the standard physiological range either at –80°C (for the dry ice temperature) or –196 °C (for the boiling point of liquid nitrogen). Cryobanking, with the application of cryopreservation technology, has been successfully applied and practiced since the 1950s. As emphasized by McClintock et al. (2007), the following are the various applications of cryopreserved collections of animal genetic resources:

1. reconstruction of population due to national needs;
2. reintroduction of breeds with genetic variation due to loss or reduction in frequency;
3. development of new breeds as utilized by research or industry; and
4. a source of genetic material.

The existing cryobank facility in the country supports the PCC’s existing genetic improvement program for livestock. It will sustain the production of superior animals in the institutional herds and uplift the carabao-based industry in the country (PCC 2013).

CCA STRATEGIES AND APPROACHES

Collection of Animal Genetic Resources

The collection of animal genetic resources in the Philippines began with buffaloes. Philippine buffaloes are mainly Philippine native carabaos or swamp buffaloes. They are introduced breeds from breeds such as Bulgarian Murrah, Brazilian, Indian, and Brahman. The PCC has also collects genetic resources from other domesticated livestock species like cattle and goats (Sarabia and Cruz 2008). Superior traits of stocks are defined as those that have animal genetic resources from indigenous species. Introduced breeds are economically important and exhibit adaptable and resilient traits toward diseases and environmental changes in the country.

The way by which the PCC prioritizes the collection of animal genetic resources is guided by the agency's vision to be the national germplasm repository of animal genetic resources of livestock species and indigenous, wild, threatened, and endangered animals for in-vitro conservation. The ecological balance of animal biodiversity implies genetic diversity between and within species. This is congruent to the mission and vision of the cryobank facility that specifically aims to secure the biodiversity conservation of animal genetic and to establish the phenotypic and genotypic characteristics of animals to be cryoconserved following the FAO recommendations.

Cryopreservation

The guidelines recommended by the FAO are validated and optimized (for animal genetic resources in the Philippine conditions) in order to maintain state-of-the-art cryopreservation techniques. Biological materials from animals (e.g., embryos, oocytes, somatic cells, semen, and blood samples) are allowed for long-term storage without deterioration (Mazur 1985). It can be pictured as a tool to store animal genetic resources in a biological "safe deposit vault," which will be used as backup in the advent of genetic problems and reconstruction of population as part of the future conservation and breeding program (FAO 2012).

Data Banking

Any information about the sources of samples and collected biological samples for storage should be accessible. Through data banking, pertinent information (e.g., phenotypic characteristics, photo documentation, collection information, molecular characteristics, and storage condition) on any cryopreserved material are properly documented for future utilization and management of the animal genetic resources (FAO 2012).

Access to Stored Animal Genetic Resources

This strategy mainly focuses on who is allowed to access the animal genetic resources that are deposited in the PCC Cryobank Facility (PCC-CF). Every Filipino, whatever is his/her title or circumstance or profession in life (farmer, breeder, researchers) and his/her institutional affiliation (government agency, private sector, small and big stakeholders) is entitled to be an animal genetic resource (AnGR) provider. According to the draft guidelines on cryobanking, an AnGR provider refers to a person who provides AnGR material as its original source. An AnGR provider who is interested in storing biological samples in the facility is protected and bound by the operating guidelines indicated in the AnGR material upon completion of the AnGR Material Transfer Agreement Form. In most cases, an individual can apply for an access to cryobanking (whether for storage and/or acquisition of animal genetic resources) for a fee.

Information Campaign

Trainings, seminars, presentation, and workshops on cryobanking are imparted to and shared with farmers, livestock and poultry breeders, investors, researchers in the academe, policy makers, government officials, and various stakeholders. Local tours to the facility are highly encouraged in order to showcase the infrastructure of the PCC-CF and the advance technologies in the cryobank laboratory. This approach aims to translate the vast research efforts from the four corners of the laboratory to the PCC's clientele. This simple information sharing enables the clients to have better appreciation and understanding of the immense initiatives being done to preserve animal genetic diversity in the country.

OUTCOMES

Cryopreservation of animal genetic resources is cheaper than maintaining live animals in a gene pool. Maintaining live animals basically requires costly high-quality feeds and veterinary drugs and other inputs, and a well-structured genepool. On the other hand, cryopreserved animals will need only continuous supply of liquid nitrogen and state-of-the-art cryobanking facility in order to maintain its viability for long-term storage life.

Cryobanking is capable of sustaining the supply of frozen semen from buffaloes to farmers, livestock breeders, and other interested clients. The availability of frozen semen in the country is advantageous to various stakeholders, since they do not have to go through the tedium and inconvenience of processing the required papers, and bear the expensive cost of importing semen from international artificial insemination centers. Stakeholders and breeders are also assured of the quality of the frozen semen, particularly in the ability of the stocks of germplasm to adapt to the changing climate in the Philippines. Likewise, breeders are assured that the stocks from which the specimen came from are of superior breeds, were raised with good nutrition, and have good physiological and reproductive qualities.

Government officials, livestock breeders associations, researchers, and farmers are now becoming aware of the vital role of cryobanking as a CCA measure. The social acceptance of cryobanking is evident from the various support extended to the agency. The *Philippine Daily Inquirer* (29 March 2015) reported that the Department of Agriculture (DA) had provided PCC with PHP 336 million to establish a research and development center, now known as the Livestock Innovations and Biotechnolgy (LIB) complex at the PCC. A significant part of the LIB complex has been made to house the cryobank facility, which consists of six cryotanks and well-structured pipeline for liquid nitrogen supply.

The PCC is negotiating and entering into several agreements with other breeders and institutions that will enable the agency to bank animal genetic resources from native species. Likewise, state universities and colleges and other government research institutions are collaborating with the PCC, such that the latter can gain access to their animals for cryopreservation. For instance, the Small Ruminants Center (SRC) at the Central Luzon State University in Nueva Ecija has entered into collaborative projects with the PCC in order to cryopreserve the SRC's commercial goat breeds (e.g., Anglo-Nubian, Alpine, Boer, Saanen). Accordingly, the SRC can use these cryopreserved samples (i.e., frozen goat semen) from the PCC-CF for their goat production.

A common sentimental saying goes, "Don't cry over spilled milk. When it is spilled, you can no longer get it back." With cryopreservation, the end result of that saying can be reversed. If animal gets "spilled" in case of natural death or extreme animal genetic wipeout in an area, there is a high probability that the same species with similar (or even identical) genetic traits can be reproduced. This is because the semen that will be used to reconstruct the population can have the same traits as those of the original animal. Animal breeding through using the cryopreserved biological samples of carabaos or other animals will have a high probability that the reproduced animal will have similar (or identical) traits as that of the original. In this way, the drastic effects of climate variability can be mitigated with the existence of a cryobanking facility. Cryopreservation can help to reconstruct identical or similar genetic traits of the animals where the cryopreserved samples originated from.

Massive deaths of an animal species can lead to genetic drift, which can eventually lead to extinction or genetic loss. Consequently, this condition can lead to ecological imbalance. Therefore, preserving animal species through cryopreservation can significantly contribute toward restoring this ecological balance. To date, the PCC has collected and is now cryopreserving the semen and embryos, oocytes, and somatic cells of buffaloes, cattle, and caprine. As of 2014, the percentage of species per individual consists of 89 percent buffaloes, 6 percent cattle, and 5 percent caprine. Various sample types from various breeds of buffaloes (Bulgarian, Indian, Brazilian, Italian, and Swamp); cattle (Girolando and Brahman); and caprine (Anglo-Nubian, Alpine, Boer, Saanen) are currently stored in the PCC-CF (Tables 13.1 and 13.2).

However, the number of species and breeds of animals with samples currently preserved at the facility are still very small to be able to represent the genetic diversity of the animals in the Philippines. As such, the PCC still needs to collect and preserve samples from threatened animals such as tamaraw (*Bubalus mindorensis*) and from indigenous species such as native chicken, native cattle, native pigs, and native ducks.

Table 13.1. Inventories of frozen semen from different species at Cryobank Philippines, 2014

Species	Breed	Doses (0.5 mL straw)
Buffalo	Brazillian	3,021
	Bulgarian	172,890
	Indian	5,279
	Italian	80
	Swamp	3,020
Cattle	Brahman	607
	Girolando	23,037
Caprine	Anglo-Nubian	322
	Alpine	52
	Boer	164
	Saanen	282

Table 13.2. Collected and cryopreserved germplasm, somatic cells, and whole blood (as of October 2015)

Species	Breeds	Embryos	Oocytes	Somatic Cells (Cryovials)	Whole Blood/ White Blood Cells
Buffalo	Native Bulgarian	16	40	10 ear skin, fibroblasts	119 doses/60 doses
Cattle	Girolando	10	25	7 granulosa cells 10 cumulus cells	(–)
Goat	Native, Anglo-Nubian	(–)	(–)	5 granulosa cells	100 doses

LESSONS LEARNED AND WAY FORWARD

Aside from collecting and maintaining germplasm from different indigenous species and introduced breeds in the country, the PCC-CF will continue to pursue advancements in documenting, promoting, and strengthening linkages and information relative to Philippine livestock breeds, including their cultural heritage and social importance.

Specifically, this objective will be done through the following initiatives:

1. The PCC-CF will increase the number of its collected genetic materials for cryopreservation from different species with genetic diversity. This will include cryopreservation of the representative population of indigenous species and of species with high economic value.

2. The facility will duplicate animal genetic resources and store them in other sites in the Philippines or through international collaboration with other laboratories that facilitate cryobanking.
3. The molecular data will be linked to the geo-tagging models in order to identify the locations of those breeds that possess genetic traits that are resilient to climate change.
4. The PCC-CF will establish genetic screening for diseases and defects of those animal samples that will be stored in the cryobank. This will facilitate proper handling and management of animal genetic resources.
5. More researchers will be capacitated with technical knowledge in cryopreservation techniques and in molecular identification.
6. DNA banks will be established, in tandem with the cryopreservation of animal genetic resources, which will encompass the storage of genomic DNA of various species (large and small ruminants other livestock species to include the poultry, indigenous species, and wild/threatened/endangered species). The genotype profiles of the specimens stored in the PCC-CF will be based on FAO recommendation.
7. The PCC-CF will assist in the establishment of the legal policies, rules, and regulations related to cryobanking activities.

CONCLUSION

Swamp buffaloes (native buffaloes or Philippine carabaos), riverine-type buffaloes, and crossbreeds of native carabaos and Murrah buffaloes are ecologically, socially, and economically important, especially in the Philippines. Through the PCC's program, these animals' genetic traits have been successfully upgraded. Thus, their valuable contribution to the sustainable agriculture and dairy industry makes it worthwhile to preserve their genetic material. Accordingly, this has become the PCC's takeoff point for establishing and enhancing the operationalization of its cryobanking facility for buffaloes and other domesticated animals in order to provide animal genetic resources that would prepare the country to the possible effects of climate change on the animal diversity in the Philippines.

The cryobanking ex-situ conservation is a support tool to the in-situ gene pool conservation. It serves as a source of genetic materials of animals with superior traits that can adapt to the environmental changes caused by the current and predicted climate changes. Cryobanking of animal genetic resource will not only preserve genetic sources from buffaloes, but it will also preserve those from other domesticated animals, as well as the threatened, indigenous species. Therefore, cryobanking will ensure that the genetic diversity of animals in the Philippines will be sustained in the future.

ACKNOWLEDGMENT

The author acknowledges Dr. Arnel N. Del Barrio (PCC Executive Director) for his continuous mentoring on the enhancement of the operationalization and management of cryobanking; and Mr. Jayson O. Villamor (Instructor I, Department of Crop/ Environmental Science, College of Agriculture, Central Luzon State University, Nueva Ecija) for sharing his expertise on environmental science and for helping to put the role of cryobanking in the right perspective of climate change.

REFERENCES

Blackburn, H. 2004. "Development of National Animal Genetic Resources Programs."*Reproduction, Fertility, and Development* 16(2): 27–32.

Fahy, G., and A. Hirsh. 1982. "Prospects for Organ Preservation by Vitrification." In *Organ Preservation, Basic and Applied Aspects* edited by D.E. Pegg, I.A. Jacobsen, and N.A. Halasz, 399–404. Berlin, Germany: Springer.

FAO. 2012. "Cryoconservation of Animal Genetic Resources." *FAO Animal Production and Health Guidelines* No. 12. Rome, Italy: FAO.

Flores, E. 2004. "Breeding for the Carabao of the Future." *PCC Newsletter* 7(2): 11, 2.

Flores, E.B., J.F. Maramba, D.L. Aquino, A.F. Abesamis, A.F Cruz, and L.C. Cruz. 2007. "Evaluation of Milk Production Performance of Dairy Buffaloes Raised in Various Herds of the Philippine Carabao Center." *Italian Journal of Animal Science* 6(2): 295–298.

PCC (Philippine Carabao Center). 2012a. "San Agustin, Isabela Showcases Upgraded Carabaos in 'Nuang Festival'." *PCC Newsletter* 11(3): 5–6.

——. 2012b. "Partnerships that Create Impact in the NIZ." *PCC Newsletter* 11(3): 8.

Mazur, P., and K. Cole. 1985. "Influence of Cell Concentration on The Contribution of Unfrozen Fraction and Salt Concentration to the Survival of Slowly Frozen Human Erythrocytes." *Cryobiology* 22(6): 509–536.

McClintock, S., D. Groeneveld, S. Hiemstra, and H. Blackburn. 2007. "Cryobanking Animal Genetic Resources." Unpublished document.

Orville, B. 2013."Genetic Diversity and Relationship of Domestic Buffalo and Cattle Breeds and Crossbreeds (Subfamily Bovinae) in the Philippines Based on the Cytochrome C Oxidase I (COI) Gene Sequence." *Philippine Agriculture Scientist* 96(1): 93–102.

Sarabia, A.S., and L.C. Cruz. 2008. "Cryobanking of Animal Genetic Resources: The Philippine Experience." Unpublished document.

Shand, H. 2000. "Biological Meltdown: The Loss of Agricultural Biodiversity." Food and Environmental Justice 7(2).

A farmer on his way home
Photo by Erik Pratama

3 Synthesis

Photo by Rita T. dela Cruz
Two men planting rice seedlings in an open, irrigated field in Naga, Camarines Sur, Philippines.

A Way Forward

Percy E. Sajise

Scaling up the good practices in climate change adaptation (CCA) in Southeast Asia to promote sustainable rural development needs to be prioritized by governments and development agencies. This is particularly important now that the global community strives to attain the 2030 Sustainable Development Goals. These goals are also reflected in the ASEAN Vision statement of "an ASEAN Socio-Cultural Community that is inclusive, sustainable, resilient, dynamic, and engages and benefits the people" as well as the ASEAN Vision 2020 of aiming to "achieve a clean and green ASEAN with fully established mechanisms for sustainable development, and ensure that protection of the region's environment and natural resources are sustained as well as the high quality of life for its people" (ASEAN 2011, 2). This has been further reinforced by the Nay Pyi Taw Declaration of 12 November 2014, which aims to promote resilience and the green technology in ASEAN Member States (AMS) (ACCWG 2014).

This vision of a sustainable development for the region can be realized only if CCA strategies and cases on-the-ground can be scaled up by building on the experiences and lessons learned from case stories such as those included in this book. However, scaling up is not easy due to the highly contextual nature of the development and application of various CCA methods, processes, and technologies across many AMS in Southeast Asia.

These case stories of CCA, as applied by several Southeast Asian countries, describe what kinds of methods, approaches, and technologies worked under a particular context. Therefore, these cases are very important as a first step in expanding these good practices. The various contexts of CCA included in this book were defined based on the various hierarchical levels involved and on how they were interconnected with one another, which accordingly led to the CCA at the farm or village levels (Appendix Table 1).

Based on the cases presented, it is also important to highlight the processes involved in identifying and implementing CCA goals and strategies. Common among the various case stories is the use of the 3P strategy: (1) participatory assessment, (2) partnership building, and (3) process-based.

P FOR PARTICIPATORY PROCESS OF ASSESSMENT

This component is crucial when implementing CCA options. This can be done by identifying the most important stakeholders, engaging them into the discussion, and involving them in the participatory process so they can assert their needs and take ownership of the overall process. This process cuts across various hierarchical levels and is common to all case studies in this book. For example, the case stories on CCA at the regional, subregional, country, village, and farm levels indicated the importance of this participatory process. This is clearly illustrated in the Climate Field School in Indonesia; the city-level CCA in Batangas City, Philippines; and in the conservation farming village, community-supported agriculture, and CCA options in the Philippines.

Why is it important to identify your key stakeholder?

This is similar to holding an event: you cannot invite the whole country or region to attend a project. Participation is preceded by the process of stakeholder identification, which works at the community and across all levels.

2P FOR PARTICIPATORY ASSESSMENT AND PARTNERSHIP BUILDING

This undertaking to promote CCA in farming and in a broad-level resource use requires partnership. One way of doing so is by identifying power relationships that can guide stakeholder identification. This, together with other methods, can help in identifying the key partners and key stakeholders in a project. The partnership could be done through the various combinations of government, academe, NGOs, farmer organizations, policy makers, and civil society. At the core (and indispensable component) of this partnerships are farmers (both men and women) or resource users in general.

These 2Ps and its importance in generating an effective CCA were clearly illustrated in the case stories from Thailand, the Philippines, Vietnam, and Indonesia.

Effective assessment tools are also very important, as shown in the case studies at the regional, subregional, country, village, and farm levels. These assessment tools should be included in the "tool kit" of those working in CCA depending on what hierarchical level is involved, which includes the need for connecting one level to another. These tools could range from landscape mapping (light detection and ranging tool and geographic information system), crop and climate modeling, participatory assessment, and effective transfer of information at all levels. Similarly, these have been illustrated in the various case stories on CCA included in this book.

3P FOR PARTICIPATORY ASSESSMENT, PARTNERSHIP BUILDING, AND PROCESS-BASED

Presenting the process involved in the various case studies is important. Further, a cost-benefit analysis will indicate the benefits to be gained if a particular suggested action or method for CCA would be adopted across different hierarchical levels. The ultimate goal is to achieve sustainability in developing an appropriate CCA in a particular context.

The combination of CCA and inclusive and sustainable agricultural and rural development (ISARD) has a wider range of options than climate change mitigation, which also handles biophysical, sociocultural, and economic factors, among others. The ability to cope with climate change through resiliency can be achieved if you have a menu of options from which you can draw alternatives or processes from anytime that you need to adopt. Not one strategy is enough. For example, adaptation as a strategy is not enough on its own because the diversity of agricultural climatic zones can change over time. It is about providing more options in addition to the available strategies.

A key in achieving this is to prioritize human resource capacity building at all levels. This was a common thread in all of the case stories described in this book. ISARD can be achieved if CCA strategies can build a strong element of resiliency in the social, economic, and ecological aspects of the human-ecological system given a particular context. These elements, in general, could be through providing the stakeholders an enabling environment that will help them to develop more options in terms of farming systems that are adaptive to extreme impacts of climate change, safety nets such as linking livelihoods or production systems to cash-base transfers, capacity building at all levels, support to national plans on CCA, securing means of production, and others. In the case studies presented, these enabling environments were in the form of an institutional umbrella (i.e., the Mekong River Commission's Adaptation Strategy and Action Plan [for a region]); financial incentive (i.e., Batangas City Local Government Unit Fund Sourcing); and integrating a planning exercise as a requirement and as created by a law (i.e., cryopreservation of animal genetic resources) in preparation for climate change.

The various case stories in this book indicate that to bring about an effective and sustainable CCA, two things have to be involved following the conclusion of Hilmi (2012) after analyzing agricultural and rural transformations over time. First is to have a very clear understanding of the enabling or constraining environments that bring about CCA. Second is to identify the necessary processes required and the methods to be used in order to develop effective interventions for enhancing or alleviating the elements in the enabling environment. This can be used as effective drivers for developing the necessary CCA at all levels.

REFERENCES

ASEAN. 2011. *ASEAN Socio-Cultural Community Blueprint*. Jakarta: ASEAN Secretariat.

Hilmi, A. 2012. *Agricultural Transition: A Different Logic*. Oslo, Norway: The More and Better Network

ACCWG (ASEAN Coordinating Council Working Group). 2014. *Nay Pyi Taw Declaration of the ASEAN Community's Post 2015 Vision*. Nay Pyi Taw, Myanmar: ACCWG.

APPENDIX

Table 1. Matrix of CCA contexts in ISARD as presented in 13 case stories

SCALE/ HIERARCHICAL LEVEL	TYPE OF CCA INTERVENTION(S)	ECOLOGICAL CONTEXT	SOCIAL CONTEXT	ECONOMIC CONTEXT	OUTCOMES
1.0. HIERARCHICAL LEVEL LINKAGES TO PILOT APPLICATION					
1.1. Regional and Subregional Levels					
Battle of the Crops? Who Will Win and Who Will Lose in the Coliseum of Climate Change *Anton Eitzinger, Peter Läderach, Linh Giang, Ammapet Ramaraj, Kennedy Ng'ang'a, Louis Parker (International Center for Tropical Agriculture)*					
Regional and subregional	Identification of which crops are most vulnerable to progressive climate change	Agriculture occupies vast areas of land in the GMS	Agriculture is the important source of livelihood in the region; more than 70% of the population of Lao PDR and 30% of Thailand's workforce are employed in agriculture	Crops such as coffee, maize, common bean, and potato are important economic commodities and could suffer tangible yield losses due to climate change	Maps of changes in crop suitability that can help policy makers to make more informed decision on which crops are likely to be affected by climate change and where this may occur
Regional and subregional	A snap shot of land-use change occurring at the GMS for the years 2000 and 2012	GMS is an area of vast ecological wealth	Increase in homogeneous tree cover/plantations in the region (15 million ha)	Small holder farmers shifting to rubber production for export	Maps identifying the trends in land-use change and where this might be occurring

Appendix Table 1 (continued)

SCALE/ HIERARCHICAL LEVEL	TYPE OF CCA INTERVENTION(S)	ECOLOGICAL CONTEXT	SOCIAL CONTEXT	ECONOMIC CONTEXT	OUTCOMES
Ensuring Food Security in the Lower Mekong Basin *Nguyen Dinh Cong (Agriculture and Irrigation Program, Mekong River Commission)*					
Regional level with pilot testing at community level	Using holistic approach of CC impact and vulnerability assessment to propose CCA measures and piloting them as follows: (1) improving water efficiency and water management; (2) strengthening resilience in rainfed and irrigated rice-based systems (3) capacity building to enhance farmer's resilience to climate change	Basinwide Flood- and drought-prone areas	Mekong River countries, piloted at representative farming community	80% of the Mekong Basin's population is composed of farmers Food security is one major concern since about 24% of population is below the poverty line	Proposed CCA measures in agriculture to ensure food security 3 CCA activities have been successfully implemented to improve local livelihood Community acceptability and guidelines for the CCA implementation process Improvement of knowledge of farmers and government authorities on risk assessment, CCA identification, and implementation

Appendix Table 1 (continued)

SCALE/ HIERARCHICAL LEVEL	TYPE OF CCA INTERVENTION(S)	ECOLOGICAL CONTEXT	SOCIAL CONTEXT	ECONOMIC CONTEXT	OUTCOMES
1.2. Country Level					
Conservation Agriculture for Climate-Resilient Rainfed Uplands in the Western Regions of Cambodia: Challenges, Opportunities, and Lessons from a 10-Year R&D Program *Kong Rada, Sar Veng, Leng Vira, Trang Sopheak, and Florent Tivet* *(Conservation Agriculture Service Center, Ministry of Agriculture Forestry and Fishery, Cambodia)* *Stephane Boulakia (Centre de Cooperation Internationale en Recherche Agronomique pour le Developpement, CIRAD-Persyst, UR Aïda)* *Lucien Seguy (Agroecoriz)*					
Field/farm/ community	Alternative and diversified CA-based cropping systems design Methodology to couple R&D with higher education	Tropical rainfed upland on oxisol and mollisol Mining approach for short-term economic benefits, to the detriment of fast soil and water resources degradation Substitute to hazardous chemical-based intensification by agro-ecological intensification sustained by organic matter fluxes	Resource-poor smallholders on the edge of poverty traps (debt) with an increasing vulnerability to climate variability (drought, extreme rainfall events)	Economic risk attached to monoculture of annual cash crops (cassava, maize) in fluctuating markets Off-farm activity attraction (assorted with long migration), buffer at short-term but also drawing poor out of agriculture sector on medium-term Soaring mecha-nization	Restore soil quality and its production capacity Increase productivity and profitability while saving more on labor and cost Provide resiliency to buffer CC as well as market change

Appendix Table 1 (continued)

SCALE/ HIERARCHICAL LEVEL	TYPE OF CCA INTERVENTION(S)	ECOLOGICAL CONTEXT	SOCIAL CONTEXT	ECONOMIC CONTEXT	OUTCOMES
Bringing Down Climate Knowledge to Enhance Farmers' Adaptation *Andi Eka Sakya, Widada Sulistya, Nurhayati, Nelly Florida Riama, Novana Sari* *(Indonesia Agency for Meteorology, Climatology, and Geophysics)*					
National	Educating extension workers and farmers through Climate Field School	Determination of appropriate crop varieties to be planted, anticipation of crops diseases and plant pests	Farmer's awareness	Increasing crop productivity	Understanding the climate information for agriculture
LiDAR and GIS Mapping Tool for Climate Change Adaptation of Farmers in Flood-Affected Areas *John Colin E. Yokingco, Perlyn M. Pulhin, and Rodel D. Lasco* *(Oscar M. Lopez Center for Climate Change Adaptation and Disaster Risk Management Foundation Inc.)*					
Municipality/ township (scalable at the national and regional levels)	Use of tools like LIDAR and GIS to recommend adaptation strategies	Lowland flood-prone areas that make use of multiple varieties such as irrigated and hybrid located near the coast	Rice-based farming communities	Declining farm yield and productivity caused by flooding	Current: Maps and methods that can help farmers to better plan and respond to climate risk such as flooding, and maximize the use of appropriate submergence-tolerant rice varieties

Appendix Table 1 (continued)

SCALE/ HIERARCHICAL LEVEL	TYPE OF CCA INTERVENTION(S)	ECOLOGICAL CONTEXT	SOCIAL CONTEXT	ECONOMIC CONTEXT	OUTCOMES
Municipality/ township (scalable at the national and regional levels)	Use of tools like LIDAR and GIS to recommend adaptation strategies	The area's flood problem is mainly caused by surface flooding	Rice-based farming communities	Declining farm yield and productivity caused by flooding	Projected: Re-introduction of submergence-tolerant varieties to be used in affected areas; follow-up studies that will improve and develop rice varieties for better adaptation and resilient farming
Climate Change and Civil Society Planning: The Case of Kularonghai Ecosystems in Northeast Thailand *Vichien Kerdsuk (Research and Development Institute, Khon Kaen University, Thailand)*					
Area-based and community	Use MRB rice to study impact of climate on rice in Kularonghai field	Kularonghai field	Community	Rice yield and income of productivity	Planting time to grow jasmine rice; planting method and management
Community	Risk assessment analysis based on multiple criteria: sensitivity, exposure, and coping capacity to climate impact criteria as frame of analysis	Kularonghai field	Farm household	Household economic	77% of households are vulnerable to extreme climate events

Appendix Table 1 (continued)

SCALE/ HIERARCHICAL LEVEL	TYPE OF CCA INTERVENTION(S)	ECOLOGICAL CONTEXT	SOCIAL CONTEXT	ECONOMIC CONTEXT	OUTCOMES
Climate Change and Civil Society Planning: The Case of Kularonghai Ecosystems, Northeast Thailand *Vichien Kerdsuk (Research and Development Institute, Khon Kaen University, Thailand)*					
Farm	Surveying and interviewing farmer by using questionnaire	Farmland	Profile of current farmer adaptation strategy	Household economic	Suggested adaptation to cope with future condition aim to increase or extend the current strategies Early warning system on climate variability, which may be implemented by the government, to help farmers to plan in order to cope better with climate impact
Community	Participatory action research and scientific information		Community plan includes CCA	Investment to resilience and robust community	CCA should include in strategic plan at the community level

Appendix Table 1 (continued)

SCALE/ HIERARCHICAL LEVEL	TYPE OF CCA INTERVENTION(S)	ECOLOGICAL CONTEXT	SOCIAL CONTEXT	ECONOMIC CONTEXT	OUTCOMES
Participatory Approach as a Way of Influencing Farmers' Capacity to Adapt to Climate Change: The Cordillera Experience *Nicasio S. Baucas (Cordillera Administrative Region, Regional Field Office, Department of Agriculture, Philippines)*					
Village (scalable at the municipal level)	Use of multi-criteria analysis tool to come up with appropriate analysis and recommendation for a GP-CCA option subjected for field trial	Ecosystem involving high, medium, and low elevations	Farming communities	Crop yield vs adaptation option tested	Vulnerability maps of the community using their observed CC risks FGDs with the farmers
Multi-stakeholder Prioritization Approach for Climate-Smart Agriculture Planning and Investment in Vietnam *Caitlin Corner-Dolloff, Andreea Cristina Nowak, Miguel Lizarazo, and Louis Parker (International Center for Tropical Agriculture)* *Mai Van Trinh (Institute for Agricultural Environment, Vietnam Academy of Agricultural Sciences)* *Tran Dai Nghia (Institute of Policy and Strategy for Agriculture and Rural Development, Ministry of Agriculture and Rural Development)*					
Regional and subregional National and subnational	Identification of which CSA practices are available at different range of scales	CSA practices can improve the ecological environment through conservation agricultural practices	CC threatens the continued production without strategic adaptation	Impacts of CC poses very real threats to small-scale producer livelihoods	List of CSA practices with the potential costs and benefits of application in order to help policy makers and stakeholders better respond to CC

Appendix Table 1 (continued)

SCALE/ HIERARCHICAL LEVEL	TYPE OF CCA INTERVENTION(S)	ECOLOGICAL CONTEXT	SOCIAL CONTEXT	ECONOMIC CONTEXT	OUTCOMES
Multi-stakeholder Prioritization Approaches for Climate-Smart Agriculture Planning and Investment in Vietnam *Caitlin Corner-Dolloff, Andreea Cristina Nowak, Miguel Lizarazo, and Louis Parker (International Center for Tropical Agriculture)* *Mai Van Trinh (Institute for Agricultural Environment, Vietnam Academy of Agricultural Sciences)* *Tran Dai Nghia (Institute of Policy and Strategy for Agriculture and Rural Development, Ministry of Agriculture and Rural Development)*					
Regional and subregional	Visualization of hotspots of climate vulnerability based on biophysical and socioeconomic data	CC affects different regions and threatens many habitats	A need exists to understand which communities are most threatened by climate change	The impacts of CC at a national scale need to be quantified spatially	Maps at a fine resolution that identify climate vulnerability with economic costs incurred in order to help policy makers prioritize projects and investments
Subnational	Climate-smart villages for piloting of CSA practices	Need for CSA to improve natural ecosystems	Participatory approach to information generation to ensure farmers' needs are met	Increase resilience to CC through increased diversification	Identify which CSA practices can help farmers increase resilience to climate change

Appendix Table 1 (continued)

SCALE/ HIERARCHICAL LEVEL	TYPE OF CCA INTERVENTION(S)	ECOLOGICAL CONTEXT	SOCIAL CONTEXT	ECONOMIC CONTEXT	OUTCOMES
1.3. City Level					
How a City Gears for Climate Change Adaptation: The Case of Batangas City, Philippines *Marisa J. Sobremisana, Decibel F. Eslava, Ma. Victoria O. Espaldon, Leonardo M. Florece, Alma Lorelei Abejero, Antonio J. Alcantara, Sofia A. Alaira (School of Environmental Science and Management, University of the Philippines Los Baños)* *Oliver Gonzales (Office of the City Mayor, Batangas City, Philippines)* *Luningning R. Morales (Provincial Environment and Natural Resources Office, Batangas City, Philippines)*					
City government to watershed	Crafting and implementation of E-Code with CCA provisions Updating of the state of the environment as input to flood and storm surge models Decision option for pollution prevention technology and site waste management plan Technology improvement such as biogas digester	River ecosystem Urban-rural ecosystem (terrestrial and hydro-ecological)	Urban-urban health, sanitation, and vulnerability	Livelihood, jobs, internal revenue	Technology innovation for biogas digesters, Localized flood and storm surge models and maps Protocol to come-up with DRRM plans

Appendix Table 1 (continued)

SCALE/ HIERARCHICAL LEVEL	TYPE OF CCA INTERVENTION(S)	ECOLOGICAL CONTEXT	SOCIAL CONTEXT	ECONOMIC CONTEXT	OUTCOMES
2.0. FARM LEVEL					
Climate Change Adaptation and Upland Development through Conservation Farming Village *Rex Victor O. Cruz, Wilfredo M. Carandang, Vida Q. Carandang, Dixon T. Gevaña, and Genevieve A. Galapia* *(College of Forestry and Natural Resources, University of the Philippines Los Baños)* *Catherine C. de Luna (Interdisciplinary Studies Center for Integrated Natural Resources and Environment Management, University of the Philippines Los Baños)*					
Provincial (Philippines)	Sustainable and climate-smart management of upland areas	Upland areas suffering from soil erosion that exceeds the tolerable soil loss of 10 t/ha	Upland farming communities have annual per capita income below the poverty threshold level	Farm yield and productivity through crop diversification	Increased household income Increased productivity Reduced soil erosion
How Filipino Farmers Cope with Climate Change through Conservation Agriculture with Trees *Agustin R. Mercado, Jr. and Rodel D. Lasco (World Agroforestry Centre)* *Manuel R. Reyes (North Carolina Agricultural and Technical State University)*					
Farm	Integrated agricultural production systems (integration of trees, crops, livestock and fishery) in upland farming system	Sloping lands, uplands, non-irrigated farmlands	Farming households	Smallholders with low agricultural cash flow	Trees provide ecological benefits to crops and livestock by controlling water runoff and soil erosion, and by enhancing biodiversity and carbon sequestration Increased income and food security

Appendix Table 1 (continued)

SCALE/ HIERARCHICAL LEVEL	TYPE OF CCA INTERVENTION(S)	ECOLOGICAL CONTEXT	SOCIAL CONTEXT	ECONOMIC CONTEXT	OUTCOMES
How Filipino Farmers Cope with Climate Change through Conservation Agriculture with Trees *Agustin R. Mercado, Jr. and Rodel D. Lasco (World Agroforestry Centre)* *Manuel R. Reyes (North Carolina Agricultural and Technical State University)*					
Community	Watershed management	Sloping lands, uplands, non-irrigated farmlands	Farming households Village and municipal leaders	Smallholders with low agricultural cash flow	Good water quality Reduced siltation of downstream communities Source of employment Quality livelihoods and landscapes
Diversity and Resilience in the Context of Climate Change Resilience: The Case of Invasive Pest of Cassava *Kris A.G. Wyckhuys (International Center for Tropical Agriculture)*					
Regional and subregional	Visualization of geographical distribution and local incidence of climate-induced pests and diseases of cassava	Cassava crops affected by a number of invasive pests and emerging diseases that thrive under CC conditions (i.e., prolonged drought and higher temperatures)	Small-scale farmers in rural settings of the GMS	Pests and diseases bring about substantial yield losses, and affect sustainability of rural livelihoods and cassava-based industries	Distribution maps that visualize pest or disease hotspots to indicate priority sites to test (or implement) adaptive management tactics

Appendix Table 1 (continued)

SCALE/ HIERARCHICAL LEVEL	TYPE OF CCA INTERVENTION(S)	ECOLOGICAL CONTEXT	SOCIAL CONTEXT	ECONOMIC CONTEXT	OUTCOMES
Diversity and Resilience in the Context of Climate Change Resilience: The Case of Invasive Pest of Cassava *Kris A.G. Wyckhuys (International Center for Tropical Agriculture)*					
Regional and subregional	Novel ICT-based farmer training modules to deliver locally validated adaptation strategies to SEA cassava growers	Severe outbreaks of climate-induced pests and diseases, triggering irrational use of (chemically synthesized) pesticides	Resource-poor smallholders in (often) remote settings	Important yield and productivity losses due to climate-induced (invasive) pests and diseases that affect farmer incomes	Farmer-to-farmer educational videos deliver key concepts and tools to local cassava growers, thus boosting their ability to tackle emerging pests and diseases (and safeguard yields)
Regional and subregional	Improved fertilization strategies and crop diversification tactics to prevent (and control) outbreaks of deleterious pests and diseases	Cassava crops largely grown under monocrop arrangements, with improper fertilization and complete abandon of crop rotation	Small-scale cassava growers, with limited access to information and inputs	Yield losses due to climate-triggered pests and diseases are exacerbated when cassava is grown under improper fertilization or crop management schemes	Guidelines on crop management interventions; diversification schemes and fertilization regimes prevent the proliferation of pests and diseases, thus sustaining local cassava yields

Appendix Table 1 (continued)

SCALE/ HIERARCHICAL LEVEL	TYPE OF CCA INTERVENTION(S)	ECOLOGICAL CONTEXT	SOCIAL CONTEXT	ECONOMIC CONTEXT	OUTCOMES
3.0. SPECIAL CASE					
Conserving Animal Genetic Diversity to Adapt to Climate Change in the Philippines *Lilian P. Villamor (Philippine Carabao Center, Philippine Department of Agriculture)*					
Municipality (regional to national level)	Cryobanking of genetic resources from livestock and related species	Preservation of animal genetic diversity	Village-based farmers on livestock	Farmers for dairy and milk products Training on village-based artificial insemination	Live birth of calves for future climate change adaptation
Municipality (regional to national level)	Cryobanking of genetic resources from indigenous species	Preservation of animal genetic diversity	Village-based farmers on livestock Village-based artificial insemination technician	Improving livelihood of farmers who utilize more resilient animals against diseases such as heat stress Additional source of food	Live birth of calves for future as a CCA tool Preservation of genetic materials from native animals that are linked to Filipinos' cultural and social heritage CC preparedness

Note: CA = conservation agriculture; CC = climate change; CCA = climate change adaptation; CSA = climate-smart agriculture; DRRM = disaster risk and reduction management; E-Code = Environmental Code; FGD = focus group discussion; GIS = geographic information system; GMS = Greater Mekong Subregion; GP = good practices; GP-CCA = good-practice climate change adaptation; ICT = information and communication technology; ISARD = inclusive sustainable agricultural and rural development; LiDAR = light detection and ranging; MRB = Mexican rice borer; SEA = Southeast Asia; UPLB = University of the Philippines Los Baños

Editorial Staff

Adviser
Gil C. Saguiguit, Jr.

Managing Editor
Mariliza V. Ticsay

Book Developer
Kalikasan C. Cuevas

Cover Design
Mark Vincent P. Aranas

Production Assistants
Avril dG. Madrid
Arlene A. Nadres

For more information
about SEARCA publications,
please contact

Knowledge Resources Unit
Knowledge Management Department
SEARCA
College, Los Baños, Laguna, Philippines
Tel. Nos. (63-2) 657-1300 to 09
(63-49) 536-2290, 554-9330 to 39,
(63-49) 536-2365 to 67 local 3201
Fax: (63-49) 536-7097 (Attention: KRU)
Email: publications@searca.org
or visit www.searca.org