# Swiss Foreign Aid Shaping Agricultural Development in Southeast Asia: Adoption and Diffusion of Agricultural Best Management Practices through the CORIGAP Project in China, Myanmar, and Vietnam

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## Executive Summary

**Background.** In Southeast Asia, rice is the staple food crop. It is predominantly cultivated by smallholder farmers. Although the Green Revolution has modernized rice agriculture considerably, farmers today face the consequences of decades-long unsustainable natural resource use. Environmental degradation has become prevalent and climate change is exacerbating the current challenges. In this context, the diffusion of agricultural best management practices and technologies is crucial for ensuring rural livelihoods and global food security. Therefore, the 'Closing Rice Yield Gaps in Asia with Reduced Environmental Footprint' (CORIGAP) project funded by the Swiss Agency for Development and Cooperation (SDC) aims to improve rice farmers' productivity and profitability in six Southeast Asian countries by disseminating sustainable agriculture practices and technologies.

**Objectives.** The central purpose of this thesis was to analyze the effect of the CORIGAP project on rice farmers' yields and livelihoods due to the introduction of sustainable best management practices and technologies. Three main research objectives were investigated: 1) the effect of the CORIGAP project on farmers' socioeconomic and agronomic situation, 2) farmers' adoption behavior of the CORIGAP recommended practices and technologies, and 3) farmers' perceptions of the practices and technologies, including economic, social, and environmental changes, since the adoption thereof. Three project countries were selected: China, Myanmar, and Vietnam.

**Research methods and data.** The impact of the CORIGAP project in the study regions was examined individually based on country-specific development objectives and diffusion strategies. An exploratory research approach was employed and a comprehensive methodology using quantitative methods was applied. Data for the empirical country analyses were collected by means of farmer questionnaire surveys using a digital questionnaire application. For the agronomic data, a household survey was conducted once before and once after the CORIGAP interventions. For the perception data, a farmer perception survey was conducted once after the introduction of the recommended practices and technologies. Data were analyzed using uni- and multivariate statistics, including Pearson correlations, t-test with Cohen's d effect size, ANOVA, Cronbach's α reliability test, exploratory and confirmatory factor analyses, hierarchical linear regression analysis, and structural equation modeling (SEM).

**Main findings.** Farmers perceived notable positive changes to their livelihoods and living conditions due to the adoption of the CORIGAP-recommended practices and technologies. In the selected study regions, rice yields and incomes rose significantly. Farmers in China perceived an average yield growth of 1.1 t/ha, attaining a mean of 6.5 t/ha, and an input cost reduction of 57.5 % since adopting the 'Three Controls' Technology (3CT). Vietnamese farmers, who participated in the national policy program 'One Must Do, Five Reductions' (1M5R), increased mean yields considerably to 6.6 t/ha and reduced input costs, particularly for seeds, NPK fertilizer, and pesticides. In Myanmar, farmers experienced an average production growth of 0.6 t/ha, achieving a yield of 3.6 t/ha due to improved input and labor use. Mean rice incomes doubled to 548.0 USD/ha after five years. The results of the perception surveys demonstrated a high rate of adoption and willingness to continue using the recommended practices and technologies. The benefits "easy to apply", "satisfies my preferences", and "fits my cropping pattern" were generally rated the highest. Furthermore, farmers expressed positive changes to their human and social capital, health, and food security. Nevertheless, environmental changes were not much perceived by farmers.

**Conclusions.** The CORIGAP project was successful in incentivizing farmers to adopt sustainable rice farming practices and technologies long-term. The project objectives were achieved and supported the transition to more eco-friendly rice cultivation in Southeast Asia. This is particularly relevant for the environment as it needs more time to regenerate. In this regard, the main recommendation of this study is to continue improving and expanding extension services for climate-smart farming. As of 2021, more than 750'000 farmers in Southeast Asia were reached through the project. However, this research only investigated 987 farmers in detail. Therefore, it is not possible to pertain to other farmers. Nonetheless, a considerable achievement has been achieved through Swiss foreign aid. The lessons learned during the CORIGAP project foster South-South cooperation and serve as a blueprint for successful long-term development assistance incorporating beneficiaries' perspectives.

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## List of Acronyms

| | |
|---|---|
| 1M5R | One Must Do, Five Reductions |
| 3CT | Three Controls Technology |
| 3R3G | Three Reductions, Three Gains |
| AASA | The Association of Academies of Sciences in Asia |
| ASEAN | Association of Southeast Asian Nations |
| AWD | Alternate Wetting and Drying |
| CAI | Computer-assisted interviewing |
| CAPI | Computer-assisted personalized interviewing |
| CFI | Comparative Fit Index |
| CGIAR | Consortium of International Agricultural Research Centers |
| CHF | Swiss Franc |
| CNY | Chinese Yuan (Renminbi) |
| CORIGAP | Closing Rice Yield Gaps in Asia with Reduced Environmental Footprint |
| DARD | Department of Agriculture and Rural Development Vietnam |
| FAO | Food and Agriculture Organization of the United Nations |
| FDFA | Swiss Federal Department of Foreign Affairs |
| GDP | Gross domestic product |
| GDRRI | Rice Research Institute of the Guangdong Academy of Agricultural Sciences |
| GHG | Greenhouse gas |
| GNI | Gross national income |
| GRiSP | Global Rice Science Partnership |
| HYV | High-yielding variety |
| IPM | Integrated pest management |
| IRRC | International Rice Research Consortium |
| IRRI | International Rice Research Institute |
| MMK | Myanmar Kyat |
| MRC | Mekong River Commission |
| NARES | National agricultural research and extension systems |
| NGO | Non-governmental organizations |
| NPK | Nitrogen-Phosphorus-Potassium |
| ODA | Official development assistance |
| OECD | Organisation for Economic Co-operation and Development |
| PAPI | Paper-and-pencil interviewing |
| RMSEA | Root mean square error of approximation |
| SD | Standard deviation |
| SDC | Swiss Agency for Development and Cooperation |
| SDGs | United Nations Sustainable Development Goals |
| Seco | Swiss State Secretariat for Economic Affairs |
| SEM | Structural Equation Modelling |
| SFLF | Small Farmers, Large Field |
| SSNM | Site-specific nutrient management |
| TFP | Total Factor Productivity |
| USDA | United States Department of Agriculture |
| UN | United Nations |
| UNDP | United Nations Development Programme |
| UNESCO | United Nations Educational, Scientific and Cultural Organization |
| USD | United States Dollar |
| VND | Vietnamese Dong |
| VnSAT | Vietnam Sustainable Agricultural Transformation Project |

# Part I

# Introduction and Theoretical Background

## Published work

The present chapters 2, 3, and 4 are based on the following published book chapters.

**Wehmeyer H.**, Singleton G. R., Connor M. (2023): Introduction—How Swiss Foreign Aid for International Development Benefits Agricultural Development Across Asia. In: Connor M., Gummert M., Singleton G. R. (eds.): Closing Rice Yield Gaps in Asia – Innovations, Scaling, and Policies for Environmentally Sustainable Lowland Rice Production. Cham, Switzerland: Springer, p. 1-26. https://doi.org/10.1007/978-3-031-37947-5_1

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# 1 Introduction

The main objectives of Switzerland's foreign aid are ending poverty and promoting peace for sustainable development. The central implementing entity is the Swiss Agency for Development and Cooperation (SDC) (Federal Department of Foreign Affairs (FDFA) 2017; SDC 2019a). Around 30 % of the SDC's budget is directed towards Asia, with an emphasis on South and Southeast Asia. Technical cooperation for sustainable development in agriculture and climate change adaptation strategies are set as the key responsibilities (SDC 2019b, 2020a; b). Southeast Asia has become a major agricultural producer in the world in recent decades. In particular, its rice exports have become essential for today's global food security (De Koninck, Rousseau 2013: 139–140; Organisation for Economic Co-operation and Development (OECD), Food and Agriculture Organization of the United Nations (FAO) 2017: 73–74). Due to the Green Revolution in the second half of the 20th century, the region has experienced a remarkable agricultural evolution that also advanced general economic development (Hazell 2009: 1). However, the negative effects of fast agricultural and economic growth materialize in environmental degradation, lingering food insecurity, increased disparities, and marginalized peripheral regions (Pingali 2012: 12303). Rice farmers often use excessive amounts of agricultural inputs, such as fertilizers, pesticides, seeds, and water. Thus, they have a particularly large environmental footprint because their intensive farming practices affect the global environment due to unsustainable natural resource use (Čuček, Klemeš, Kravanja 2015: 131–132; OEDC and FAO 2017: 82,89-90). Consequently, rice farming is greatly responsible for environmental degradation and the evolution of climate change. It plays a significant role in emitting greenhouse gases (GHG) such as methane and nitrous oxide. This poses a threat to human health, biodiversity, and global food security (Redfern, Azzu, Binamira 2012: 296–301).

In this regard, the SDC-funded 'Closing Rice Yield Gaps in Asia with Reduced Environmental Footprint' (CORIGAP) project aims to improve rice farmers' livelihoods by promoting sustainable agriculture practices in six South and Southeast Asian countries (SDC 2020c). It focuses on reducing yield gaps and optimizing the productivity of lowland-intensive rice cultivation to diminish farmers' environmental footprint. The two main targets are to increase farmers' rice yields by 10 % and to improve their profitability by 20 % until the end of the project in 2022. The project utilizes adoption-diffusion strategies adapted for each country in collaboration with country officials, regional leaders, and other development projects (International Rice Research Institute (IRRI) 2017a: 2-4,16). The adoption and diffusion of new farming practices and technologies have become integral elements for improving farming systems. A high rate of technological change is recognized as a critical feature for resource optimization and agricultural efficiency improvement (Zilberman 2008: 1). Therefore, innovation diffusion is considered to be an essential factor for accelerating economic growth and development overall (Dearing 2009: 1; Kaur, Kaur 2010: 289).

## 1.1 Research Objectives

This study concentrates on the evaluation of the CORIGAP project in three project study regions China, Myanmar, and Vietnam. It assesses the interrelationship between rice farmers' socioeconomic and agronomic factors and the adoption of sustainable best management practices and technologies. It aims to understand:

**1. The effect of the CORIGAP project on farmers' agronomic and socioeconomic performance indicators for livelihood development.**

**2. Farmers' adoption behavior of agricultural best management practices and technologies recommended by the CORIGAP project.**

**3. Farmers' perceptions of the recommended agricultural best management practices and technologies, including perceived economic, social, and environmental changes since the adoption thereof.**

This thesis is designed as an explorative study. An evaluation of the CORIGAP project in Guangdong Province, China, Bago Region, Myanmar, and in the provinces of An Giang and Can Tho, Vietnam, is performed utilizing data from the selected study areas. The country-specific innovation diffusion strategies and the resulting impact on farmers' economic, social, and environmental conditions in the chosen study regions are investigated. The selected regions represent different types of agricultural practices and technology applications as well as diverse social, cultural, historical, and ecological circumstances. Hence, a multifactorial analysis including socio-cultural-political, geographical-environmental, and social-behavioral aspects is conducted. Ultimately, a comprehensive picture of farmers' livelihood development, as well as technology adoption behavior and perceptions due to the implementation of different innovation diffusion strategies, is outlined.

The following research design schematic illustrates the conceptual approach from the theoretical background, the CORIGAP project as a case study, and the relevance to the research objectives. The three subsequent country analyses evaluate different best management practices and technology policy programs promoted through the CORIGAP project. They serve as the empirical research component of this thesis to exemplify the effect of an SCD-funded agricultural development project in Southeast Asia. For each project country, a specific rationale is delineated. Different datasets per country are available and the applied data analysis methods are adapted to each country assessment. The synthesis of this research demonstrates the implications of the CORIGAP project on rice farmers in Southeast Asia. It discusses opportunities for continuing Switzerland's efforts to advance sustainable agricultural development (Figure 1.1).

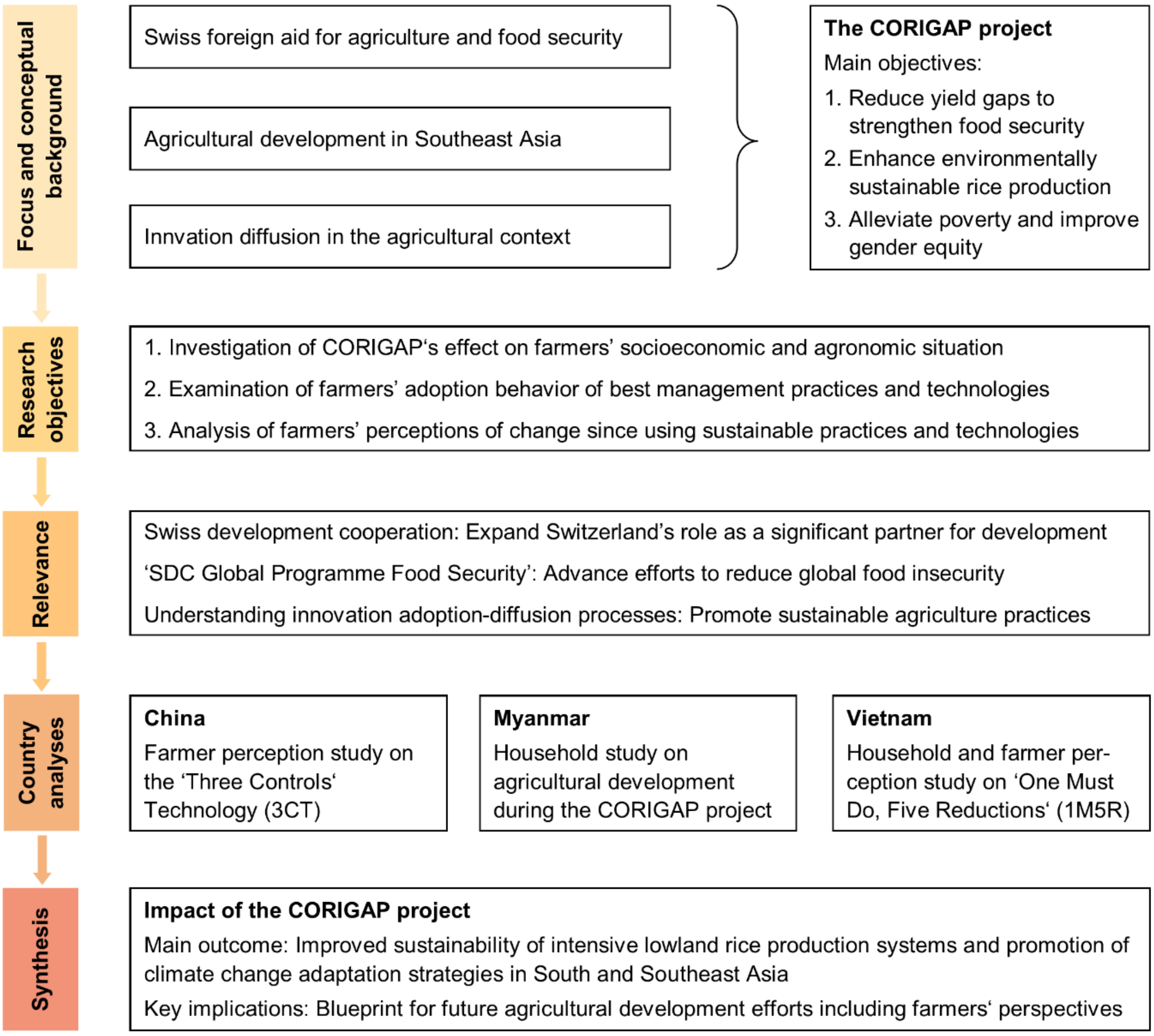



Figure 1.1 Research design schematic
Concept: H. Wehmeyer (2021)

## 1.2 Relevance

This thesis contributes in various ways to current research on validating Switzerland's efforts for sustainable agriculture for advancing rural development and improving global food security.

**Relevance for Switzerland's development cooperation.** The Swiss government has been actively involved in international development assistance for more than 60 years. Its budget has risen considerably over the decades. In the 1960s, official development assistance would go from CHF 60 million for the period 1961-1963 to an annual budget of CHF 130 million by the end of the decade (Holenstein 2010: 51; Waldburger, Scheidegger, Zürcher 2012: 48). Today, the Swiss government's contribution to global development efforts is one of the highest in the world. Globally, Switzerland ranks 8th place in absolute numbers for development cooperation expenditures and 11th regarding its official development assistance (ODA) to gross national income (GNI) ratio. Nevertheless, the ODA to GNI ratio remains under the UN target of 0.7 % at 0.44 %. (SDC 2020d). Switzerland's ODA has risen from CHF 2.4 billion in 2010 to CHF 3.3 billion in 2020, of which the SDC received CHF 2.3 billion. Development cooperation led by the SDC and the State Secretariat for Economic Affairs (Seco) accounts for almost 80 % of Switzerland's budget for ODA (SDC 2021a). In this regard, the Swiss development activities directly impact international foreign aid strategies and have significant implications for advancing sustainable development worldwide.

Overall, Switzerland's contributions to development aid have had a sizeable effect in many parts of the world and demonstrated long-term and beneficial change. For example, in the early 1960s, the first bilateral projects were established in Nepal and India with a clear emphasis on agricultural development and industrial production (Jäger, Stricker 2007: 16,30; Waldburger, Scheidegger, Zürcher 2012: 53–57; SDC 2017a). Until today, Switzerland remains actively involved in the region and beyond. Across its priority regions and countries, its efforts aim to create jobs locally and improve economic development, find innovative solutions to reduce poverty, and address migration challenges and climate change mitigation strategically (FDFA 2020: 27). In this respect, Switzerland's role as a reliable partner for international development will remain strong and necessary to advance sustainability efforts through bilateral and multilateral collaborations. In particular, this is achieved by the SDC's 'Global Programmes'. Through these, Switzerland addresses five global challenges, namely, climate change, food security, water management, health, and migration (SDC 2021b). Thereby, the country actively engages in largescale, worldwide advancements for achieving the Sustainable Development Goals (SDGs) by 2030.

**Relevance for 'SDC Global Programme Food Security'.** The SDC's current strategy considers planetary health and global environmental sustainability crucial for Switzerland's long-term prosperity. A profound transformation of the global food systems is necessary. Therefore, the SDC concentrates on enhancing global governance and agroecological food production, improving inclusive agricultural and food market systems, and promoting sustainable and healthy diets for improved nutrition (SDC 2020g: 4–6). This thesis is embedded in these strategic objectives and contributes a further element for evaluating Switzerland's efforts for improved food security in the world. Regarding the geographic focus, the SDC emphasizes that Asia is a critical region for expanding its long-term food security program strategy. The continent has become a significant producer of staple food crops such as rice. Asia is a net rice exporting region accounting for 70 % of the world's rice exports (FAO 2014: 5). In particular, South and Southeast Asian countries are considerable contributors to local, regional, and global food security. In particular, Africa's food security highly depends on Asia's ability to maintain its agricultural exports, especially rice (FAO 2014: 5). Hence, the policy implications for improving sustainable agricultural development in Asia can have a considerable regional and worldwide influence. The SDC-funded CORIGAP project addresses these issues and is, therefore, an important element to accomplish the objectives of the 'Global Programme Food Security'.

**Relevance of understanding innovation adoption-diffusion processes.** A large body of research has been dedicated to studying and improving the diffusion of innovations for agricultural development. A farmer's decision to either adopt or reject the technology is the most critical stage during the adoption-diffusion process. Hence, concentrating on the aspects influencing farmers' decision-making process is essential for long-term adoption (Rogers 2003: 179; Ugochukwu, Phillips 2018: 364). In this respect, improving farmers' willingness to adopt an innovation is at the center of the CORIGAP project's approach. Understanding farmers' motivations and barriers to the adoption of innovations determines the success of the CORIGAP project even after its completion. It will only be successful if farmers perceive the recommended practices and technologies to suit their personal needs, benefit their rice production, and fit their lifestyle. Therefore, the project utilizes an adaptive research methodology that includes farmers' and stakeholders' feedback on the innovation diffusion strategy and the recommended practices and technologies (IRRI 2017a: 2–3; Tuan, Wehmeyer, Connor 2021; Flor et al. 2021). Participatory methods enhance farmers' active involvement in development projects and acknowledge their role as a key player in driving innovation diffusion (Flor et al. 2016: 166). In addition, the CORIGAP project supports the expansion and upgrading of extension services and is also involved in policy developments to improve regional and national dissemination efforts (IRRI 2017a: 4). This is an important element for achieving wide-ranging and beneficial implications on multiple aspects related to sustainable development. Farmers' practices influence economic, social, and environmental factors and can have far-reaching consequences. Thus, an effective policy environment for extension services is necessary to successfully promote sustainable practices and technologies. In this context, this thesis not only contributes to the research on the CORIGAP project and Swiss development efforts. It also adds a relevant element to adoption-diffusion literature in general and establishes valuable insights on the drivers that incentivize farmers to improve their farming methods.

## 1.3 Methodological Approach and Data

Due to the use of adaptive research methodologies within the framework of the CORIGAP project, an exploratory research approach is applied to this thesis. A comprehensive methodology including quantitative methods used in different social sciences is employed to investigate the impact of the CORIGAP project. Hence, the empirical research model is designed as a multidisciplinary study. For the country analyses, farmer questionnaire surveys were selected as the primary method for data collection. Data were gathered using two questionnaire survey designs and collected by means of farmer interviews with a digital survey questionnaire application. The first survey was a household survey. It was conducted twice, once before the first CORIGAP interventions and once after. The household survey was performed in Myanmar in 2012 and 2017 as well as in Vietnam in 2015 and 2019. The survey questionnaire consisted of five sections, including sociodemographic questions, farm characteristics and cropping pattern, farmers' rice production quantities and sale, farming practices and input quantities, as well as harvest and postharvest activities. The second survey design used for this thesis was the perception survey conducted once after introducing CORIGAP recommended best management practices and technologies. The perception survey was performed in China and Vietnam in 2019. The perception survey questionnaire included four main sections: sociodemographic information, best management practice and technology adoption behavior, perceived changes since adopting recommended best management practices and technologies, and dimensions of change, including social, economic, and environmental changes. The household and perception survey questionnaires were translated into country-specific languages and adapted to the regional and cultural context. The sampling of the farmers was performed individually for each country and survey. Thus, the number of survey participants differs between the countries and surveys. Finally, data are analyzed utilizing uni- and multivariate statistics in Microsoft Excel and IBM SPSS. In addition, statistical modeling employing structural equation modeling (SEM) is conducted in IBM AMOS.

## 1.4 Structure of the Thesis

This thesis contains four main parts. First, the introduction and the theoretical background are outlined. In the second part, the CORIGAP case study and methodological approach are described. The three CORIGAP country analyses, namely China, Myanmar, and Vietnam, are presented in the third part. In section four, the synthesis in part four illustrates the most important findings and implications of the research.

**Part I – Introduction and Theoretical Background**
Following the introduction (**Chapter 1**), the historical background of Swiss foreign aid and its current priorities for agricultural development are presented in **Chapter 2**. **Chapter 3** focuses on agricultural development in Southeast Asia and the effects of the Green Revolution. It also discusses the prospects and current challenges for further agricultural development in the region. **Chapter 4** gives an overview of innovation diffusion theories and reviews the relevance of geographic elements in technology dissemination. Furthermore, innovation diffusion in agricultural development centering around models applied in Southeast Asia are described.

**Part II – Case Study and Methodological Approach**
In **Chapter 5**, the CORIGAP project and its objectives are presented. This chapter forms the conceptual background of this thesis and describes the context for the subsequent country analyses. **Chapter 6** describes the methodological approach, including the research rationale and its operationalization through the research questions. It illustrates the empirical research model using a multidisciplinary approach. This is followed by the description of the sample selection as well as the data collection approach. Finally, the questionnaires and resulting datasets are described.

**Part III – Country Analyses**
**Chapter 7** and **Chapter 8** center around rice farming in South China and the CORIGAP activities regarding the 'Three Controls' Technology (3CT) in Guangdong Province. Chapter 7 describes fertilizer consumption in rice farming in China and explains the development as well as diffusion strategy of 3CT. This chapter serves as the conceptual background for Chapter 8, in which the China CORIGAP study on farmers' adoption behavior and perceptions of 3CT is presented. **Chapter 9** and **Chapter 10** focus on the development of the rice sector in Myanmar and the introduction of the CORIGAP best management practices and technologies. Chapter 9 describes Myanmar's transformation of the rice sector as well as current constraints and opportunities for development, specifically rural development. In Chapter 10, the Myanmar study based on the household survey data is presented. It discusses the evolution of farmers' rice production from the first phase of the CORIGAP project to its second phase. **Chapter 11, Chapter 12,** and **Chapter 13** concentrate on Vietnam and the development of its rice sector as well as current challenges related to climate change. Chapter 11 serves as a background chapter and gives an overview of Vietnam's rise to becoming a global rice producer and exporter. Nevertheless, this chapter also highlights the challenges rice farmers in the Mekong River Delta are facing today. In this regard, Chapter 12 includes the study based on the household survey data. It aims to analyze how farmers' socioeconomic and agronomic situation has changed under the CORIGAP activities promoting 'One Must Do, Five Reductions' (1M5R) practices and technologies. Lastly, in Chapter 13, the Vietnam study on farmers' perceptions of specific 1M5R technologies is presented with the objective to examine the various changes to their farming practices and living conditions since adoption.

**Part IV – Synthesis**
The main findings are summarized in **Chapter 14**. This chapter presents the synthesis and consolidates the most important results. Suggestions for further development projects centering around the diffusion of sustainable agriculture practices and technologies are given. Additionally, the weaknesses and limitations of this research are discussed. The chapter ends with concluding remarks on the overall impact of the CORIGAP project and Switzerland's role in successfully advancing sustainable agricultural development.

# 2 Swiss Foreign Aid for International Development

In this chapter, Switzerland's history of development assistance and its foreign aid objectives are presented. This is followed by a description of Switzerland's current development cooperation strategy and priorities for the upcoming decade. Finally, the SDC's efforts towards agricultural development in the Global South and specifically in Southeast Asia are introduced.

## 2.1 Historical Overview of Swiss Development Assistance

Since its beginnings in development assistance, Switzerland has remained focused on fighting poverty and providing humanitarian aid. It has been promoting peace and equality under the dictum of neutrality and solidarity. Its main objective has been to position Switzerland at the center of international policy efforts as a reliable partner for bilateral and multilateral cooperation (Waldburger, Scheidegger, Zürcher 2012: 15). Swiss development cooperation started in the 1950s concurrently with global efforts targeting the reduction of poverty and boosting economic development (Holenstein 2010: 49–51; Waldburger, Scheidegger, Zürcher 2012: 48–49). Until the end of the 1950s, development assistance had played a relatively minor role in Swiss foreign policy. The private sector was a much more significant contributor to development aid. In 1960, the Swiss Federal Council established the 'Service for Technical Cooperation' (Dienst für technische Zusammenarbeit). This introduced a new phase to Switzerland's foreign aid efforts and provided fixed financial resources (Rist 2009: 1–2; Holenstein 2010: 49–51; Waldburger, Scheidegger, Zürcher 2012: 48–49). Official development assistance concentrated on technical assistance, infrastructure development as well as humanitarian and refugee aid. First bilateral projects were launched in Nepal and India. These focused on agricultural development and industrial production. For example, cheese dairies in mountainous Nepal were established. Bilateral development aid expanded to countries such as Burundi, Cameroon, Rwanda, Tanzania, Tunisia, Turkey, Bolivia, and Peru (Jäger, Stricker 2007: 30; Holenstein 2010: 50–53; Perrenoud 2010: 84–86; Waldburger, Scheidegger, Zürcher 2012: 51–58; SDC 2017a). Switzerland also began multilateral work and became involved with multiple international organizations, including the International Committee of the Red Cross and the United Nations High Commissioner for Refugees (Rist 2009: 2; Holenstein 2010: 52–53).

In the 1970s, Switzerland's development assistance followed the new paradigm of development centering around 'redistribution with growth'. This paradigm shift set new goals for the Swiss development policy objectives. It linked growth-oriented development strategies with redistribution plans to combat poverty (Goetschel, Bernath, Schwarz 2005: 95; Holenstein 2010: 66–67). Africa became a priority for Switzerland because many African countries were belonging to the poorest in the world. Recent independence movements had made these states particularly vulnerable. Bilateral aid was distributed to countries such as Kenya and Madagascar (Perrenoud 2010: 86; Waldburger, Scheidegger, Zürcher 2012: 115). A milestone in the history of Swiss development assistance was the 'Federal Law on Development Cooperation and Humanitarian Aid' (Bundesgesetz über die internationale Entwicklungszusammenarbeit und humanitäre Hilfe), which came into effect in 1976. It combined humanitarian and development aid together under foreign aid. The overall goal was to achieve more equality worldwide (Holenstein 2010: 65; SDC 2017a). It specified that "poorer developing countries, regions, and population groups are the main recipients of development assistance" (Federal Assembly 1976). The Service for Technical Cooperation was merged with the 'Division on Disaster Assistance and International Relief Organizations' (Sektion für Katastrophenhilfe und internationale Hilfswerke) and formed the new 'Directorate of Development Cooperation and Humanitarian Aid' (Direktion für Entwicklungszusammenarbeit und humanitäre Hilfe) (SDC 2017a). The main instruments of Swiss development policy were technical cooperation for agricultural development, provision of funds for artisanal manufacturing and small-scale industries, economic policies, and humanitarian aid (Gabriel, Fanzun 2003: 25; Holenstein 2010: 65; SDC 2017a).

Due to global economic disturbances in the 1970s and 1980s, Switzerland's development aid shifted according to the evolution of the paradigm of neoliberalism and globalization. Efforts targeted to enhance global economic competitiveness for the Global South through further market competition, deregulation, export increases, and privatizations (Holenstein 2010: 77–83; Waldburger, Scheidegger, Zürcher 2012: 124–125). Public criticism appeared due to the reorientation of the government's development assistance objectives. The Swiss public criticized that the global economic disturbances left many countries in the Global South experiencing financial difficulties despite their participation in the international markets (Kuhn 2007: 81; Holenstein 2010: 80–83; Waldburger, Scheidegger, Zürcher 2012: 109). Under public pressure, the Swiss government decided to waive the debts of the poorest countries they shared bilateral partnerships with. By the end of the century, a new perspective on development assistance was pronounced to avoid the issues mentioned above. Holistic development assistance integrating economic, social, cultural, historical, and environmental aspects would become the new policy principle (Holenstein 2010: 82–83; Waldburger, Scheidegger, Zürcher 2012: 151).

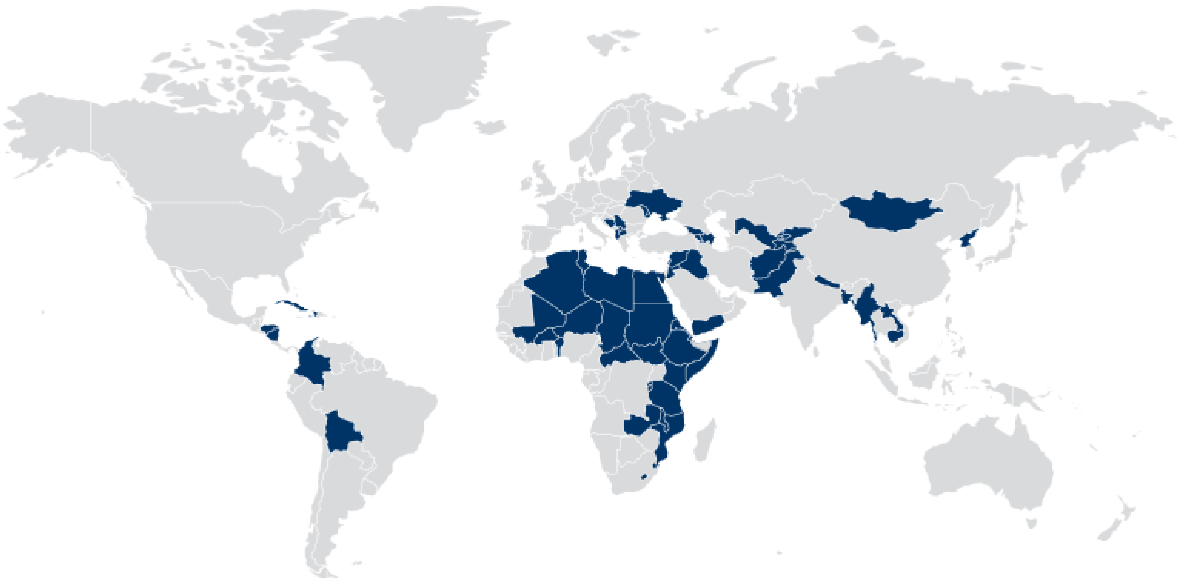
By the end of the Cold War, Switzerland's focus also turned to eastern Europe. The 'Division for the Cooperation with Eastern Europe' (Büro für die Zusammenarbeit mit Osteuropa) was set up in 1990 (Gabriel, Fanzun 2003: 26; Holenstein 2010: 90–91; SDC 2017a). In accordance with international practice, the Swiss government included the promotion of good governance, human rights, the rule of law, and democracy in their guiding principles for the development cooperation (Holenstein 2010: 97–98; Waldburger, Scheidegger, Zürcher 2012: 144–147). This led to an additional important milestone in the history of Swiss development assistance. In 1994, the Federal Council declared the new North-South guidelines. The objectives were the protection and promotion of peace and security, human rights, democracy, and rule of law. Furthermore, advancing welfare, social equality, and the protection of natural livelihoods were also included (Federal Council 1994: 1218). The new guidelines stipulated that development cooperation should be thought of as an all-inclusive process. All political sectors should be included in the development efforts (Federal Council 1994; Holenstein 2010: 97–98; Guldin 2011: 152).

In 1995, the Division for the Cooperation with Eastern Europe was integrated into the Directorate of Development Cooperation and Humanitarian Aid and renamed the 'Directorate of Development and Technical Cooperation and Humanitarian Aid for Central and Eastern Europe'. A year later it received its current denomination 'Swiss Agency for Development and Cooperation' (SDC) (Direktion für Entwicklung und Zusammenarbeit DEZA). Today, the SDC is the central institution for official development assistance, humanitarian aid, development cooperation with eastern and central Europe as well as the cooperation with multilateral institutions (Waldburger, Scheidegger, Zürcher 2012: 148; SDC 2017a). In 2000, The SDC redefined the purpose of Swiss development assistance in its 'Strategy 2010'. Five thematic focus areas were defined in alignment with the objectives of sustainable development, reduction of poverty, and removing structural causes of conflict: 1) crisis prevention and management, 2) good governance, 3) income generation and employment, 4) increased social justice, and 5) the sustainable use of natural resources. Priority regions were identified taking into consideration geographical aspects, development needs, and potential, as well as the SDC's relative advantage and Switzerland's political interests (Torp, Sager 2003: 9; Goetschel, Bernath, Schwarz 2005: 100–101). As of today, the FDFA's 'Foreign Policy Vision Switzerland 2028' (Aussenpolitische Vision Schweiz 2028 AVIS28) seeks to give development cooperation a more significant role as a foreign policy instrument. The Swiss government aims to foster economic development, reduce poverty, and address migration challenges in close collaboration with the private sector and other partners. Furthermore, the use of digital technologies and innovation projects is emphasized (FDFA 2020: 27–35).

## 2.2 Current SDC Priorities

The SDC's current strategy focuses on alleviating poverty and promoting peace for sustainable development following the 2030 Agenda. It advances long-term solutions for enabling access to essential resources and services, namely, employment, food, water, healthcare, and education (FDFA 2011: 8–9; SDC 2019a, SCD 2020e). Through more than 500 development programs and projects, Switzerland is supporting the development of ten thematic areas. These priorities are 1) basic education and vocational skills development, 2) private sector development and financial services, 3) state reform, local administrative reform, and civic participation, 4) management of fragility, 5) gender equality, 6) agriculture and food security, 7) water, 8) climate change, 9) health, and 10) migration (SDC 2019b, SDC 2020a).

Until 2024, Switzerland is providing active development assistance in 46 countries in the Global South as well as eastern and southeastern Europe (Map 2.1). Afterward, the number of SDC priority countries will be reduced to 35. Resources will be redistributed to four priority regions, in particular, North Africa and the Middle East, sub-Saharan Africa, Asia (Central, South, and Southeast Asia), and eastern Europe. Most will be reallocated to countries in sub-Saharan Africa where the challenges remain the greatest. Bilateral development cooperation will withdraw from Latin America and few countries in Africa and Asia (SDC 2020a). The SDC's current south cooperation concentrates on 21 countries that belong to the poorest and structurally weakest globally. These countries and regions are located in Africa, the Middle East, Asia, Latin America, and the Caribbean. Regions and countries include southern Africa (e.g., Zambia, Zimbabwe), North Africa and the Middle East (e.g., Libya, Syria), Central America (e.g., Nicaragua, Honduras), the Mekong Region (e.g., Cambodia, Laos), and South as well as Southeast Asia (e.g., Bangladesh, Myanmar) (SDC 2019b, SDC 2020a). The majority of the SDC budget is distributed to African countries with CHF 393 million, followed by Asia with CHF 371 million and CHF 114 million for countries in Latin America in 2019. Approximately two-thirds are spent on development aid and one third is for humanitarian aid (SDC 2020b).



Map 2.1 Current SDC priority regions and countries
Source: SDC (2020f)

### 2.2.1 Thematic Priority: Agriculture and Food Security

One of the SDC's ten thematic priorities is agriculture and food security. The SDC seeks to improve production systems and rural services that favor the sustainable use of natural resources and fight hunger and malnutrition. Overall, by promoting sustainable agriculture, the SDC aims to provide a healthy and balanced diet to vulnerable and marginalized groups, preserve biodiversity, and secure constant food access to reach food security (SDC 2019c; d). The main issues related to agriculture, food, nutrition, and health are addressed by SDC's 'Global Programme Food Security' (Figure 2.1).

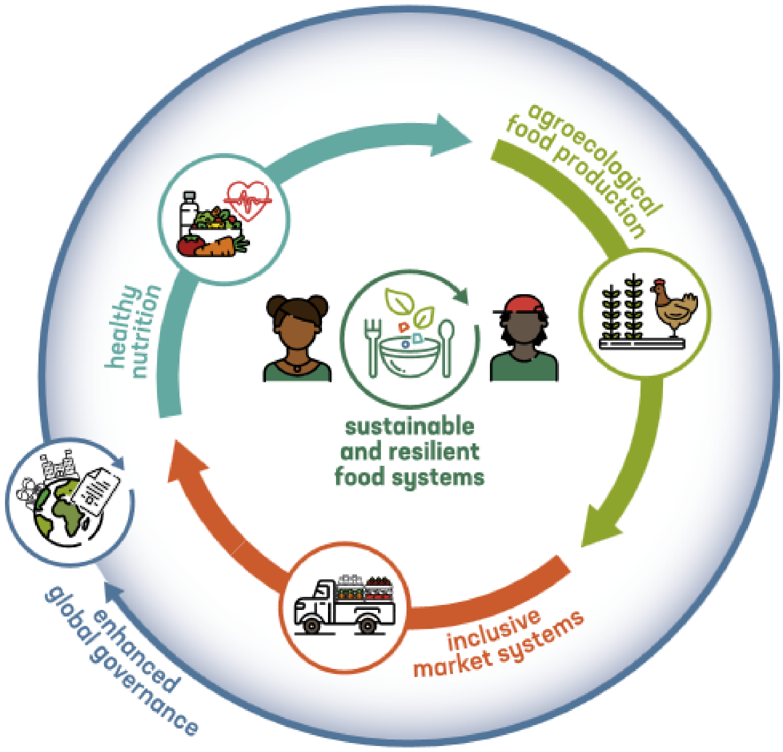



Figure 2.1 Key elements of SDC's 'Global Programme Food Security' program framework
Source: SDC (2020h: 10)

The SDC is working with multiple international, national, regional, and local institutions to ensure access to good-quality food in its priority regions. For example, it is collaborating with the 'Consortium of International Agricultural Research Centers' (CGIAR), a global association of 15 international agricultural research centers. The CGIAR aims to increase food security, reduce environmental degradation and poverty, and improve health and nutrition by sustainably managing natural resources. Switzerland supports the CGIAR through technical and financial contributions for research and innovation programs. These follow the entire food value chain from the production in the fields to storage and processing, markets, trade, and transport as well as consumers and nutrition. There is a strong emphasis on increasing smallholder resilience with regard to the harmful effects of climate change. Improving adaptation to changing environmental conditions, specifically focusing on biodiversity, is a major focus. In this context, the SDC works on six food and agriculture-related challenges (SDC 2019c; d):

1. **Access to food:** The SDC's objective is to ensure the right and access to adequate and sufficient food for poor, disadvantaged, and marginalized populations. It promotes diversified agricultural production systems by advancing sustainable agricultural development. The main areas of work are the right to food, providing balanced nutrition, diversification of agricultural production and food systems, and crop forecasting to prevent food emergencies. Furthermore, the SDC supports value chain efficiency efforts and encourages food policies that guarantee secure food access. Examples include farmer trainings on organic farming or facilitating start-up opportunities for food retailers in rural and urban areas. Thereby, the SDC supports economic and social development while strengthening food systems. Innovative solutions developed by Swiss universities and companies are also being implemented to improve the quality of food systems. These promote, for instance, sustainable cropping systems and support the transfer from scientific evidence to a real-world context. In addition, policy efforts focus on the dissemination of these approaches (SDC 2019e).

2. **Production, advisory services, and marketing for smallholder and family farming:** The SDC supports smallholders to become more resilient and adapt to climate change. In smallholder agriculture, food losses are often due to inadequate harvesting, processing, and storage as well as a lack of market access. Therefore, efforts center around giving smallholder farmers improved access to production resources and

agronomic advice tailored to their needs (SDC 2019f; g). The SDC encourages research and promotion of advisory services, the improvement of the food value chains, and the endorsement of agroecology for sustainable production. In this regard, areas of work are, for example, plant cultivation and management, partnerships with the private sector, and postharvest loss reduction. Additionally, Switzerland is committed to represent the concerns of smallholder farmers and strengthen farmer organizations. For that reason, the SDC is involved in establishing an international framework supporting smallholder agriculture (SDC 2019f).

3. **Land rights:** The SDC is working on enabling fair access to land and natural resources. The goal is to strengthen the autonomy of rural communities in consideration of urban expansion, large-scale agriculture, and industrialization. Smallholder farmers are especially vulnerable to land grabbing, blocked land access, and the loss of land rights. The SDC advocates for regulations at the regional, national, and global level to ensure fair access to land and other natural resources. For example, Switzerland played an influential role in the development of the 2012 UN 'Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries and Forests in the Context of National Food Security' (FAO 2012; SDC 2019h).

4. **Biodiversity:** The SDC supports initiatives focusing on the preservation of agrobiodiversity to ensure food security and healthy nutrition. Switzerland has committed to double its international commitment within ten years under the UN 'Convention on Biological Diversity' to address issues related to agrobiodiversity. The critical work areas are preserving crop diversity, improving seed systems, and conserving traditional varieties through local knowledge. An example is preserving frequently used crop varieties in seed banks, which in turn can improve existing seed systems. The SDC works with local, regional, and global institutions to preserve agrobiodiversity and maintain the sustainable use of ecosystems (SDC 2019i).

5. **Preventing desertification and soil erosion:** Soil degradation due to desertification and soil erosion have become a major challenge due to climatic and human factors. Practices such as overgrazing, deforestation, and unsuitable irrigation are contributing to the worldwide desertification of soils. Therefore, promoting sustainable land, forest, and water management to preserve soil fertility and water resources is central to the SDC. It focuses on sustainable agriculture and forest management initiatives in arid regions, namely in the Sahel, the Horn of Africa, and central Asia. Correspondingly, Switzerland ratified the UN 'Convention to Combat Desertification' in 1996. The convention is legally binding. It promotes sustainable environmental use and the development of ecological land management in drylands. The objective is to improve the living conditions of local populations and mitigate the effects of drought and soil degradation (SDC 2019j).

6. **Food aid:** In order to combat undernourishment and malnutrition, the SDC is engaging in food aid as a humanitarian resource. The objective is to provide basic food supplies as well as other goods and services to people caught in crises and disasters. In this area, Switzerland collaborates with the UN World Food Programme and non-governmental organizations (NGOs). An example of Switzerland's efforts is the supply of milk powder worth CHF 7 million to 16 countries in need of food aid in 2017. Since 2018, Switzerland's contributions to food aid are being channeled directly through to the World Food Programme (SDC 2019k).

## 2.3 Swiss Foreign Aid for Agricultural Development in Southeast Asia

As part of the SDC's cooperation with the Global South, efforts in Southeast Asia center around economic development, promotion of good governance, and agricultural development. Regarding agricultural development, the SDC works on improving food security and modernizing agriculture through innovation and technological advancements. Activities include disseminating low carbon emission technologies, reducing agricultural input use, creating farmer business models, and introducing crop insurances (SDC 2017b: 16,21,24, 2018a). The SDC's Asia Division in Southeast Asia concentrates its efforts in Myanmar and the Mekong Region. Many activities in other Southeast Asian countries are conducted in collaboration with the Seco, for example, in Vietnam and China (SDC 2019l; SDC, Seco 2020).

Rice farming is a significant area of work because rice is a staple food crop in many Asian countries. An example of Switzerland's contribution is the SDC co-led 'Remote sensing-based Information and Insurance for Crops in Emerging economies' (RIICE) project. This project aims to reduce the vulnerability of rice smallholder farmers in low-income countries in Asia. By mapping and observing rice growth in the selected regions, it aims to help governments take decisions and make provisions to meet potential food shortages and avoid food crises. In collaboration with IRRI and other public and private sector actors, a public-private partnership has been put in place to make use of remote sensing technologies (SDC 2016a: 4, 2017b: 23; RIICE 2020).

**China.** In China, Switzerland focuses mainly on three environmental development objectives. The first objective aims to find global solutions to reduce climate change and adapt to the new challenges in cooperation with Chinese authorities and experts (FDFA 2018). Activities center around technology transfer and knowledge sharing of low carbon solutions, integrated water resources management training, and forecast of extreme weather events (FDFA 2018; SDC 2018b). The second environmental objective focuses on advancing the dialogue on international development cooperation policies and strategies regarding the 2030 Agenda. In particular, the SDGs related to poverty and disaster risk reduction are at the center. Lastly, the third objective is to strengthen the cooperation on emergency preparedness and response (FDFA 2018).

**Myanmar.** Myanmar is a geographic focus region of the SDC. Due to deforestation, unsustainable agricultural practices, and other destructive activities, Myanmar's environment is deteriorating. Biodiversity has been decreasing fast and Myanmar is one of the world's most disaster-prone areas. The SDC's main objective is to sustainably increase agricultural production while boosting climate change resilience and improving disaster risk reduction activities. For example, through the 'Livelihoods and Food Security Fund' (LIFT), the SDC, in collaboration with other donors, reached 9.4 million people in rural areas. More than 800'000 households were able to improve their income. For its 2019-2023 strategy in Myanmar, the SDC has combined agriculture and food security with peace, state-building, and protection activities. Furthermore, it aims to prioritize market and skills development as well as improve the participation of vulnerable communities and women in decision-making processes (FDFA 2019: 10,12-13,16-18).

**Vietnam.** In Vietnam, the SDC began to focus on rural and poor populations in the early 2000s. It has been emphasizing activities, especially toward ethnic minorities and women. The projects primarily targeted poverty reduction by improving value chains through enhanced participation. Participatory processes were introduced in rural communities. A successful undertaking was, for example, the 'Public Service in Agriculture and Rural Development' program. It aimed to improve community development structures by creating a community development fund. The subsequent 'Community Management Project' encouraged the local population to independently decide on infrastructure investments, such as road and water projects, and clearly define the implementation and use (SDC 2017c: 3). Another SDC venture was the 'Market Access for the Rural Poor through Value Chain Promotion' (MARP) program. The program started in 2012 in Vietnam, Laos, and Myanmar intending to enable poor rural households to increase their income. Until 2016, the program supported four projects. These were the development of high-quality tea value chains for ethnic minorities, leveraging the spice sector in Vietnam, scaling up pro-poor rattan and bamboo value chain development for women, and improving women's livelihoods working in the textile industry. Over 25'000 households, of which 46 % were headed by women, participated in the projects. More than 15'000 households increased their total annual income. Income rose by an average of USD 575 during the project phase of three years (Schoen, Ngoc Linh 2016: 4; SDC 2016b: 1–2, 2017c: 4, 2020h: 1).

# 3 Agricultural Development in Southeast Asia

Agricultural development in Southeast Asia has undergone multiple phases. Today much of Southeast Asia's agriculture is following relatively modern farming practices. This is due to the introduction of new varieties and technologies during the Green Revolution. Nevertheless, traditional practices remain present and are especially relevant to smallholder farmers, who predominantly cultivate staple crops such as rice. New challenges have emerged due to environmental, social, and economic imbalances across Southeast Asia. These limit agricultural growth and pose a threat to rural livelihoods. In this chapter, the development of the agriculture sector in Southeast Asia with a particular focus on rice cultivation is discussed. This is followed by an overview of the Green Revolution and its effects on Southeast Asian economies, environments, and farmers. Finally, the prospects and challenges of agricultural development in the region are assessed.

## 3.1 Traditional Agriculture in Southeast Asia

In Southeast Asia, traditional agriculture mostly prevailed until the Green Revolution in the latter half of the 20th century. It was characterized by small-scale farming and subsistence agriculture, predominantly cultivating rice. Traditional farming practices are still present today in certain parts of Southeast Asia, for example, in the northwest mountainous regions of Myanmar or parts of Cambodia and Laos (Map 3.1) (Marten 1986: 7; Lim 2004: 72; Vicol, Pritchard, Htay 2018: 451).


Map 3.1 Political map of the countries in the region of Southeast Asia
Cartography: H. Wehmeyer, Cartographic base: Database of Global Administrative Areas (GADM) (2020)

Nowadays, most Southeast Asian countries are considered to be at a transitional stage of agricultural development. Elements of modern agriculture, such as chemical fertilizers, have been introduced widely since the 1960s. In general, a dual household economy in which subsistence agriculture combined with other income-generating activities within or outside the agriculture sector has become the norm. As a result, the engagement of the rural population with the market economy has been continuously increasing; thus, weakening the rural-urban divide, boosting migration, and transforming the rural economy (Lim 2004: 71–72; Lagerqvist, Connell

2018: 304). An important aspect to consider regarding the development of industrialized agriculture in Southeast Asia is the significant rise in population between the 1870s and the 1960s. The population in the region grew from approximately 60 million to over 350 million (Boomgaard 2007: 214–215). This pushed agricultural land expansion and permanently changed forests to arable land impacting the natural environment considerably. However, the expanded cultivation area would increase more slowly than the overall population leading to considerable food shortages, environmental impacts, and social upheavals (Fogel 2009: 7; Global Rice Science Partnership (GRiSP) 2013: 80; Ricepedia 2020a).

**Traditional rice agriculture.** Rice has been the pre-eminent crop in Southeast Asia for over 2000 years. Traditional wet rice farming practices were developed in southern China along low-lying river valleys. In Southeast Asia, rice was initially grown under dry conditions until the Chinese farming practices carried over. Wetland rice cultivation was first introduced to northern Vietnam, parts of Indonesia, and the Philippines (Rigg 1991: 33; GRiSP 2013: 2). Traditional rice production has been oriented towards subsistence needs to ensure the basic food requirements of a household or village. Hence, the necessary resources are generally mobilized locally. Extensive agriculture with one rice-growing season – wet or dry – is common. Local rice varieties are often grown in combination with other crops, such as soybeans, peanuts, or chilies, through intercropping or crop rotation. Fertilization is achieved by using manure, mulch, compost, and rice straw burning. Additionally, there is an essential need for human labor, especially for transplanting and harvesting. Trade possibilities and rice marketing are limited due to insufficient rice quantities and a lack of marketing facilities. Commercialization and monetization are low (Thandee 1986: 162; Rigg 1991: 37–40; Hill 1997: 56; Lim 2004: 77–78). Today, traditional lowland and upland rainfed rice farming supplies over 20 % of global rice production and is mainly located in Southeast Asia. Over 30 % of rice cultivation areas consist of rainfed lowlands with relatively low yields, little input use, and high seasonal variability (Box 3.1) (Seck et al. 2012: 10; GRiSP 2013: 17,37).

### Box 3.1 Rice Cultivation Agroecosystems

In rice agriculture there are different types of agroecosystems for rice cultivation based on hydrological characteristics. The two predominant types are irrigated and rainfed lowland rice farming. Both are especially common in Asia. Together, these two agroecosystems cover more than 90 % of the world's rice cultivation areas. Other types of rice agroecosystems are upland or dryland rice farming and deep-water or floating rice cultivation (Rigg 1991: 35–36; Seck et al. 2012: 10–12; GRiSP 2013: 16). Several aspects have pushed wet rice cultivation to become the dominant rice production system. Much of the investments and research on improving rice agriculture during the Green Revolution in Southeast Asia focused on wet cultivation systems. This increased the differences between wet and dry rice cultivation. Average yields from irrigated and rainfed rice farming have become significantly higher than in dry farming conditions. Furthermore, in dry conditions a fallow period of one or two seasons after one or two seasons of rice cultivation is necessary. This is because dry rice production systems consume significantly more nutrients from the soil than wet systems (Lim 2004: 65–66).

**Irrigated rice cultivation.** The principal rice cultivation system in the world today is irrigated lowland rice farming, covering 85-90 million hectares (Mha) of land. More than half is located in Asia. In Southeast Asia, irrigated systems occupy up to 83 % of the rice production area in certain regions (Seck et al. 2012: 9–10; GRiSP 2013: 16–17; FAO 2020c). In China, essentially all rice production is irrigated. Lowland irrigated rice cultivation generates over 75 % of the world's rice production. Therefore, it has a tremendous importance for global food security. Since the 1970s, irrigated lowland rice cultivation systems have increased considerably in Asia, especially due to the decline in upland and deep-water rice cultivation (GRiSP 2013: 16–17). Depending on the region, farmers plant rice once, twice, or thrice per year in the same field. Rice is planted mainly as a monoculture using transplanting or direct seeding as a method of crop establishment. Rotation with another crop, for example rice-wheat systems, are also present. Irrigated rice is grown in flooded conditions with water coming from underground sources and irrigation wells to provide water for rice production. During the wet season, irrigation is used as a supplement to rainwater. However, during the dry season, rice production is entirely reliant on irrigation. Overall, rice cultivation consumes two to three times more water than the production of other cereal crops. Fields of irrigated systems are generally small, ranging from 0.5-2 ha. Rice fields of lowland irrigated systems are surrounded by dikes – bunded – and irrigation systems supply and control the depth of water ranging from 5 to 10 cm. Fertilizer and pesticides are usually applied (Rigg 1991: 36; Seck et al. 2012: 9–10; Materu et al. 2018: 2; FAO 2020c). Yields from irrigated systems are on average higher than from other rice production systems. Average irrigated yields range between 2.6-9.1 t/ha with a mean of 5.4 t/ha. The highest rice yields are obtained in Japan, Korea, and China (Seck et al. 2012: 9–10).

**Box 3.1 Rice Cultivation Agroecosystems (continued)**

**Rainfed rice cultivation.** Rainfed lowland rice agriculture is characterized by bunded fields that are flooded with rainwater during the wet season or at least a part of the cropping season. The fields are covered with a layer of standing water up to 50 cm. This system provides about 20 % of the world's rice production and is used on approximately 40-45 Mha globally. In Asia, rainfed lowland rice systems cover about a fourth of the rice growing area. Nevertheless, in countries such as Thailand and Myanmar, this ecosystem accounts for a substantial fraction of the rice cultivation area with 72 % and 53 %, respectively (Seck et al. 2012: 10; GRiSP 2013: 17–18). Rice yields from rainfed lowland rice systems in Asia are relatively low ranging from 1.8-4.6 t/ha and averaging around 2.8 t/ha (Seck et al. 2012: 10). Farmers producing rice under rainfed lowland conditions generally apply fewer inputs, e.g., chemical fertilizers and pesticides, and have less control over the conditions in their fields. They are heavily dependent on seasonal rain patterns. Hence, rainfed environments experience high uncertainty in the timing, duration, and intensity of rainfall. Furthermore, multiple abiotic stresses, such as droughts, floods, and poor soil properties as well as biotic factors, e.g., weed infestations, limit yields. Water scarcity and irregular weather patterns pose a high risk to farmers and their rice crops. Cultivated rice is sensitive to water shortages. With regard to droughts, areas in northeastern Thailand and Laos are most affected in Southeast Asia. Farmers aim to maintain flooded conditions in their fields to ensure that there is enough water for the rice crops (Rigg 1991: 36; Seck et al. 2012: 10; GRiSP 2013: 17–18; FAO 2020a; Ricepedia 2020b). Thus, in rainfed rice agriculture, water conservation practices are essential for farmers to cope with uncertain conditions.

## 3.2 The Green Revolution in Southeast Asia

The Green Revolution was a period between the 1950s and 1980s in which the agricultural productivity of smallholder rice and wheat farmers in Asia and Latin America significantly increased. It was a continuing process of change driven by an agricultural technology revolution (Hazell 2009: 1–3). The Green Revolution was initiated by high rates of public investment for crop research, infrastructure, and market development. New farming methods were introduced to developing countries through the implementation of agricultural modernization policies. In combination, these elements accelerated agricultural productivity growth (Kaosa-ard, Rerkasem 1999: 4; De Koninck 2003: 196; FAO 2004: 27). In the first half of the 20th century, rice yields and labor productivity in the countries of Southeast Asia were concerningly low, considering the increasing population in all countries of the region. Poverty was widespread, particularly among rural communities, and severe hunger and malnutrition were prevalent. Agriculture was the most important source of employment. The international community decided that agricultural yields had to be improved to avoid food shortages leading to famines. Growing dependence on food aid from wealthy countries should also be reduced. Consequently, public investments, policy support, and research for modern agricultural development were initiated to transform global agriculture (De Koninck 2003: 192–195; FAO 2004: 27; Hazell 2009: 1).

### 3.2.1 Modern Varieties and Growth Development

A key element for the rise of the Green Revolution was the introduction of 'improved' crop varieties. In Southeast Asia, the main focus was on rice. Hence, the promotion of improved rice seeds was central (FAO 2004: 25; Hazell 2009: 1). New varieties were developed with the aid of modern plant breeding techniques starting in the 1950s. International breeding programs began with the creation of international research centers under the CGIAR. In 1960, the IRRI opened as the first CGIAR center and supported the development of high-yielding varieties (HYVs) (Kaosa-ard, Rerkasem 1999: 4–5; De Koninck 2003: 197; FAO 2004: 27). These improved varieties were generally superior to traditional varieties. They had a higher yield potential, improved tolerance to pests and diseases, better adaptability to a broad range of latitudes, more insensitivity to the length of daylight as well as faster responsiveness to fertilizer and irrigation (Figure 3.1) (Kaosa-ard, Rerkasem 1999: 5; Hazell 2009: 4). Furthermore, the new varieties often required a shorter growth period. This made it possible to establish intensive cropping systems by increasing cropping ratios from one to at least two crops a year. HYVs were shown to reach 10 tonnes per hectare (t/ha) under ideal conditions at IRRI. This was a significant increase compared to the 2 t/ha average rice yields from local varieties (Kaosa-ard, Rerkasem 1999: 5; Lim 2004: 75; Hazell 2009: 4; GRiSP 2013: 45). From the Asian rice breeding program at IRRI, a notable example is the development of the semidwarf rice variety IR8. With the introduction of the shorter IR8, a variety that was particularly suited for irrigated regions was provided to Asian rice farmers. A typical characteristic of traditional rice varieties is a long and tall stem. This can lead to lodging if it cannot support the rice grains. Plants with weaker stems cannot grow properly and buckle more easily. Therefore, due to its reduced height in combination with high yield potential, lodging resistance, fertilizer response, and insensitivity to daylength, IR8 became popular and was widely adopted (Hargrove, Cabanilla 1979: 731; Lim 2004: 75). Rice yields increased by 109 % between 1960 and 2000 over all developing countries. This significantly helped to increase food production and supply in many parts of Asia. (FAO 2004: 30). During the strongest period of the Green Revolution between 1963 and 1983, the total annual production of paddy rice rose by 3.1 % on average (Rapsomanikis 2015: 10). The Green Revolution in Southeast Asia initiated a change in agricultural practices. In particular, the use of HYVs in packages including fertilizers and pesticides influenced the predominance of specific cropping systems. Irrigated lowland rice cultivation became the standard in most countries (Hazell 2009: 20). Ultimately, the Green Revolution has markedly influenced most forms of agricultural production throughout Southeast Asia and other regions. Substantial yield increases were not only achieved for rice, but also for several other staple food crops, such as wheat, maize, and cassava as well as for cash crops, including rubber, oil palm, sugar, and coffee (De Koninck 2003: 200).


Figure 3.1 Comparison of rice plants representing traditional varieties (left), Green Revolution HYV semidwarf rice (IR8, middle), and new low tillering ideotype (right)
Source: Breseghello, Coelho (2013: 8283)

Agricultural production in Southeast Asia since 1960 has been growing twice as fast as the global average (De Koninck, Rousseau 2013: 148–149). Therefore, the rate of food self-sufficiency increased in the region, as did its share in the global agricultural produce trade market. New trading patterns were initiated, in particular regarding new methods of food processing and transport. The demand for rural labor increased. This generated jobs for the poor and raised the unskilled labor wage rates (Hazell 2009: 10; Rapsomanikis 2015: 1). The productivity increases contributed towards economic growth by reducing the price of staple foods. Food supply in developing countries increased by more than 12 % from 1960 to 1990. Without the modern technologies and practices of the Green Revolution, world food prices would have been 35-65 % higher today. Moreover, it has been estimated that without the creation of the CGIAR centers and national and international breeding programs, total food production quantities in developing countries would have been almost 20 % lower. Hence, considerably more land would be required for cultivation (Pingali 2012: 12303). In this regard, possibly the most positive aspect of the Green Revolution was the prevention of deforestation due to a reduced need for arable land to increase food output. The global cultivated area has grown only by 12 % over the last 50 years, while agricultural production increased up to three times during the same period. As a whole, the positive economic effects of the Green Revolution were especially beneficial for the poor. They gained relatively more from the agricultural productivity growth and decreasing food prices because they spend a more significant share of their income on food (Kaosa-ard, Rerkasem 1999: 10–11; McKittrick 2012: 422; Pingali 2012: 12303).

**Agricultural and economic growth.** The essential characteristic of Asia's agricultural evolution was the rapid economic growth over the past five decades due to boosted agricultural productivity levels. These resulted from the interventions introduced during the period of the Green Revolution. In other areas of the world, such as Latin America or sub-Saharan Africa, agricultural growth rates have been far behind countries such as Indonesia, Vietnam, or Thailand. The Southeast Asian agriculture sector increased on average by 4.6 % from 1980 to 1990 and 3.2 % from 1990 to 2001. In comparison, agricultural growth rates during the same periods in Latin America (2.3 % and 2.4 %) and sub-Saharan Africa (2.2 % and 2.8 %) were considerably lower. Additionally, the average gross domestic product (GDP) growth rate for Southeast Asia between 1980 and 2001 was 7.5 % compared to 2.5 % in Latin America and 2.1 % in sub-Saharan Africa (Barichello 2004: 6–8; Rapsomanikis 2015: 10). Thus, rural poverty has declined substantially, and GDP per capita has grown strongly in Southeast Asia from the 1970s onwards (Figure 3.2). Furthermore, absolute poverty fell by 28 % from 1975 to 1995, although the total population in the region grew by 60 % over that same period (Fogel 2009: 8,53; Hazell 2009: 9–10). Reduced poverty resulted directly from increased farmer income due to higher outputs and improved profitability of smallholder farmers. Indirectly, new employment opportunities in postharvest operations, such as storage, milling, marketing, and transportation, raised employee wages. Income increases were seen due to reduced prices of agricultural products. Furthermore, migration to favorable areas where employment opportunities were higher increased rural incomes. This created new off-farm activities and led to more diversification of rural economies. Additionally, landless and non-agricultural households also benefited from improvements in real wages and saw an increase in income (Kaosa-ard, Rerkasem 1999: 9).

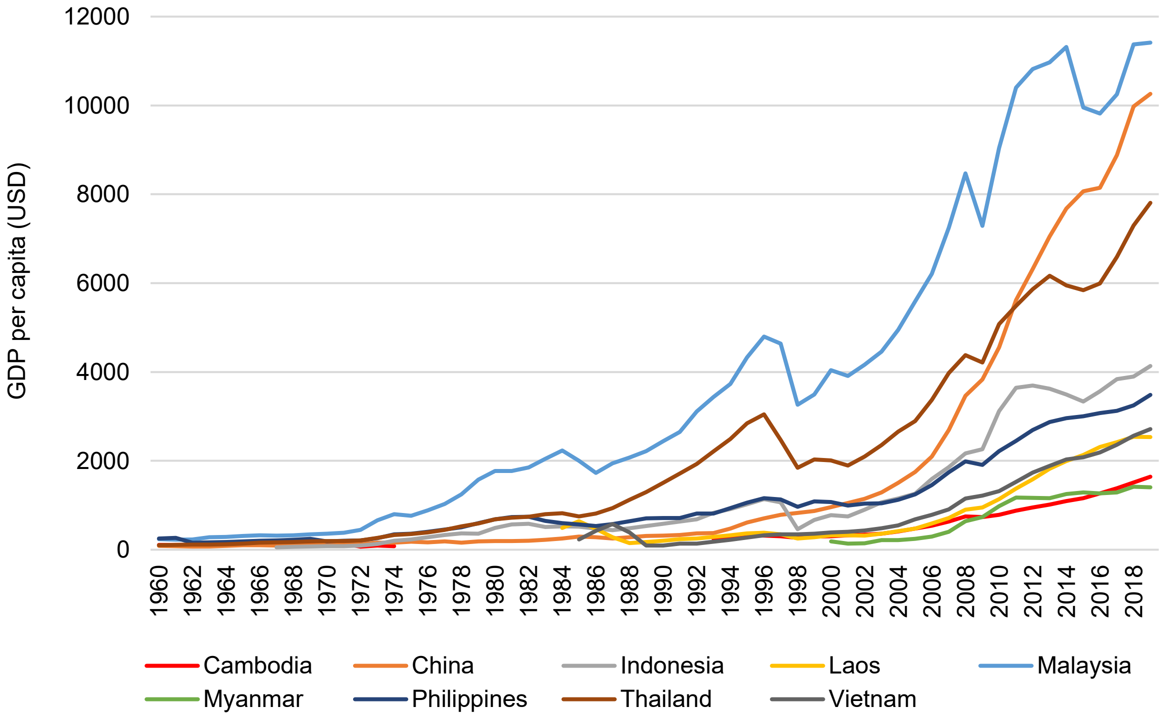



Figure 3.2 GDP per capita in USD in selected Southeast Asian countries from 1960-2019
Source: World Bank (2020a); Concept: H. Wehmeyer (2021)

The growth of the agricultural sector in Southeast Asia has led to a chain of multiple developments in different sectors. Rapid rice production increases stimulated the demand and prices for land, labor, non-agricultural goods, and services. Thus, agriculture has shown to be an engine of economic growth, in particular for the rural non-farm economy (FAO 2004: 30; Hazell 2009: 9). Due to the production increases rising, a significant shift in the food supply system took place. Agricultural exports multiplied and countries' export performance was strengthened (De Koninck, Rousseau 2013: 149). Furthermore, modern agricultural production systems required far less human labor. This released a significant surplus labor force benefitting the industrial sector. The new industrial labor force then profited from the reduction in staple food prices and rising incomes from 1960 to the early 2000s. In this regard, lower food prices with increased income levels changed salary spending ratios. This allowed for higher spending capacity, particularly of the poor, and hence for rapid economic growth. In addition, the impact on nutrition due to an increase in per capita food supply met the needs of millions in Asia (Hazell 2009: 10–12; Pingali 2012: 12303). Today, Asia is a major producer of grains for the world and holds a global rice production share of 90 %. This is mainly because more than half of the global rice production is concentrated in China and India (OECD, FAO 2020: 81,130).

### 3.2.2 Consequences of Growth

The Green Revolution brought significant change in relieving poverty, advancing agricultural productivity, and stimulating overall economic growth. However, there have also been negative consequences. These include the unresolved issues of food insecurity and endemic hunger as well as the fact that global poverty levels are remaining high. This is mainly because the interventions of the Green Revolution bypassed Africa, which has contributed to the persistent global imbalance (FAO 2004: 28; McKittrick 2012: 423; Pingali 2012: 12303). Nowadays, the impact of the Green Revolution on the environment is seen twofold. On the one hand, it is regarded as the crucial element to have impeded the conversion of millions of hectares of land, particularly forests, for agricultural use worldwide. Thus, it curbed deforestation and saved natural habitats. On the other hand, the Green Revolution is seen as an environmental failure due to unprecedented levels of environmental degradation. The improper management and overuse of modern inputs have led to water and air pollution as well as soil nutrient depletion and desertification, among other problems. These issues have been intensified by inadequate extension services and institutional deficiencies. Furthermore, governmental policies have focused intensely on input pricing subsidies that made modern inputs cheap and encouraged excessive use (McKittrick 2012: 421–422; Pingali 2012: 12303).

**Unattained objectives.** In Southeast Asia, the relative weight of the agricultural sector has been declining. As a result, an imbalance between the evolution of the agricultural sector and other sectors developed, particularly with the industrial sector. From 1980 to 2001, the agricultural sector grew on average 3.9 % per year. This is approximately half as much as the total annual GDP rate (7.5 %) of the region during the same period (Barichello 2004: 6–7). Thus, agricultural growth has been stagnating since the mid-1980s, and returns on investment have been declining. Yet, fertilizer and seed prices have increased significantly since the beginning of the 2000s. Although some Southeast Asian countries have become rice self-sufficient, e.g., Thailand and Vietnam, sustaining self-sufficiency has been difficult for others. Several Asian countries, for instance, Indonesia and the Philippines, still import rice to meet their populations' needs (The Association of Academies of Sciences in Asia (AASA) 2011: 26–27; GRiSP 2013: 41,87,140-141). Furthermore, the Green Revolution promoted technologies from non-renewable energy sources. The majority of modern agricultural materials are based on fossil fuels. Considering the economic instability since the 1970s, farmers have become more vulnerable to external forces, particularly price hikes in the global oil market (Kaosa-ard, Rerkasem 1999: 10; AASA 2011: 25–26). Up until today, the agriculture sector remains the primary source of employment for the increasing population in Southeast Asia. However, the widening of the income discrepancies between rural and urban areas in most Asian countries is ongoing. Regarding poverty reduction since the Green Revolution, an overall increase of 1 % in crop productivity reduced the number of people living in poverty only by 0.48 % (De Koninck, Rousseau 2013: 150; Pingali 2012: 12303–12304; Rigg, Salamanca, Thompson 2016: 122).

**Selective approach.** One major criticism regarding the Green Revolution is the selective and biased approach towards resource-rich regions. The new fertilizer-responsive technologies required a favorable environment, technical knowledge, and financial capital. They were generally introduced to favorable environments where sound irrigation systems were present or could be built quickly to see fast dissemination. Therefore, farmers in favorable irrigated areas were able to improve their productivity levels more easily relative to less favorable – mostly rainfed – areas (Kaosa-ard, Rerkasem 1999: 8–9; Hazell 2009: 10; Pingali 2012: 12305). By the mid-1980s, almost full adoption of rice HYVs had been achieved in the irrigated environments of Asia. However, at the same time, adoption rates in environments with scarce rainfall or poor water control were low. In addition, adopting farmers in the favorable regions were generally wealthier primarily due to owning more land. This also facilitated their ability to take credit loans to further advance their farming business (Kaosa-ard, Rerkasem 1999: 9; Pingali 2012: 12304–12305). Another bias was that technology transfer largely focused on male farmers. The Green Revolution overall missed addressing female farmers who would generally show low adoption rates compared to their male counterparts. To this day, women face barriers to access the needed resources and technologies for productivity growth (Pingali 2012: 12304). The Green Revolution has increased interregional disparities and migration. As a consequence, this has further aggravated the unequal distribution of income and exacerbate inequalities between resource-rich and resource-poor regions. Therefore, the equity of the interventions of the Green Revolution has been questioned considerably (Lim 2004: 77; Hazell 2009: 10–12; AASA 2011: 24–28; Pingali 2012: 12305).

**Environmental impacts.** Degradation of ecosystems, biodiversity, and natural habitats has been shown to be linked to the rapid agricultural intensification since the 1960s. The Green Revolution innovations substantially disturbed ecological processes due to high input use and resource-intensive crop cultivation practices. These unsustainable farming practices have depleted agricultural soils, which has started negatively affecting crop yields in Asia (De Koninck, Rousseau 2013: 150–151). The main reasons for today's environmental problems are 1) the heavy and inappropriate use of fertilizers and pesticides, 2) false irrigation practices that lead to high salinity degrees in soils, and 3) dropping groundwater levels because of bad irrigation practices (Rapsomanikis 2015: 34). The cycle started with the introduction and widespread adoption of HYVs. The strong push in favor of monoculture cultivation required mechanization for monocultures and standardized plants. This has narrowed the number of cultivated plant species to a few staple crops. These have become more susceptible to diseases, pests, and natural disasters. Furthermore, single-crop farming is more vulnerable to economic volatility and natural disasters. Biodiversity levels have been decreasing considerably and the risk of pest and insect attacks has increased. However, after long-term utilization of pesticides, diseases and pests become more resistant. Additionally, due to biodiversity losses, the number of natural enemies of pests is decreasing drastically and species are threatened to go extinct. This increases the severity of the harmful dynamic and the negative cycle continues (AASA 2011: 24–28; Pingali 2012: 12304–12305; Rapsomanikis 2015: 34). The continued excessive and inappropriate use of agricultural inputs has polluted and degraded the environment in Asia. Intensive irrigation and mechanization practices have reduced groundwater levels. This has accelerated soil degradation, such as loss of soil fertility, soil salinization and hardening as well as chemical runoff polluting soil and waterways resulting in yield decline. Also, methane emissions from irrigated rice fields represent 10-15 % of the global methane emissions and considerably affect climate change. All in all, this has led to severe environmental impacts beyond the areas cultivated in many regions of the world, including Southeast Asia (McKittrick 2012: 422; Pingali 2012: 12304–12305; Rapsomanikis 2015: 34). Nevertheless, the environmental consequences as such were not just caused by the technologies and practices introduced during the Green Revolution. The policy environment promoted the excessive overuse of inputs (Hazell 2009: 21; Pingali 2012: 12304).

## 3.3 Prospects for Sustainable Development in Southeast Asia

**Sustainable growth.** Sustainable growth aims to enhance productivity through the responsible use of natural resources and better adapting agricultural cultivation practices to the environment. Precisely, production increases should be achieved by improving agricultural efficiency. This means higher yields per unit area with reduced input use and avoiding the expansion of the farming area (Kaosa-ard, Rerkasem 1999: 199). Agricultural productivity in Southeast Asia is projected to increase during the upcoming years. This optimistic forecast is due mainly to improved total factor productivity (TFP) over the past decades. TFP is growth from factors other than additional land, labor, capital, and material inputs (fertilizer, pesticides, etc.) (FAO 2015: 3–4). Farmers have been able to increase their productivity by enhancing allocative efficiency. Between 2001 and 2013, 60% of output growth was achieved by TFP growth. Hence, most of the agricultural output rise has been due to factors other than the higher use of conventional inputs. This was achieved by, e.g., crop diversification and intensification. This includes irrigation infrastructure expansion and the use of improved seed varieties (OECD, FAO 2017: 67,82, OECD, FAO 2020: 81). An example is planting drought-tolerant varieties (Figure 3.3). Drought is a major problem because it is the most widespread and damaging of all environmental stresses. Thus, promoting adapted varieties can improve productivity more sustainably due to a reduced need for irrigation (IRRI 2018a). Overall, the estimated high levels of growth in Southeast Asia are expected to change the regional and national food markets significantly. First, poverty levels are projected to fall. This will reduce levels of undernourishment and contribute to a higher demand for agricultural products. Second, incomes will rise considerably and change the nature of demand, mainly regarding staple foods, such as rice, which will be replaced by increased consumption of animal products. Third, population growth will stimulate changes in economic growth. Thus, food demand will increase overall which will boost income effects (OECD, FAO 2017: 81–82, 2020: 123–124).

Figure 3.3 Drought-tolerant rice
Source: IRRI (2018a)

**New policy orientation.** Over the past decade, agriculture as an engine of growth has been reintroduced to new development policy strategies in Southeast Asia. Due to the sector's declining significance in many emerging economies, it has been neglected over time. This has created inefficiencies in resource allocation and discouraged private investments. Furthermore, this has led to budgetary difficulties of governments spending substantial financial resources on inefficient activities that could be invested in other public areas of interest

(OECD, FAO 2017: 77). Especially low-income countries have been experiencing continued levels of food deficits. Therefore, new policy efforts driven by concerns about food insecurity and poverty are refocusing on how agricultural development can boost economic growth. Consequently, agricultural investments for a Green Revolution 2.0. have been on the rise (Pingali 2012: 12305–12306). The states' main priority is to strengthen policies and institutions concerning the use of natural resources for sustainable agriculture. They aim to introduce economic, legal, and social instruments to improve the conservation of natural resources and the environment. The public sector in several Southeast Asian countries has been investing in education and technology for sustainable agricultural development. In addition, the public sector has been facilitating private sector activities for agricultural development (Pingali 2012: 12305–12306; OECD, FAO 2017: 69). The strength of the agricultural policy agendas of the Southeast Asian countries is the broad thematic policy perspective. It includes a vast macroeconomic environment and intergovernmental collaborations, mainly through the Association of Southeast Asian Nations (ASEAN). These collaborative governance efforts involve the continuation of common macro-fiscal and monetary policy settings as well as human capital and labor market cooperation, among others. Specific policy efforts concentrate on improving environmental governance, regulations on land, water, and biodiversity resources, as well as investments in infrastructure and agricultural R&D (OEDC,FAO 2017: 69-70,78-79).

**R&D and the private sector.** The private sector has become an essential contributor to the development of modern agricultural technologies and also takes a critical role in the dissemination of innovations. Companies have been focusing on, for example, improving yield potential, grain quality, water productivity, and tolerance of abiotic stresses in new varieties (FAO 2004: 25,31; Pingali 2012: 12305–12306; GRiSP 2013: 54). Thus, a paradigm shift in agricultural research and related activities has started to take place. Private entities expand efforts in agricultural development next to and in collaboration with public institutions. Hence, the industry is playing an active role in the promotion of sustainable farming practices (Kaosa-ard, Rerkasem 1999: 201; FAO 2004: 25,31; Pingali 2012: 12306). Nevertheless, private sector R&D activities are generally restricted to specific crops, especially hybrid crops, e.g., maize, rapeseed, sunflowers, and vegetables. This leaves out most staple crops, such as rice, wheat, soybean, pulses, and roots (Kaosa-ard, Rerkasem 1999: 197). The dominance of the private sector in agricultural biotechnology raises concerns regarding access to and affordability of innovations. Notably, farmers in developing countries for whom these technologies are not readily available are left out. Due to interregional differences in productivity, there is also a risk for more impoverished regions to be bypassed by companies for reasons of profit (FAO 2004: 31; Pingali 2012: 12304,12306). Ultimately, finding a balance between public and private initiatives and their respective objectives to modernize the agriculture sector and the entire food system remains a difficult challenge (Reardon, Timmer 2014: 116).

## 3.4 Challenges for Sustainable Agricultural Development

**Climate change.** Multiple risks concerning agriculture in Southeast Asia are expected to be tied to climate change and related extreme weather events. More frequent storms, droughts, flooding, and rising sea levels are significant threats to low-lying coastal areas. Coastal zones are particularly vulnerable to the impacts of climate change. Four types of primary physical effects are of major concern: saline water intrusion, drainage congestion, extreme events, and changes in coastal morphology (Alam, Sawhney 2019: 29). With regard to rice cultivation, climate change is expected to have a significant impact on yields and cultivation practices. GRiSP simulations for the main rice-growing regions of Asia forecast that for every 1 °C rise in mean temperature, yield decreases of 7-10 % will occur. In addition, the issue of water scarcity and salinity in the low-lying coastal areas is increasing, intensely hitting the Southeast Asian rice sector that is highly dependent on water for irrigation. GRiSP estimates show that 15-20 million hectares (Mha) of irrigated rice cultivation areas will suffer some degree of water scarcity by 2025 (GRiSP 2013: 50–52). Hence, to counteract the adverse effects of climate change, the agriculture sector will also have to direct its effort towards mitigating the risks. Current policy environments, especially in Southeast Asia, have not yet considerably changed their adaptation responses due to many conflicts of interests related to short-term economic goals. This could potentially exacerbate the negative impacts of climate change in the region (OECD, FAO 2017: 69,94-95; Alam, Sawhney 2019: 29).

**Yield gaps.** Considerable potential for increasing production in Southeast Asia is seen in the closure of yield gaps. Yield gaps are the difference between the maximum potential yield and the actual farm yield (Figure 3.4). Potential yield is only constrained by genotype and environment. The larger the gap between potential yield and actual farm yield, the higher the opportunity to improve farming practices to increase production quantities. In rice production systems, the economically attainable yield or exploitable yield is defined as 80 % of the potential yield. Exploitable yield is limited by the same factors as potential yield and additionally by agronomic practice, socioeconomic and institutional factors as well as access to inputs and technology. To reduce yield gaps in rice production, concentrating on the gap between actual yield and exploitable yield is essential (Stuart et al. 2016: 45). In this regard, focusing on smallholder farmers is crucial. They produce most of the food consumed in the developing world and, specifically, rice in Southeast Asia. However, productivity growth has been stagnating, particularly for small farms. There are multiple reasons for this current situation. One major factor is the suboptimal use of inputs. Also, insufficient adoption of best management practices and technologies slows the improvement of agricultural efficiency. Therefore, it is crucial to assist smallholders in adopting innovations to improve their yield gap. Furthermore, enhancing labor productivity is of particular interest because it pushes food production and employment opportunities. Increased labor productivity through optimal technology use strengthens the demand for skilled labor, and thus raises rural wages (Rapsomanikis 2015: 10,33).

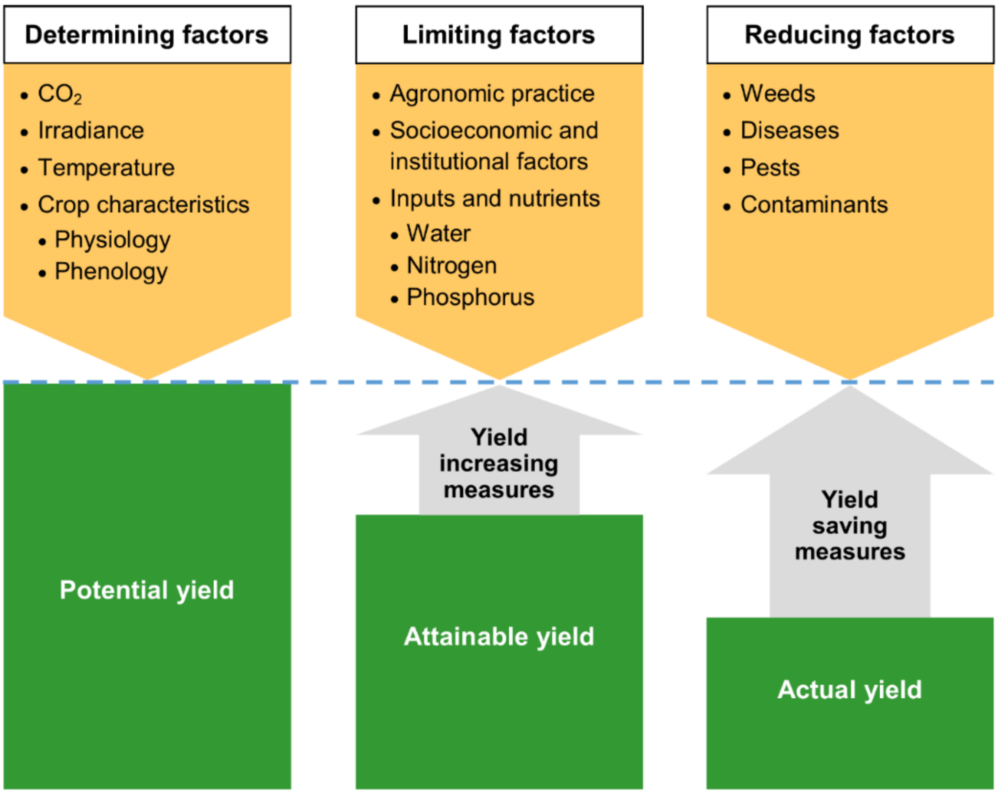



Figure 3.4 Determination of crop yields and growth-defining, growth-limiting, as well as growth-reducing factors influencing yield gaps
Source: Adapted from Rabbinge (1993: 9) and Lewandowski et al. (2018: 114)

**Food security and global market dependence.** Southeast Asia has made significant progress in terms of improving food security since the 1990s. By 2016, rates of undernourishment fell from 31 % to 10 %, or approximately 60 million (excluding China). Nevertheless, there are wide discrepancies between the countries in Southeast Asia. The varying levels of development emphasize that food security remains an important issue (OECD, FAO 2017: 60–61). Agriculture and food security policy efforts center mostly around rice. Rice self-sufficiency is the primary emphasis in policymaking for most countries and has only become more dominant since the 2007/08 global food price crisis. The countries set production targets. They employ different methods to pursue these objectives. Importing countries (e.g., Indonesia, Philippines) make use of strategies such as price support, trade barriers, and input subsidies to boost domestic production. Policies for increasing domestic prices of rice with the aim to expand the availability of domestically produced food have been utilized. These, however, have not been successful at addressing food insecurity for vulnerable consumer households and the ongoing problem of low farm incomes. Exporting countries (e.g., Thailand and Vietnam) use policies that directly intervene in export markets through taxes, bans, or licensing arrangements and keep back a certain quantity of rice production to assure their food security (OECD, FAO 2017: 77–78). With regard to globalization, producers and consumers in Southeast Asia are more exposed than ever to international markets. This is due to the growing number of exports and imports, especially of agricultural products. Hence, next to domestic agricultural policies, policy settings of other countries and regions have a substantial impact on the market. Global value chains have changed the agriculture sector in manifold ways. Distorting national rice prices through price support affects overall agricultural resource allocation. This pushes farmers to continue low productivity rice farming and avoid profitable diversification of cultivation. As a consequence, this limits the production of higher-value crops and higher agricultural incomes, which can enhance agricultural development. Furthermore, the elevated price for staple foods may hamper the possibility for low-income households to afford enough food in general. Subsequently, this increases the current levels of food insecurity of vulnerable households. It also reduces the variety of foods families can purchase, limiting the opportunity for a healthy diet (OECD, FAO 2017: 73,75).

**Rural development and smallholder value chain inclusion.** The largest number of smallholder farmers in the world is in Asia, with around 420 million or 74 % of small farms globally. The majority are located in China and India, 9 % are in Southeast Asia and the Pacific (ca. 50 million) (Lowder, Skoet, Raney 2016: 20–21; SDC 2019f). Smallholders in Southeast Asia deal with multiple difficulties and threats to their livelihoods. Farm sizes are becoming smaller due to the current rural population growth trends. This leads to farming being economically unviable and further marginalizes the rural population. Rural areas remain underdeveloped and barriers to labor mobility pose a problem for rural development. Governmental efforts to support smallholders have had a less substantial impact on smallholder farmers' livelihoods than on larger farms. Input and output subsidies, in particular, have contributed less to the productivity growth of small-scale farming (GRiSP 2013: 50; Reardon, Timmer 2014: 116; Rapsomanikis 2015: 34–36; Lagerqvist, Connell 2018: 311). The major challenge lies in the economic balance between fair commodity prices for smallholder farmers on one side and achieving affordable prices for low-income populations on the other side. Low commodity prices depress the profitability of farming and thus hit small-scale producers particularly hard. They then become increasingly isolated from the economic environment and the global value chains (GRiSP 2013: 50; Reardon, Timmer 2014: 116; Rapsomanikis 2015: 34–36; Lagerqvist, Connell 2018: 311).

# 4 Innovation Diffusion and Technology Adoption Approaches

The adoption and diffusion of innovations have been studied intensely. Their relevance to the dissemination of knowledge and technologies has been described as a principal mechanism to achieve change in a multitude of fields. In this chapter, the basic principles of innovation diffusion and technology adoption are presented. Rogers' innovation-diffusion process and specific geographic considerations regarding knowledge dissemination are highlighted. In addition, diffusion approaches employed for agricultural development and current fields of application of the innovation diffusion principles in Southeast Asian agriculture are discussed.

## 4.1 Innovation Diffusion and Technology Adoption Principles

Innovation diffusion is a key mechanism to social and economic change because it is regarded as the process of governing the utilization of innovations. The progress of innovations and technological development are considered important engines of economic growth (Brown 1968: 7; Kaur, Kaur 2010: 289). Geography and other social science disciplines understand innovation diffusion as an information-gaining process. It requires not only the study of social and economic aspects but also the examination of spatial characteristics and their influence on the availability of information (Brown 1968: 7). Technology diffusion has been widely studied since the beginning of the 20th century. Different scientific perspectives have tried to understand the implications on people's economic, socio-cultural, and environmental livelihoods (Dearing 2009: 1; Kaur, Kaur 2010: 289).

The term innovation can be used broadly to define a new product, technique, practice, or idea that is perceived as new by an individual. In general terms, if an idea seems new to the individual, it is considered an innovation (Brown 1981: 1; Rogers 2003: 12). Innovation diffusion is the process by which an innovation spreads throughout a population or social group or from one place to another. Overall, diffusion is the cumulative adoption resulting from a series of individual decisions. The diffusion rate is determined by summing up these individual decisions to assess how well the innovation has been adopted by a social group or population over time (Brown 1981: 1; Hall, Khan 2003: 1–3; Kaur, Kaur 2010: 290). Innovations are considered necessary to upgrade or improve the standard of an individual, social group, and society in general. Correspondingly, three key factors are essential in order for diffusion of innovation to occur: 1) reducing uncertainties of potential adopters regarding new information, 2) responding to individuals' perceptions of what others are thinking and doing with regard to the new information, and 3) general social pressure felt by the individual to follow the same venture other peers have already done (Box 4.1) (Dearing 2009: 4–5; Kaur, Kaur 2010: 289).

Technology adoption is an individual's choice to acquire and use a new innovation. The choice is mainly determined by the benefits received from the adoption and the costs of adopting the new technology. Benefits and costs can be of economic matter but also include other aspects, such as socio-cultural, religious, political, environmental, and personal characteristics (Hall, Khan 2002: 1,8). Adoption itself does not take place as a single decision. It can instead be described as a process of several thought cycles. The initial perceptions of an innovation are modified until a decision for adoption or rejection is performed. During this decision process, the need for the new innovation is identified and alternatives are evaluated (Kaur, Kaur 2010: 290). An individual's mental framework, such as attitudes, habits, cultural background, and lifestyle, influences the perception of an innovation and the adoption-decision process. Additionally, the behavior of other members of the social group towards the adoption of an innovation also indirectly influences a person's perceptions and eventual decision to adopt or reject (Seligman 2006: 110; Kaur, Kaur 2010: 290).

**Box 4.1 Components of the Classical Diffusion Paradigm**

- **The innovation:** The innovation is the main element to start the adoption-diffusion process and according to Rogers, five critical attributes are necessary to explain and predict the rate of adoption (2003: 12,257-258):
  1. The relative advantage of the new technology to the adopter, in particular its effectiveness and cost efficiency relative to alternatives.
  2. The complexity of the innovation in regard to how easily understandable it is and how simple its use is perceived.
  3. The compatibility of the innovation meaning the fit of the innovation to the adopter's established ways of practicing to accomplish the same goal.
  4. The observability of the innovation regarding the degree to which the results are visible to others.
  5. The trialability of the innovation signifying the degree to which an innovation may be experimented with on a limited basis to encourage the adopter to fully adopt the innovation.
- **The adopter:** The adopter's degree of innovativeness and openness to new ideas are defining for the timing of adoption.
- **The social system:** The social system plays a pivotal role in the adoption-diffusion process due to the opinion of local informal opinion leaders and the social pressure to adopt a new technology perceived by the potential adopter.
- **The individual adoption process:** During this process, the adopter undergoes different decision stages including awareness, persuasion, decision, implementation, and continuation before adopting the innovation.
- **The diffusion system:** Within a diffusion system, each element supports the widespread adoption and diffusion of an innovation. The structure focuses on providing knowledge through multiple sources. Specifically, external change agencies deploy agents to foster adoption. They intervene directly with the system's opinion leaders and early innovators to push the adoption-diffusion process and concentrate many activities on the local level.

Adapted from Dearing (2009: 4)

### 4.1.1 Rogers' Innovation Diffusion Theory

E.M. Rogers' 'Diffusion of Innovation' theory has become one of the most popular adoption-diffusion models and has been widely used in multiple disciplines as a theoretical framework for adoption and diffusion studies (Sahin 2006: 14). Rogers' definition of diffusion is "*the process by which an innovation is communicated through certain channels over time among the members of a social system*" and he describes adoption as "*a decision of full use of an innovation as the best course of action available*" (2003: 6). In his theory, there are four main elements necessary for the diffusion of innovation. These are 1) innovation, 2) communication channels, 3) time, and 4) social system. Rogers defines an innovation as "*an idea, practice, or object that is perceived as new by an individual or other unit of adoption*" and more specifically a technology as "*a design for instrumental action that reduces the uncertainty in the cause-effect relationships involved in achieving a desired outcome*" (2003: 12–13). Communication channels serve as a tool through which participants create and share information with each other with the objective of reaching a mutual understanding. Hence, communication about an innovation occurs through channels between sources. Rogers considers time crucial to analyze the adoption-diffusion process. He argues that time is required for an individual to go through the innovation-decision process to pass from first knowledge of an innovation to either adoption or rejection. Time is a relevant measure to categorize the adopters from the non-adopters by analyzing the adoption timing of an individual compared to others. The adoption rate of a system is being measured as the number of members of the system who adopt the innovation in a given time period. Rogers' fourth main element for innovation diffusion is the social system. It is a set of interrelated social units, e.g., individuals, informal groups, organizations, or subsystems that are engaged in joint problem solving to accomplish a common goal. Overall, Rogers' theory describes how an innovation is being communicated through certain channels over time among members of a social system (Rogers 2003: 12–26; Sahin 2006: 14–15).

From the four main elements of the diffusion of innovation theory, Rogers developed the innovation-decision process consisting of five different stages illustrating an individual's decision process to adopt a new technology that allows innovation diffusion. He describes it as follows:

*"The innovation-decision process is the process through which an individual (or other decision-making unit) passes from gaining initial knowledge of an innovation, to forming an attitude toward the innovation, to making a decision to adopt or reject, to implementation of the new idea, and to confirmation of this decision."*
(Rogers 2003: 20)

The five stages of the innovation-diffusion process follow a linear path through which an innovation is diffused. The steps are knowledge, persuasion, decision, implementation, and confirmation (Figure 4.1).

1. **Knowledge:** During this stage, the potential adopter becomes aware of the innovation and learns about how it functions. The decision-making process is being started. In essence, knowledge is information that an innovation exists and how it works. Awareness and knowledge of an innovation can be conveyed through different communication channels, including individuals, trainings, media advertisements, social networks, etc. (Rogers 2003: 169; Kaur, Kaur 2010: 292).

2. **Persuasion:** Persuasion occurs when a potential adopter forms a favorable or unfavorable attitude towards the innovation. The potential adopter mentally applies the innovation to the personal situation in the present and anticipated future. This is followed by a decision to try out the innovation or not to try it. The main activity in this stage is the potential adopter developing an opinion regarding the innovation and determining its value by weighing the benefits, costs, and trade-offs associated with the new technology. In particular, the potential adopter decides if the innovation is favorable or not to the personal preferences (Rogers 2003: 169; Kaur, Kaur 2010: 292; Ugochukwu, Phillips 2018: 364).

3. **Decision:** During this stage, the potential adopter decides to either reject or adopt the innovation. The trialability of the innovation is crucial for the individual to be able to take this decision because the result of the trial mostly determines to either adopt or reject the innovation (Rogers 2003: 169; Kaur, Kaur 2010: 292).

4. **Implementation:** The implementation stage arises when the individual starts using the innovation. At this stage, the adopter is able to clearly analyze the usefulness and applicability of innovation specifically to the personal context and needs. There is a continuous evaluation of the technology to ensure that it meets expectations. In the following, the adopter discovers whether or not the initial knowledge and perceptions of the innovation were true (Rogers 2003: 169; Kaur, Kaur 2010: 292; Ugochukwu, Phillips 2018: 365).

5. **Confirmation:** During the final stage, the adopter is seeking reinforcement for the adoption decision made, and the decision is being reaffirmed or rejected. The adopter seeks factual evidence to support the adoption decision. If the adopter is satisfied, the technology is objectively adopted. However, the adopter may reverse the previous decision if exposed to conflicting messages about the innovation which could trigger rejection of the innovation (Rogers 2003: 169; Kaur, Kaur 2010: 292; Ugochukwu, Phillips 2018: 365).

Rogers illustrates the innovation-decision process as an ongoing process in which the individuals within a social system do not adopt an innovation at the same time. Therefore, he classifies individuals into different adopter categories based on the timing of adoption. Rogers considers this an individual's level of innovativeness and describes the individuals in a category as similar in terms of their innovativeness. In his theory, innovativeness is the degree to which an individual is relatively in advance to adopting new ideas compared to other members of a social system. Furthermore, it demonstrates an individual's willingness to change common practices. The five adopter categories, according to Rogers, are innovators, early adopters, early majority, late majority, and laggards (Figure 4.2). Only individuals who have decided to adopt an innovation over time are included in the classification (Rogers 2003: 22; Sahin 2006: 19; Kaur, Kaur 2010: 292–293).

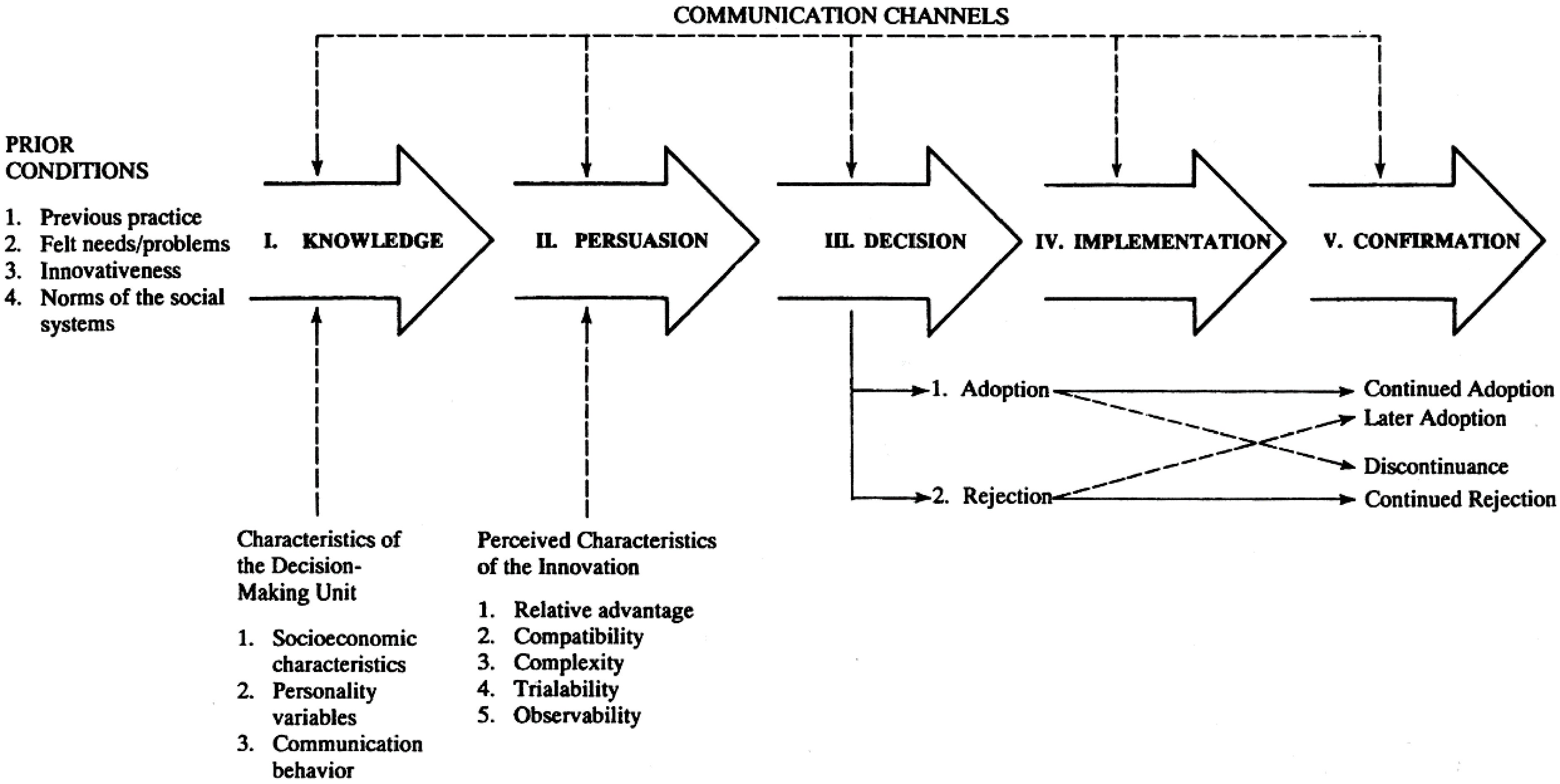



Figure 4.1 Innovation-decision process after E.M. Rogers
Source: Rogers (2003: 170)

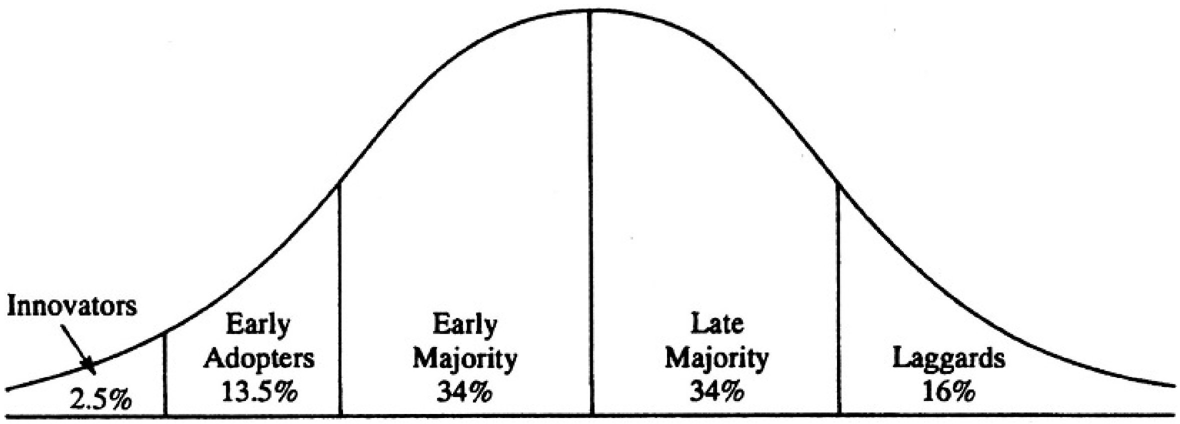



Figure 4.2 Adopter categories after E.M. Rogers
Source: Rogers (2003: 280)

**Rate of Adoption.** Rogers describes the rate of adoption as the relative speed with which an innovation is adopted by members of a social system. In general, it is measured as the number of individuals who adopt an innovation in a specific time period, for example, one year. Rogers showed that most of the variance in the rate of adoption of an innovation is explained by five attributes: relative advantage, compatibility, complexity, trialability, and observability (Box 4.1). In addition to these, other aspects affect the adoption rate, for instance, the type of the innovation-decision process (optional, collective, authority), the communication channels (mass media or interpersonal channels), the nature of the social system (norms or network interconnectedness), and the efforts of change agents who boost innovation diffusion (Rogers 2003: 221).

Rogers deduced several generalizations based on the innovation-decision process and its five classifications of adopters. Over time, adopter distributions follow an S-shaped curve approaching normality which research has shown extensively (Brown 1981: 20–21; Sunding, Zilberman 2001: 229–230; Rogers 2003: 274). Regarding age in general, no differences were found between earlier and later adopters. However, for other sociodemographic and socioeconomic variables, such as the number of years of education, literacy levels, the height of social status, and the size of an individual's unit (e.g., farm, company, school, etc.), differences could be distinguished between earlier and later adopters. Usually, earlier adopters are more likely to have a higher socioeconomic status than later adopters. Furthermore, Rogers explains that personality traits also differ between earlier and later adopters. Among other traits, earlier adopters have greater empathy and rationality, higher levels of intelligence, a more favorable attitude toward change, a more favorable attitude toward science, and a greater ability to cope with uncertainty and risk. Another characteristic that sets earlier adopters apart from later adopters is their communication behavior. As a whole, earlier adopters, among other characteristics, show more social participation, are more cosmopolitan, and have greater exposure to mass media channels as well as greater knowledge of innovations. Overall, research has shown significant differences between earlier and later adopters of innovations in sociodemographic and socioeconomic aspects, personality attributes, and communication behavior (Rogers 2003: 297–298).

### 4.1.2 Geographic Considerations

The role of geographic settings, particularly in relation to distance, has been emphasized strongly in adoption-diffusion research (Hägerstrand 1952, 1967; Rogers 1962; Brown 1968, 1977, 1981). In general, potential adopters who are in farther locations from a regional center are more likely to adopt new technologies later. This is due to patterns of communication as well as transport and travel costs for gaining information on a new technology, receiving training, and implementing the new technology. These costs increase with distance (Sunding, Zilberman 2001: 234–235). In this context, diffusion and barriers to adoption have become a prominent subject in geographic research. For an innovation to spread effectively throughout a population, region, or social group, geographic elements of distance, direction, and spatial variation need to be considered.

Environmental features, such as lakes, rivers, or mountains, as well as cultural environmental conditions, for example, built environments or industrial and agricultural areas, can have a distinct effect on the diffusion of an innovation. Furthermore, social characteristics related to human interactions, e.g., language variations, social class discrepancies, or rural-urban differences, can strongly influence how, when, and who will adopt an innovation. In this regard, diffusion studies are relevant because they aim at clarifying questions concerning the development of cultural differences due to environmental circumstances, the spatial configuration of cultural areas, and the evolution of culture-related features on Earth (Brown 1981: 16–17).

Physical environments set two barriers to adoption and diffusion: climatic variability and distance. Broad adoption and diffusion of a technology is a greater challenge across different climatic regions and varying ecological conditions. Likewise, an important factor for accelerated adoption is investments in infrastructure to reduce transportation costs, particularly roads and railroads, electrification as well as telephone and/or internet connection. In developing countries, distance in combination with poor infrastructure is a major obstacle to the adoption and diffusion of technologies. Geographic research has shown the importance of distance in adoption behavior and diffusion processes by providing three empirical regularities related to distance. The Swedish geographer Torsten Hägerstrand introduced the S-shaped curve for diffusion (1) from the field of rural sociology to the field of geography and found two more empirical regularities in the adoption-diffusion process, namely, the hierarchy effect of diffusion in space (2) and the neighborhood effect for diffusion in space (3) (Figure 4.3) (Brown 1981: 20–21; Sunding, Zilberman 2001: 229,235).

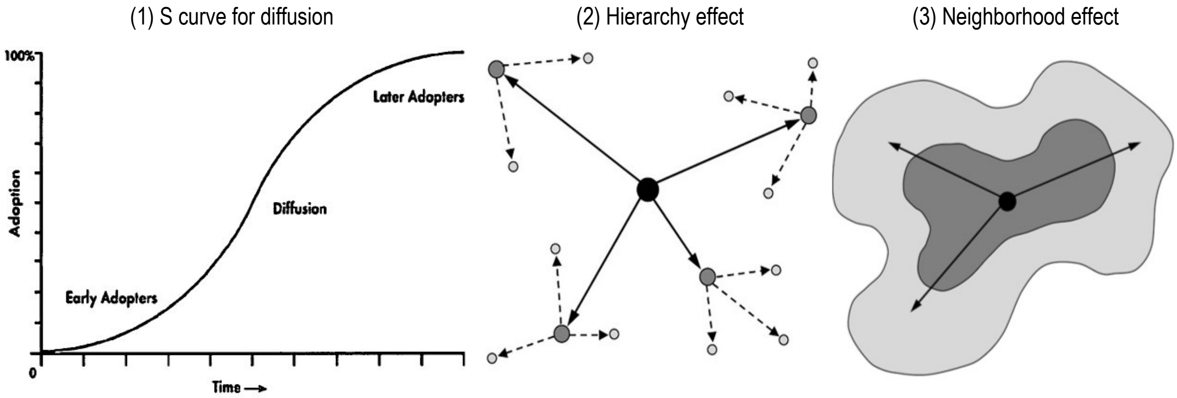



Figure 4.3 Empirical regularities in diffusion processes
Sources: (1) Rogers (1995: 11); (2) and (3) Bleha, Ďurček (2019: 335)

In general, regions that are farther away from a central point (e.g., major cities or regional centers) have a lower diffusion rate, and hence a slower overall diffusion. This emphasizes the importance of geographic circumstances related to distance and time for diffusion. The S-shaped diffusion curve visualizes this. It shows the evolution of the adoption rate over time. Adoption is relatively low in the initial period of the adoption-diffusion process and increases with time. This is notably influenced by the hierarchy and neighborhood effect. The hierarchy effect describes that the diffusion is expected to proceed from larger to smaller centers within a system. The neighborhood effect demonstrates that outside of a center, diffusion is expected to proceed outward from the center. The nearby locations are reached first and far-away locations are reached later. This also applies to the personal context of adopters. The likelihood of an innovation spreading from one adopter to another is higher if they are close than if they are farther away from each other (Brown 1981: 20–21; Sunding, Zilberman 2001: 229,235; Rogers 2003: 90–91).

## 4.2 Innovation Diffusion for Agricultural Development

In the field of agriculture, innovation diffusion plays a particularly pivotal role as a vehicle for change. Therefore, a great amount of literature is available discussing factors influencing the adoption and diffusion processes. For example, agronomists concentrate their interest on how emerging technologies could improve food production and enhance food security. In the field of development economics, technology transfer from developed to developing economies is a key objective to achieve agricultural and overall economic growth. Environmental scientists focus on how innovations could be employed for more efficient natural resource management use. Furthermore, private actors promote technologies that aim to reduce production costs to increase efficiency by selling tailored solutions to farmers, farmer groups, or others (FAO 2004: 30–31; Ugochukwu, Phillips 2018: 361).

**Adoption and diffusion of agricultural best management practices.** When farmers decide to adopt a new technology or practice, a wide variety of factors comes into play. On an individual level, the adoption of new farming practices depends on factors such as socioeconomic characteristics, personal needs, environmental factors, access to agricultural inputs, market demands, and extension activities (Bopp et al. 2019: 320–321; Connor et al. 2020a: 91; Wehmeyer, de Guia, Connor 2020: 3). Additionally, psychological factors have been shown to explain and affect the adoption behavior of farmers. For example, intrinsic and extrinsic motivation, risk perceptions, benefits perceptions, and affective reactions towards the innovation have been shown to influence the level of adoption (Dang et al. 2014: 12; Ekane et al. 2016: 642–643; Bopp et al. 2019: 321–322; Connor et al. 2020a: 98–99; Wehmeyer, de Guia, Connor 2020: 16). Agricultural technology diffusion strategies are diverse because diffusion at the community level requires decision-making processes. These are interrelated due to the multitude of possible interactions between the individual factors. It has been shown that social networks and trust in institutions are particularly important for the diffusion process of a new technology. Hence, well-established formal and informal networks, which promote an innovation through their specific communication channels, have a positive impact on the adoption (Rogers 2003: 19; Thierfelder, Wall 2011: 1275; Hunecke et al. 2017: 222). Appropriate dissemination requires an effective communication strategy to renew farmers' existing farming knowledge with information about the new innovation. The general objective is to demonstrate to the farmers that the innovation fits the five critical attributes (Box 4.1), which makes it superior to the traditional practice. This necessitates strategic communication to broadcast the knowledge of the new technology either through mass media or through interpersonal communication channels. In this context, agricultural extension services have been shown to be a remarkably successful instrument to foster change in agricultural and rural development (Rivera et al. 2001: 4; Thierfelder, Wall 2011: 1275).

Risk is a particularly important element that farmers consider when deciding on the adoption or rejection of an innovation. Farmers' notion is that the adoption of an innovation could increase the amount of risk associated with farming, particularly financial risk (Lee 2005: 1329). If farmers spend a large capital investment on a new technology or adapt their farming system to a new practice, they face the uncertainty of having potentially made an irreversible investment for a product they might not like (Sunding, Zilberman 2001: 235). Another aspect to consider regarding risk is the farmers' manner to adopt. Research has shown that farmers often do not adopt fully. Rather, they choose to partially adopt to avoid risks associated with full adoption, e.g., high capital investment cost, long training periods, infrastructural challenges, etc. In this regard, risk considerations are crucial in explaining these diversifications (Sunding, Zilberman 2001: 235; FAO 2004: 30; Mukasa 2016: 6). Financial aspects of reducing farmers' perceived risk investing in a new technology or practice can be alleviated by introducing product warranties with a technical support and maintenance system. This is often utilized by agribusinesses. The availability and quality of the support system also strongly determine the risk farmers face when planning on adopting an innovation. Additionally, other elements to reduce farmers' risk aversion are being used. They include, among others, communication of product information through educational materials in various media formats or hands-on demonstrations. For instance, farmers can visit farm machinery showrooms or receive new seed varieties samples by the manufacturer to test for free (Sunding, Zilberman 2001: 239).

**Institutional constraints to agricultural technology adoption and diffusion.** Farmers may face several institutional constraints related to credit regulations, environmental guidelines, infrastructure development, or input subsidies. These affect farmers' decision-making process and adoption behavior significantly, particularly regarding climate change adaptation strategies. Financial services, e.g., credits and loans, in relation to tenure status and financial status can be considered important constraints, especially for resource-poor farmers (Sunding, Zilberman 2001: 246; Lim 2004: 82). Increased household income and value of productive assets are directly related to increased access to credit. Thus, farmers who have fewer financial means must often use their own equity to finance at least part of the technology investment. This is because credit availment is often impeded due to their low financial status. In other cases, assets, such as land or the crop itself, are used as collateral for financing a new technology (Mohamed, Temu 2008: 76–78). Furthermore, uncertain conditions in agriculture and financial markets influence the credit market, which in turn affects adoption behavior (Sunding, Zilberman 2001: 246-247).

Regarding complementary inputs and infrastructure development for the diffusion of new technologies, increased demand for inputs and a drastic need for infrastructure enhancements may be experienced. This can result in a limited supply of necessary inputs. Subsequently, this leads to areas being excluded from the adoption-diffusion process due to slow infrastructure changes that constrain adoption among farmers. For example, HYVs require increased water and fertilizer use. If farmers are not able to purchase the required inputs and do not have the appropriate irrigation infrastructure, it is more difficult to entirely adopt the new varieties and use them to their full potential. Nevertheless, it has been shown that improvements in transportation infrastructure are useful for improving adoption because they guarantee a more reliable access to complementary inputs (Sunding, Zilberman 2001: 249). Input subsidies also affect farmers' adoption behavior, especially pesticide and fertilizer subsidization. Domestic agricultural price policies on fertilizers have been commonly used to increase agricultural production quantities. In China, for example, farmers started using chemical fertilizers with great success and were disincentivized to apply ecologically friendlier methods that could affect yield. Nowadays, overuse has led to environmental degradation. Subsidies are being limited as part of structural adjustments and sectoral policy changes. Instead, the elimination of subsidies and taxation of chemical inputs may lead to the adoption of more sustainable technologies (Sunding, Zilberman 2001: 252; Lee 2005: 1331; Wehmeyer, de Guia, Connor 2020: 2–3). Another aspect that influences farmers' adoption behavior is environmental regulations. Pesticide bans, for instance, provide a strong incentive for manufacturers to develop alternatives and for farmers to adopt other strategies, such as non-chemical treatments or biological control (Sunding, Zilberman 2001: 252).

### 4.2.1 Application of Innovation Diffusion Models in Southeast Asian Agriculture

Several authors have described the successful application of Rogers' innovation diffusion model and adapted variations for the agricultural context. Many studies focus on the adoption and diffusion of sustainable farming methods, such as integrated pest management (IPM), the use of crop rotations and intercropping systems, applying more organic fertilizer options (e.g., application of compost), and soil and water conservation measures (e.g., incorporation of crop residues or use of leguminous cover crops) (Pender 2007: 76). For example, Nordin et al. studied farmers' perception of new green fertilizer in granary paddy fields in Malaysia by applying the basic principles of Rogers' innovation diffusion theory (2017: 690). In Malaysia, the process of dissemination, training, and provision of resources is centrally managed by the Ministry of Agriculture who dispatches extension officers. Technology transfer is performed by introducing policies and creating a development plan for innovation diffusion projects. The results of the study showed that farmers lacked information provided by official sources. They had to find information about the new fertilizers through other sources, generally from informal networking, i.e., other farmers. The researchers conclude that extension services should focus more on raising awareness and providing knowledge because their function is crucial for technology transfer. They also suggest that manufacturers and distributors from the private sector should be included in disseminating knowledge about new technologies. Particularly, coordinated efforts between government extension officers and liaison officers from the private sector are necessary (Nordin, Redza, Saad 2017: 692-693,699-700).

Another example is a study conducted by Li et al. in which the factors influencing the technology adoption of lychee farmers in South China were examined (2020: 1). The researchers state that technology adoption in agriculture in China rather focuses on top-down promotion than analyzing farmers' adoption behavior. The main barriers to agricultural technology adoption are cost and risk. Agriculture extension services are seen as a key element for better technology adoption. The scientists emphasize the importance of trainings organized by extension services that show farmers how to apply a new technology and reduce uncertainties. The results showed that the better and more frequent contact with extension officers was, the higher the chance of farmers adopting a new technology. Ultimately, the researchers suggest that extension services should be promoted more strongly in agricultural policymaking to improve technology adoption (Li et al. 2020: 2,11).

Farmer field schools have been used to promote IPM practices in South and Southeast Asia. The FAO and other development organizations have started promoting these in the 1990s as an innovative approach to adult education and as a complementary alternative to extension services. Unlike traditional agricultural extension, farmer field schools enable groups of farmers to develop solutions to their own problems by using innovative and participatory methods. Through that, a learning network is created in which a participatory learning process takes place to improve human resource development. Farmers gain knowledge through sharing and receiving information from the network members (Pontius, Dilts, Bartlett 2002: 1; Mariyono et al. 2010: 1065; FAO 2020a). Studies reported positive impacts on rice yields and profits as well as decreased pesticide use when IPM was introduced through farmer field schools in several South and Southeast Asian countries, e.g., Sri Lanka, Thailand, and Vietnam (Feder, Murgai, Quizon 2004: 46). However, Peshin et al. suggest that although IPM programs resulted in savings and reduced pesticide use, farmers often did not perceive much of these positive impacts (2009: 19). As a result, the overall adoption rate was generally slow. Additionally, savings of time and effort were not immediately observed by farmers. This further negatively affected the adoptability of IPM and the rate of adoption (Peshin, Vasanthakumar, Kalra 2009: 19).

Overall, the adoption of technologies and practices may be delayed if the policy environment is unfavorable and extension programs are not reaching the farmers. In regard to climate change adaptation, a harmonized and enabling legislative direction is essential. It requires the inclusion of all stakeholders for the formation of appropriate policies. Especially policy and institutional reforms that correct inappropriate incentives (e.g., high input subsidies, ineffective extension activities, etc.) need to take place. These support farmers and the entire agriculture sector to transition to more sustainable agriculture, improved livelihoods, and reduced rural poverty. Ultimately, the general aim should be directed towards enabling a higher standard of living and a higher quality of life for the farmers under sustainable conditions (Lim 2004: 83; Hazell 2009: 22; GRiSP 2013: 67).

# Part II

# Case Study and Research Methodology

## Published work

The present chapter 5 is based on the following published book chapter.

**Wehmeyer H.**, Singleton G. R., Connor M. (2023): Introduction—How Swiss Foreign Aid for International Development Benefits Agricultural Development Across Asia. In: Connor M., Gummert M., Singleton G. R. (eds.): Closing Rice Yield Gaps in Asia – Innovations, Scaling, and Policies for Environmentally Sustainable Lowland Rice Production. Cham, Switzerland: Springer, p. 1–26. https://doi.org/10.1007/978-3-031-37947-5_1

Weblink: https://link.springer.com/chapter/10.1007/978-3-031-37947-5_1

# 5 An SDC-funded Development Project in Southeast Asia: The CORIGAP Project

In this chapter, the development of the CORIGAP project is presented. It is based on a previous collaboration between the SDC and IRRI under the 'Irrigated Rice Research Consortium' (IRRC). Starting with its predecessor the IRRC and continuing with the two phases of the CORIGAP project, this chapter describes the project's objectives and activities as well as the milestones reached during the project's period of eight years from 2013 to 2020. A special focus is given to China, Myanmar, and Vietnam.

## 5.1 Before CORIGAP: Irrigated Rice Research Consortium

The IRRC was one of the leading consortia in agricultural research and extension under the leadership of IRRI. It was an international platform for the development and dissemination of innovative production technologies for lowland irrigated rice farming systems. The IRRC fostered technology research in sustainable rice farming as well as the delivery of appropriate technologies for rice production in Asia from 1997 to 2012 (Palis et al. 2010: 4). Its main objective was to help rice farmers achieve increased profitability, food security, and environmental sustainability through innovative agricultural technologies adapted to their needs. The IRRC worked under a partnership framework between IRRI, national agricultural research and extension systems (NARES), and other stakeholders. The aim was to facilitate and intensify NARES research and technology delivery. With funding from the SDC, the projects and activities formed under the IRRC have contributed to making progress toward the Millenium Development Goals by helping resource-poor farmers increase food security, profitability, and environmental sustainability (Palis et al. 2010: V,2,4).

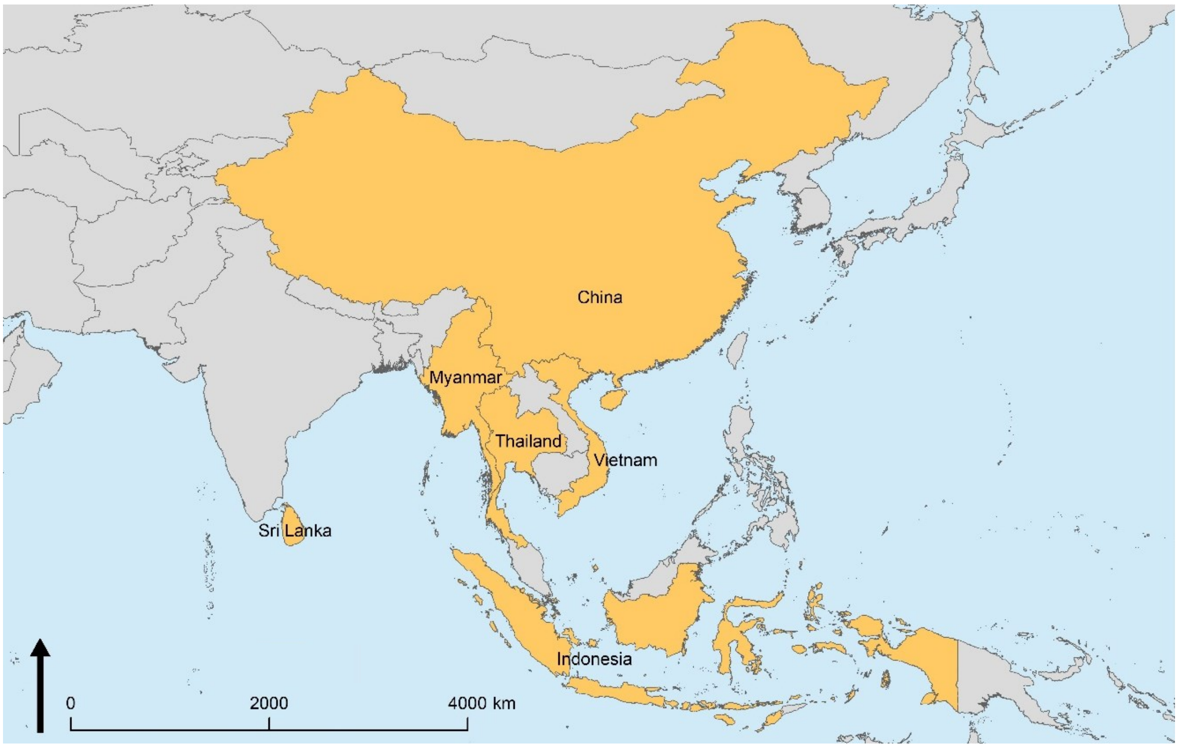
IRRC's Phase I started in 1997 intending to develop a multidisciplinary approach to irrigated rice research and a technology dissemination strategy in South and Southeast Asia. Instead of following the traditional top-down approach of knowledge production to diffusion, the IRRC followed an innovation system with evolving and interconnected actors. These actors were involved in the production, dissemination, and use of knowledge. During Phase II from 2000-2004, working groups based on regional needs assessed and developed research-extension partnerships. They continued their work during Phase III (2005-2008). Their progress led to the integration of technologies across disciplines and strengthened the linkages between research and extension partners to address effective technology delivery. In the IRRC's Phase IV from 2008 to 2012, the consortium was active in eleven Asian countries in South and Southeast Asia (Bangladesh, Cambodia, China, India, Indonesia, Laos, Myanmar, the Philippines, Sri Lanka, Thailand, and Vietnam). It put an increased focus on strengthening research extension networks to facilitate the delivery of technologies to improve food security and reduce poverty. The main objective was to increase rice production and smallholder farmers' household income through stronger collaboration between IRRI, NARES partners, and other stakeholders (Palis et al. 2010: 2–5).

The IRRC adapted its focus during Phase III to a broader strengthening of stakeholder partnerships to bridge research outputs and extension activities. The 'IRRC Country Outreach Program' (ICOP) was launched and facilitated stakeholder partnerships within the countries. The stakeholders were able to better ensure actual technology integration and impacts through integrative social learning. Stakeholders from various organizations in research and government, NGOs, and extension services, as well as the private sector and farmer organizations, formed multi-stakeholder partnerships led primarily by the NARES partners. This accelerated the scaling up and scaling out of best management practices. The first countries that were introduced to the ICOP were Myanmar and the Philippines in 2006 and Indonesia in 2007. The implementation of ICOP intensified the research-extension linkages and facilitated the work on national policy initiatives. The ICOP was extended to Thailand and Vietnam in Phase IV of the IRRC (Palis et al. 2010: 3).

During the final phase of the IRRC, the decision to continue the activities was taken. Hence, the conceptualization of the CORIGAP project began. Its objectives were decided upon the results and experiences gathered from the IRRC to continue the cooperation between the SDC and IRRI. The national IRRC partners had already started to take the lead on the technology development and demonstration activities in their respective countries due to the introduction of ICOP. The final step of the IRRC was to facilitate and strengthen NARES research and technology delivery through the launch of the first phase of the CORIGAP project. CORIGAP's first phase began in 2013 and lasted until 2016. The second phase of the project started in 2017 and ended in 2020 (IRRI 2014: 2; Palis et al. 2010: 3).

## 5.2 CORIGAP Phase 1: 2013-2016

The CORIGAP project is an agricultural development project funded by the SDC and led by IRRI. Its main objectives are to improve food security, advance gender and youth equity, and alleviate poverty. It does so by supporting farmers to optimize productivity, resource use efficiency, and sustainability of irrigated rice production systems. Closing rice yield gaps, increasing farmers' incomes, and improving environmental sustainability are the main projected outcomes. CORIGAP aims to benefit over 500'000 smallholder rice farmers (IRRI 2017a: 2; SDC 2020i). The project promotes national policies on agricultural best management practices to improve sustainable rice production and reduce negative environmental impacts. CORIGAP is active in six countries in South and Southeast Asia: China, Indonesia, Myanmar, Sri Lanka, Thailand, and Vietnam (Map 5.1) (IRRI 2020a). It builds on good agricultural practices and supports the development of science-based, quantitative tools and participatory methods. Multiple stakeholders such as national agriculture departments, civil society groups, farmer cooperatives, the private sector associated with the rice value chain, and NGOs are partnering together (SDC 2020c). A needs assessment analysis of smallholder rice farmers is the basis for the interventions to improve the management of lowland irrigated rice production (Willett, Barroga 2016: 2).




Map 5.1 Countries participating in the CORIGAP project in South and Southeast Asia
Cartography: H. Wehmeyer; Cartographic base: GADM (2020)

The main objective of CORIGAP Phase 1 was to assess farmers' agricultural practices. This gave a better understanding of rice yield gaps and their contribution to food security. It was able to determine the yield gaps for each project country and define farmers' needs for sustainable rice production. Through tools, such as the field calculator and participatory methods, e.g., learning alliances, CORIGAP also fostered collaborations and outreach. Hence, in its first phase, the project was able to generate evidence on farming practices through an integrated approach to crop management and natural resource management. Furthermore, it guided dissemination strategies for sustainable rice production with the goal of reducing rice yield gaps. These achievements positively impacted national policy decisions in the CORIGAP countries (IRRI 2014: 2,28-29; Willett, Barroga 2016: 7–8).

In Phase 1 of the CORIGAP project, the following activities were conducted in six irrigated rice granaries in South and Southeast Asia (SDC 2020c; IRRI 2020b):

1. Assessment of needs and constraints of farmers and other stakeholders along the rice value chain in six rice granaries to create appropriate monitoring and evaluation systems for improved rice production by introducing innovations.
2. Creation of the 'field calculator', a computational framework to evaluate integrated, high-yielding, and profitable rice production systems with minimum environmental footprint.
3. Use of adaptive research concepts to establish an iterative process between farmers, extension agents, and relevant rice value-chain partners to test cropping systems and technologies in two major rice granaries by 2016 and in six granaries by 2020.
4. Development of mechanisms for outreach and scaling up of best management practices to be effectively used by 10'000 smallholder farmers in Vietnam, China, and Thailand. This includes farmer participatory videos, business model development, and strengthening the market integration of farmers.
5. Improvement of NARES capacity and stakeholders' abilities to use the developed tools and methodologies and increase knowledge on sustainable rice production to generate changes at the policy level.

In Table 5.1, the technologies introduced during the CORIGAP project in the six project countries are described. These technologies serve as tools for farmers to support their development towards more sustainable rice cultivation. Different technologies were recommended for each country as farmers have different needs and are at different levels agronomically. Furthermore, environmental conditions also determined the introduction of a technology to a specific region or not. Overall, alternate wetting and drying (AWD), drum seeder, and laser land leveler are the technologies that were introduced in most CORIGAP countries.

In the following, the progress of CORIGAP Phase 1 is demonstrated year by year from 2013 to 2016, with a special focus on the countries that have been selected for the case studies.

**2013.** In the first year, progress in China and Vietnam was strongest due to the previous implementation of national policy programs during the IRRC Phase IV, namely 3CT in China and 'One Must Do, Five Reductions" (1M5R) program in Vietnam. In Thailand, Indonesia, and Sri Lanka, data collection and training activities for local staff were the major outputs (IRRI 2014: 2). Furthermore, the field calculator was developed as a decision support tool based on a program by Wageningen University for other crops (Wageningen University & Research 2012). For CORIGAP, the field calculator was established for rice using field data collected in Can Tho and An Giang Province in Vietnam. The field calculator summarizes data collected for rice production to indicate the environmental and economic impacts of different technological packages such as 1M5R (IRRI 2014: 7).

Table 5.1 Technologies and practices introduced by the CORIGAP project

| Technology | Countries introduced | Description |
|---|---|---|
| Alternate wetting and drying (AWD) | China, Indonesia, Sri Lanka, Thailand, Vietnam | A water management technique where irrigation is applied at intermittent intervals resulting in alternating wet and dry soil conditions. Hence, the soil is allowed to dry out for one or several days after the disappearance of ponded water before it is flooded again. This mitigates GHG emissions from rice production as the field is not continuously flooded. [1,2] |
| Combine harvester | Indonesia, Sri Lanka, Thailand, Vietnam | Mechanical harvesting machine that reduces postharvest losses and promotes sustainable mechanization as well as supports direct and indirect reduction of GHG. It combines several operations into one: cutting the crop, threshing, cleaning. [1,3] |
| Drum seeder | Indonesia, Myanmar, Sri Lanka, Thailand, Vietnam | A machine that plants rice seeds, preferably pre-germinated, directly in neat rows. It supports an efficient cropping process and sustainable mechanization. [1] |
| Ecologically-based rodent management | Indonesia, Myanmar, Thailand, Vietnam | Practice based on the principles of IPM that integrates a range of ecological management practices. They together provide a more effective management of pest species such as rodents. [4] |
| Flatbed dryer | Myanmar, Vietnam | A mechanical dryer that removes water from wet grains by forcing air through the grain bulk. [5] |
| High-yielding varieties (HYVs) | Indonesia, Myanmar, Sri Lanka, Vietnam | Improved rice varieties that are well adapted to soil conditions, tolerant to droughts, floods, and salinity, and achieve higher yields. They show a high response to chemical fertilizers, are shorter with stiff straw compared to traditional varieties, and mature faster. This enables farmers to grow two or three crops in a year. [6] |
| IRRI super bag | Indonesia, Myanmar, Thailand, Vietnam | A hermetic storage bag for cereal grains to be stored safely for extended periods. It extends the germination life of seeds from 6 to 12 months, controls insect grain pests without chemicals, improves head rice recovery, and provides quality seeds. [1,7] |
| Laser land leveler | Indonesia, Myanmar, Sri Lanka, Thailand, Vietnam | Laser leveling is a process of smoothing the land surface (± 2 cm) from its average elevation using laser-equipped drag buckets on a four-wheel tractor. Laser-assisted precision land leveling saves irrigation water, nutrients, and agrochemicals. It can also enhance environmental quality and crop yields. [8,9] |
| Lightweight thresher | Myanmar, Vietnam | A technology that helps to save labor costs, accelerates postharvest processes, and reduces yield losses when separating the grain from the straw. Many farmers use a power thresher technology to replace manual threshing. [10,11] |
| Mechanical rice transplanter | Indonesia, Myanmar, Sri Lanka, Vietnam | A mechanical rice transplanter is a manually operated machine which transplants rice seedlings in rows. Mechanically transplanting rice reduces fuel, labor costs, and water. It also supports direct and indirect reduction of GHG. [1,12] |
| Solar bubble dryer | Indonesia, Myanmar | A low-cost drying technology developed by IRRI, Hohenheim University, and GrainPro. It is superior to the traditional sun drying process because it eliminates the re-wetting of grains during rain and losses due to animals, spillage, and cars running over the grains if they are spread on roads. [13] |
| Three Controls Technology (3CT) | China | Nitrogen fertilizer saving technology that includes the control of nitrogen application timing and quantity, limits the number of tillers, and controls for pesticide applications [14] |

Sources: [1] Connor et al. (2021a: 2); [2] Sustainable Rice Platform (SRP) (2019a: 9); [3] IRRI Rice Knowledge Bank (2021a); [4] Singleton et al. (1999: 20); [5] IRRI Rice Knowledge Bank (2021b); [6] Grigg (2001: 6390); [7] IRRI Rice Knowledge Bank (2021c); [8] Chandiramani, Kosina, Jones (2007: 1); [9] Jat et al. (2006: 1); [10] IRRI Rice Knowledge Bank (2021d); [11] Adri et al. (2020: 3–4);[12] University of the Philippines Los Baños (2018); [13] IRRI Rice Knowledge Bank (2021e); [14] Wehmeyer, de Guia, Connor (2020: 2)

In China, a baseline survey and needs analysis were conducted. In total, 248 households in Guangdong Province that had either fully adopted, partially adopted, or not adopted the 3CT guidelines were interviewed. Additionally, focus group discussions with 34 farmers in four villages took place. The results showed that rice farmers have the potential to increase their grain yield by reducing fertilizer input. In particular, nitrogen and phosphorus use can be diminished by improved nutrient management. Farmers also mentioned rat and bird damage, lodging, low income from rice production, and lack of available labor as major constraints to their rice farming (IRRI 2014: 10–11).

In Vietnam, the focus was to extend 1M5R best management practices for sustainable rice production in the provinces of Can Tho and Long An. A new initiative on mushroom production was rolled out in one village in each province to provide more jobs for women and make better use of rice straw. Furthermore, the 'Small Farmers, Large Field' (SFLF) initiative was designed with the national partners and implemented at the project sites. SFLF aims to increase efficiency in rice production by better aligning smallholders to traders and millers through the consolidation of small fields of individual farmers. This creates larger fields while the boundaries of ownership and farming are maintained. Overall, 34'500 farmers participated in training on 1M5R in eight provinces in the Mekong River Delta. An estimated 240'000 farmers already implemented 1M5R. However, farmers' constraints included the need for improved market models for selling rice, inconsistent quality of seed, problems with straw management, and pest infestations (IRRI 2014: 13–15).

In Myanmar, CORIGAP supported capacity-building activities for staff on postharvest and ecological pest management training. Furthermore, research on natural resource management of rice-based cropping systems, best practices for reducing postharvest losses, GIS mapping of different domains for crop and stress management, and participatory varietal selection was supported (IRRI 2014: 24).

**2014.** Continued progress in China, Vietnam, and Thailand was made. Activities in Myanmar and Indonesia were aligned with national priorities for rice production. In addition, market chain studies through focus group discussions with multiple stakeholders were carried out in Indonesia, Thailand, and Vietnam. Learning alliances, a network of multiple stakeholders to promote learning on innovative practices and technologies at the community level, were established in Myanmar and Vietnam (IRRI 2015: 2–3, 2017a: 29).

In China, research and outreach work on reducing water consumption and reducing GHG emissions continued. Participatory demonstration trials for farmers and partners in three counties of Guangdong Province took place to promote 3CT and AWD (IRRI 2015: 7–8). Additionally, two field experiments were completed to examine GHG emission effects after the application of the innovations. Results indicated that the combination of 3CT and AWD increased yields and economic returns compared to 3CT alone and farmers' traditional water practice. Methane emissions were also significantly reduced. Hence, AWD could be used for maintaining a stable yield while reducing water consumption and decreasing GHG emissions (IRRI 2015: 7–11).

In Vietnam, the focus was put on the continuous extension of 1M5R in the provinces of Can Tho and Long An as well as on working with the national partners on the promotion of SFLF. The field calculator was further refined by comparing three different management approaches, namely, 1M5R, SFLF, and regular farmer practice. Furthermore, business models for better management of rice straw were developed by the national partners to strengthen extension on market integration of mushroom production. In general, companies tend to encourage the adoption of good agricultural practices for contract farming arrangements (IRRI 2015: 12–15).

Activities in Myanmar examined natural resource management of rice-based cropping systems, introduced best management practices for reducing postharvest losses, conducted GIS mapping of different domains for crop and stress management, and promoted participatory varietal selection. A gender study in Maubin Township in Bago Region was initiated and a learning alliance in the same township was established (IRRI 2015: 20).

**2015.** The CORIGAP countries showed progress in identifying the causes of yield gaps. They continued to demonstrate the integration of technologies for reducing agricultural inputs. Field-tested interventions resulted in increased profitability mainly due to diminished input costs for farmers in Vietnam, Indonesia, Thailand, and China. Potential could be seen in Sri Lanka and Myanmar, where the balanced use of fertilizer remains a challenge. Further, CORIGAP was able to achieve community-level impacts through supportive activities, such as postharvest grain protection, learning alliances, and capacity-building activities as well as local and national policy support. In total, a network of 65 farmer groups was working with local partners to transfer research outcomes into community benefits. However, the progress of CORIGAP was uneven between the countries, particularly with regard to establishing integration of systems to support changes in on-farm practices. For example, China and Vietnam demonstrated higher rates of technology adoption and environmental improvements. In Vietnam, farmers also already forged a stronger link with the private sector compared to Myanmar and Thailand. Therefore, Vietnam represents a model that could be applied to the sites in the countries that are less advanced (Willett, Barroga 2016: 2-3,15-16).

In China, the extension of research recommendations continued. 3CT and AWD were demonstrated to farmers in participatory field trials as a package to obtain higher yields with fewer inputs and higher economic returns. Results of trials under CORIGAP showed evidence that farmers could reach 13 % higher yields by adopting 3CT and AWD. Multiple extension activities were conducted. This included the positioning of technical boards, email and website communication as well as trainings and field days. Since 3CT was aligned with China's policy on environmental protection and its use was recommended by national rice production programs in 2012, more funding from the government for the diffusion of 3CT was secured (Willett, Barroga 2016: 15,17,23).

CORIGAP activities in Vietnam included the diffusion of best management practices through trainings organized by the local partners. Policy advancement supported the scaling out of activities on entrepreneurship through contract farming. The local learning alliance promoted practices for rice straw management and mechanization as well as mushroom production, including universities and the private sector. Of all CORIGAP countries, Vietnam demonstrated the most developed market integration. Close linkages between rice producers and rice purchasers, such as millers and distributors, were established. This dynamic also drove the adoption of the best management practices included in 1M5R and SFLF. Evidence of increased net profits through the adoption of 1M5R and SFLF was found due to farmers reducing their production costs. However, farmers expressed difficulty reducing the seed rate, and little progress in reducing the 27 % yield gap was made. Furthermore, increasing farm profitability through improved rice quality and reducing environmental stress remained challenging. One possibility is the intensification of contract farming. Farmers could be rewarded for their efforts to improve rice quality and for adopting sustainable farming practices. Reports showed that buyers would give a premium per kilogram of rice. They would pay 4−5 % above market value if the rice were produced under SFLF (Willett, Barroga 2016: 9-10,13-14,16,23).

In Myanmar, the CORIGAP activities were consistent with the government's priorities, but the project did not significantly influence agricultural policies. Creating learning alliances was the central undertaking. These introduced stakeholders to improved postharvest activities and increasing rice quality with better varieties. The private sector engaged in capacity-building activities. The agronomic analyses showed that rice yields were considerably lower compared to the other project countries. The use of low-quality seeds coupled with low input use was prevalent. Myanmar, therefore, differs from the other CORIGAP countries because yield gaps could be diminished by increasing input use to raise overall rice production, rather than reducing fertilizer and pesticide use as it is promoted in the other countries. Through the adoption of recommended practices, particularly on fertilizer use, a similar potential for increased profitability could be expected (Willett, Barroga 2016: 13,19,24,27).

**2016.** The results of the yield gap analysis in four CORIGAP countries demonstrated that the exploitable yield gaps ranged from 23-42 % (1.4–3.8 t/ha) (IRRI 2017b: 2; Stuart et al. 2016: 50). Furthermore, the findings of a gender study showed that there is a research gap regarding the state of gender equality in Southeast Asian agriculture (Akter et al. 2017). Regarding adaptive research strategies and multi-stakeholder learning alliances, efforts were intensified and the approaches in each country were aligned with national initiatives on food security. Overall, 125'000 households were reached during CORIGAP Phase 1 (IRRI 2017b: 3–4).

In China, the extension activities of 3CT through demonstration sites were the main activity. 3CT was showcased at 68 demonstration sites in Guangdong, Jiangxi, Guangxi, Hainan, and Zhejiang Province. Evidence demonstrated a reduction of yield gaps and increased profits. Nitrogen input decreased by 13.5% and yields increased by 9.3%. Farmers reported a mean increase in profit of 301 USD/ha per season (IRRI 2017b: 2).

In Vietnam, working with value chain stakeholders was rather difficult because of the reluctance of actors to reveal sensitive business information. Furthermore, the private sector and public stakeholders emphasized mostly economic sustainability. Therefore, more training on the three dimensions of sustainability for the stakeholders should be included. Overall, the rice value chain evolved from traditional procurement to modernized procurement. Especially direct sales from farmers to exporters were on the rise. Exporters focused on more efficient ways of sourcing high-quality rice (IRRI 2017b: 2,7).

With 37 %, Myanmar had one of the highest yield gaps out of the six CORIGAP countries (IRRI 2017b: 2; Stuart et al. 2016: 51). There is a great potential to increase yields through best management practices. Linkages between farmers and markets that pay a premium for better quality rice and the adoption of best management practices were implemented through the learning alliance. This included the adoption of mechanized drying combined with inventory storage, the development of suitable business models for farmers, and exchange visits for farmers to premium markets. In addition, awareness at the private-sector level was created regarding the effect of grain quality on farmers' practice during production and postharvest (IRRI 2017b: 2).

## 5.3 CORIGAP-Pro: 2017-2020

In the second phase, the project focused on the intensified integration of country-specific best management practices to further reduce yield gaps. CORIGAP-Pro aimed to reach 500'000 smallholders in six granaries. Yield increases of 10% and profits of 20% for 200,000 households in South and Southeast Asia were targeted by 2020 (SDC 2020i). Consequently, the priorities in Phase 2 were scaling out and scaling up the outcomes of Phase 1. The main activities included outreach to farmers and the private sector. Also, in-depth training of policymakers on the integration of sustainable management practices was key. The alignment of activities with national extension programs was crucial to guide national policy developments. Learning alliances and the inclusion of the private sector and NGOs helped foster this goal. At the end of this phase, the adoption of best management practices would demonstrate environmental benefits, improve gender- and youth-positive developments, and provide opportunities for smallholders in the rice value chain (IRRI 2017a: 2–4).

In Phase 2, the following activities were conducted in project countries (IRRI 2017a: 4; SDC 2020i):

1. Increase capacity of NARES, intensify public-private partnerships via learning alliances for strengthened linkages with the private sector for outreach purposes.
2. Adoption of a more integrated approach to mechanization to increase environmentally sustainable irrigated rice production in all CORIGAP countries.
3. Closer contact with policymakers to provide policy recommendations on natural resource management in rice farming and assessment of strategies for inclusive value chain upgrading.
4. Expansion of best management practices and technology dissemination activities in Myanmar and Sri Lanka with the start of the field calculator.
5. Improvement of profits of smallholder farmers in a gender-inclusive manner.

**2017.** Large-scale diffusion of best management practices continued in Indonesia, China, and Vietnam. Overall, 379’000 smallholder farmers were reached in the CORIGAP countries. Additionally, more than 86’000 smallholders increased yields and profits by more than 10 % on average. A survey was conducted in Indonesia and Myanmar to assess the influence of CORIGAP technology adoption on the income and spending power of smallholder families (IRRI 2018b: 2–3; Connor, San 2021; Connor et al. 2021a; b).

In China, large-scale promotion of 3CT with the addition of AWD was expanded across seven provinces through training events for extension specialists and key farmers. In total, 5399 new farmers were reached. 3CT was adopted by more than 200’000 farmers in Guangdong Province. Farmers increased grain yields by 11 % and profit by 14 % (IRRI 2018b: 9–10).

In Vietnam, more than 51’000 farmers across eight provinces adopted 1M5R recommended practices in addition to the 85’000 farmers reached during CORIGAP Phase 1. CORIGAP activities were mostly concentrated in the provinces of Can Tho and An Giang and focusing on the diffusion of 1M5R and SFLF. Field trials in Can Tho Province demonstrated that farmers who adopted the recommended practices and technologies had a mean profit increase ranging from 14 % to 30 %. However, there was no yield gain. Profits increased due to savings in labor costs and fertilizer use. Furthermore, market data was collected to achieve policy recommendations for upgrading the rice value chains in the Mekong River Delta (IRRI 2018b: 3,14).

In Myanmar, activities included conducting multiple surveys on household farming data and on the financial benefits of those who adopted recommended practices as well as farmer interviews on livelihood changes. Learning alliance meetings and cross-site learning activities were conducted on topics such as mechanization of land preparation through laser land leveling. Two demonstrations were conducted to increase awareness of the benefits of this technology (IRRI 2018b: 8,11-12).

**2018.** Progress in all six CORIGAP countries was strong. In total, 7520 NARES partners were trained on the promotion, application, and management of best management practices. More than 600’000 farmers were reached and 118’000 farmers adopted recommended practices and technologies. An in-depth analysis of yield gaps in Vietnam, Thailand, and Myanmar revealed that they were mainly due to unsuitable management practices. Farmers’ rice variety selection was also shown to have an impact. The potential to close yield gaps by optimizing the sowing and planting dates was high. Consequently, the next step was to understand the importance of various factors towards the management of the yield gaps and to comprehend how socioeconomic aspects influence farmers’ management choices (Stuart et al. 2016: 8,10-11; IRRI 2019a: 3,28).

In China, outreach activities in Guangdong Province were supported by the World Bank project on non-point source pollution (Chapter 7.3). More than 300’000 farmers participated in trainings and promotion events on 3CT, AWD, and conservation agriculture. Results of field trials on water use for rice cultivation showed a reduction of more than 20 % and a substantial decline in methane emissions. Fertilizer rates dropped by 36 %, pesticide use decreased by more than 50 %, and yields increased by 8 % after four years (IRRI 2019a: 7,9,13-14).

In Vietnam, the World Bank-funded ‘Vietnam Sustainable Agricultural Transformation’ (VnSAT) project facilitated scaling out 1M5R recommendations. It incentivizes farmer organizations to motivate farmers to adopt 1M5R practices and technologies. They then receive financial support for machinery and infrastructure upgrading. A major area of work is promoting the mechanization in rice harvesting processes and climate mitigating rice straw management, particularly rice straw burning. A survey on farmers’ trust in institutions, perceptions of risks, acceptance of the methods, and knowledge about climate change regarding different rice straw management options was conducted. The findings showed that farmers burned their rice straw although they perceived high risks, few benefits, and low levels of acceptance. However, farmers were aware of climate change, but their sustainable behavior depended on the acceptability, feasibility, and perceived benefits of the sustainable options for straw management (IRRI 2019a: 10; Connor et al. 2020a: 90, b: 1).

In Myanmar, survey results showed that farmers adopted a variety of best management practices and technologies. They also experienced increased yields and higher incomes (Chapter 10.3.2). In addition, interviews were conducted to investigate farmers' perceived changes through the adoption of best management practices for rice farming. Farmers mentioned that their living conditions and livelihoods had improved and that they were able to expand their farm business as well as produce rice more sustainably (IRRI 2019a: 9; Connor, San 2021: 56; Connor et al. 2021b: 1).

**2019.** In total, more than 750'000 farmers were reached since the beginning of the CORIGAP project in all six countries (IRRI 2020c: 2–3; SDC 2021c). Over 130'000 farmers adopted the recommended practices and technologies, and farmers increased rice yields and profits. Training events in China, Myanmar, and Vietnam were co-funded by World Bank projects that promoted best practices. This also enhanced CORIGAP's outreach (IRRI 2020c: 2–3).

In China, the out scaling was mostly achieved as part of the World Bank project. Overall, more than 300'000 farmers participated in activities promoting 3CT, AWD, and conservation agriculture. First evidence from farmer field diaries showed that farmers who adopted the technologies improved yields by more than 10 % and profits by more than 13 % compared to the standard farmer's practice. Additionally, a survey on farmers' perceptions of 3CT with 142 participants was conducted in three townships of Guangdong Province (Chapter 8) (IRRI 2020c: 7; Wehmeyer, de Guia, Connor 2020).

In Vietnam, the main CORIGAP activities took place in Can Tho Province. Continued extension activities of 1M5R were the main focus of 1M5R. This was achieved by working closely with the national partners on SFLF to better align farmers with traders and millers. The demonstration of farming techniques for mechanization of sowing, a field day that included a series of seminars with participants from the public authorities, the private sector, and many farmers as well as technicians, were organized. The outreach of best management practices was further facilitated by the World Bank VnSAT project, which reported more than 800'000 beneficiaries, including all people residing in a rural household. Additionally, a survey on farmers' perceptions of 1M5R with 465 participants was conducted in the provinces of An Giang and Can Tho (Chapter 13) (IRRI 2020c: 8,38; Connor et al. 2020a: 92–93).

In Myanmar, activities focused on increasing rice productivity in an environmentally sustainable manner. Field sites were established in six villages working with 28 farmers. Demonstration of improved land preparation, benefits of quality seed, direct seeding via drum seeder and mechanical transplanter as well as community actions for rodent management, site-specific nutrient management, weed management, and improved postharvest practices were included in the field activities. Outreach was intensified through linking CORIGAP with the World Bank funded 'Agricultural Development Support Project'. A pilot field project based on the outputs from Vietnam on sustainable rice straw management technologies and business models was established by partnering with the national Agricultural Mechanization Department (IRRI 2020c: 27).

**2020.** The COVID19 pandemic challenged the research activities. Planned documentation of some project outcomes and impacts was impeded. Furthermore, working directly with the research partners in the countries became impossible and some activities were subsequently delayed, especially field surveys. Work shifted to online meetings and webinars as a response to the challenge. The CORIGAP countries were affected differently by the pandemic. Hence, research opportunities were impacted differently in the project countries. In Vietnam, the situation was managed well, allowing for a continuation of most of the field activities. Activities in China and Myanmar were paused. New research addressing some of the effects of the crisis was initiated by CORIGAP. For example, a study on farmer inclusiveness in the context of the COVID19 pandemic and how it affects the rice value chain was launched. In Myanmar, the fragile political situation since February 2021 has halted the project. In-country colleagues have been unable to continue their research activities. At this stage, there is no clear path to overcome this disruption (IRRI 2021: 6–7).

# 6 Research Methodology

In the first part of this chapter, the rationale for this thesis is illustrated. This is followed by a description of the research gaps and the operationalization of the research questions. In the second part, the data collection approach is explained. The different questionnaire types are discussed, including a detailed description of the survey questionnaires. Lastly, the final datasets used for the case study analyses are specified.

## 6.1 Rationale

The context of this thesis is embedded in a multidisciplinary perspective on the impact of the CORIGAP project. It investigates sustainable agricultural development promoted through adoption-diffusion processes (Figure 6.1).

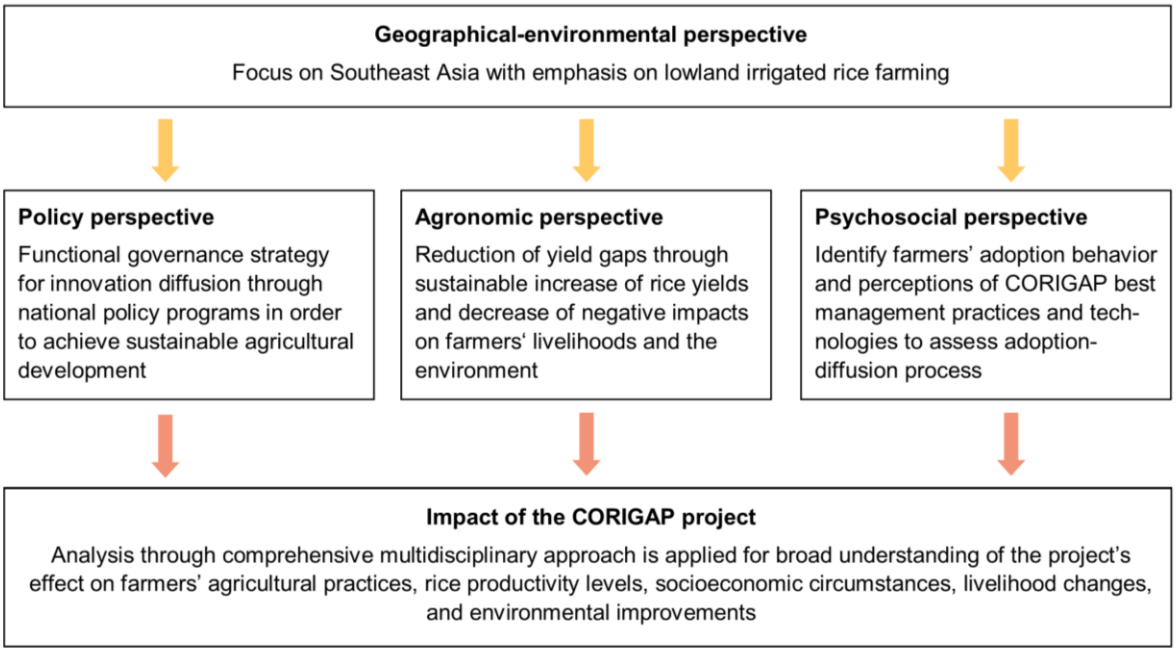



Figure 6.1 Empirical research model on the impact of the CORIGAP project using a multidisciplinary approach
Concept: H. Wehmeyer (2021)

The first perspective of this study is the geographical-environmental perspective focusing on Southeast Asia. This aspect is further narrowed by concentrating on lowland irrigated rice farming as well as the environmental and socioeconomic specificities of the CORIGAP countries. This also includes common development hurdles that affect the rice agriculture system in each project country. The associated geographic insights can then be applied to farming policies for sustainable agricultural development. Therefore, the second perspective of this study is the policy perspective. This aspect is necessary to link farmers and farmer organizations, researchers, extension agencies, the private sector, and government officials. A comprehensive approach over all levels of the agriculture sector is necessary. It has been shown that involving all stakeholders to carry out a governance strategy for sustainable agricultural development is pivotal for a successful outcome (Neef, Neubert 2011: 180; Hargrove, Heyman 2020: 3). The CORIGAP project specifically approaches this aspect holistically. Several project countries have applied the learning alliance concept in which farmers and different stakeholders have participated in trainings and workshops together. The third relevant perspective for understanding the impact of the CORIGAP project is the agronomic perspective. This thesis concentrates on the project's main objective to sustainably increase rice yields without raising the burden on the environment from intensive rice farming; thereupon, achieving the reduction of rice yield gaps and improving the environment of lowland rice farming ecosystems. In this regard, farmers' economic and social circumstances are decisive for implementing a suitable technology adoption-diffusion strategy. Each CORIGAP country has developed a specific strategy to reach the farmers optimally. China's agronomic focus lies in vastly reducing the negative impacts of input overconsumption and reaching yield stability. In Vietnam, the objective is to decrease agricultural input use and improve agricultural efficiency for growing higher-quality rice. Myanmar is aiming at increasing productivity levels while avoiding environmental degradation and attaining stable livelihoods for farmers. Finally, this thesis includes the psychosocial adoption perspective. This is necessary to understand farmers' adoption behavior and perceptions of the CORIGAP recommended practices and technologies. By including the views of the beneficiaries and their experiences with these in the assessment, a better picture of the adoption-diffusion process can be generated. Ultimately, a comprehensive approach is applied to the analysis of the impact of the CORIGAP project. The findings and conclusion of this thesis can advance policymaking for upgrading rural lives, improving the economic prospects of rural livelihoods, and enhancing the social development of farmers.

**Research Gaps.** A large number of farmers, namely more than 700'000, were reached in South and Southeast Asia by 2020 through the extension activities promoted by CORIGAP (IRRI 2020c: 3). Nonetheless, the success of the CORIGAP project in increasing rice yields has not yet been analyzed in detail. So far, it has been shown that there is a large variation in the size of the yield gaps in the project countries (Stuart et al. 2016: 50). Since two survey cycles on farmers' agronomic performance have been completed, the evaluation of the impact on rice yields and farmers' profitability can be undertaken. Other aspects of CORIGAP's effect on farmers' lives have not yet been examined much. The social impact of the adoption of the recommended technologies has not been explored in depth. Yield and profitability changes can affect farmers differently regarding factors such as social and human capital as well as health and food security. Therefore, farmers' perceptions of such changes need to be analyzed. This can serve as an indicator of the broader impact of the CORIGAP project on rural development. Furthermore, this can lead to the design of new objectives to further improve rural livelihoods in Southeast Asia. In this respect, the long-term adoption of sustainable best management practices is crucial for farmers to benefit from these changes even after the ending of the project. Consequently, the analysis of farmers' satisfaction with the new technologies and practices needs to be investigated. Only a little research on how applicable and rewarding the adoption of the practices and technologies has been conducted. By examining farmers' perceptions of these, an adoption-diffusion tendency can be recognized. This is important for adapting future activities related to extension efforts and dissemination strategies. Finally, long-term adoption is critical with respect to achieving a long-lasting beneficial environmental impact. Because environmental change can take longer, it is of great significance that farmers have definitively adopted the recommendations. This aspect of the CORIGAP project has not yet been investigated much. Overall, a clearer picture of how the project has transformed farmers' economic and social livelihoods as well as environmental circumstances is central to this thesis.

### 6.1.1 Research Questions

Three main research questions were conceptualized to analyze the impact of the CORIGAP project on 1) farmers' agricultural performance, 2) farmers' adoption behavior and perceptions of sustainable best management practices, and 3) overall project-level analysis and implications for future development projects. In the following chapters, these are operationalized for each country analysis within the scope of the country's project objectives. Furthermore, comprehensive research questions on the overall impact of the project duration were formulated to conclude this thesis from a project-level perspective.

1. **Which socioeconomic and agronomic changes occurred for rice farmers under the CORIGAP project in China, Myanmar, and Vietnam?**
    - Have the rice yields increased in the selected countries over the course of the CORIGAP project?
    - How has farmers' input use, yield, and income changed within and between the farmer groups since the introduction of the recommended best management practices?
    - What are the differences between the selected countries regarding the agronomic indicators, namely input use, rice yield, and income level?

2. **How did the adoption and diffusion of the CORIGAP recommended practices and technologies affect farmers' livelihoods, including environmental, social, economic changes?**
   - To which degree did farmers adopt the recommended best management practices and technologies, and if farmers decided not to adopt, what were the reasons for their rejection?
   - What are farmers' perceptions of the practices and technologies regarding their benefits and disadvantages as well as satisfaction and expectations for long-term adoption?
   - How did livelihood dimensions change due to the adoption of the new practices and technologies?
   - Have farmers perceived environmental changes since having adopted the practices and technologies, and, if so, which kind of differences did they see?

3. **Which implications do the CORIGAP activities have on rice farmers in Southeast Asia?**
   - What is the potential of sustainable change to the rice systems of the three selected countries?
   - Did the CORIGAP project have a sustainable and long-lasting impact on the farmers' agricultural and socioeconomic situation?
   - Which elements should be included or emphasized for future adoption-diffusion development projects in the agriculture sector?

### 6.1.2 Sample Selection

Three countries – China, Myanmar, and Vietnam – serve as case studies to examine the agronomic, social, and environmental impact of the CORIGAP project. These countries have been selected based on their specific project focus, particularly regarding socioeconomic and environmental aspects. Furthermore, they were chosen due to their different intervention strategies adapted to each socio-cultural and political setting. China and Vietnam were selected to analyze a country-specific technology or intervention policy program that has been implemented through and promoted via the CORIGAP project. These are 3CT in China and the 1M5R national policy program in Vietnam. They have been developed specifically for the rice farmers in the respective country and adapted according to the local farmers' needs. Both policy programs have been promoted by national and regional governments. In Myanmar, the project focus lied on the introduction of a multitude of new practices and technologies related to achieving sustainable rice production. These included improved varieties, sustainable input management, and adapted mechanization. Farmers were able to choose which and how many technologies and practices to adopt. They were being supported by the local extension staff when they expressed the wish to adopt the practices and technologies. They also received information materials next to the demonstration trainings. Since the agriculture sector in Myanmar is not as developed as in the two other countries, a different approach to the diffusion of the best management practices was chosen. Regarding the other CORIGAP countries, the reasons for not including them in this thesis are diverse. Indonesia was not selected due to limited data availability and time constraints. Sri Lanka had not introduced CORIGAP related best management practices at the beginning of this thesis. In Thailand, the data availability was limited due to the low number of participating farmers in the household survey.

## 6.2 Data Collection Approach

Collecting farmer information on farmers' agricultural practices can be done using several methods. For this research, conducting questionnaire-based surveys through face-to-face interviewing was chosen as the main data collection method. Two approaches for gathering farmer data were applied throughout the CORIGAP project. In the beginning, paper-and-pencil interviewing (PAPI) through an enumerator was used for collecting farmers' household baseline data. This method was replaced by computer-assisted personalized interviewing (CAPI) with the assistance of an enumerator in the late Phase I and used for the entire Phase II. It was applied for the remaining household baseline and endline surveys as well as for the perception surveys.

**Paper-and-pencil interviewing.** For this method of data collection, a paper questionnaire is filled out manually either by the interviewer (PAPI interviewer-administered) or by the surveyed person themselves (PAPI self-administered). PAPI is an effective method for surveying a small sample with a simple questionnaire that would take longer to be programmed into a computer-assisted interviewing (CAI) tool (Lavrakas 2008: 573). Another benefit is the fact that it is not reliant on a technological system, such as a computer or having an internet connection during the interviews. In addition, it does not require technical expertise or programming skills. Hence, it can be practical for survey implementation in remote areas where uncertainties may be encountered and changes to the survey design would have to be made (World Bank 2020b).

In general, PAPI is inferior to CAI in many ways. It is considered a rather outdated method for data collection if the aforementioned exceptions are not present. PAPI is mainly limited by the sample processing and the limitation of possible questionnaire complexity compared to CAI. First, sample processing has to be done manually. This entails an increased risk of error during the interviewing process as well as during the data digitalization process. Especially the non-response of questions and legibility of open-ended questions can be problematic (Lavrakas 2008: 573–574). Although there are various possibilities to digitize data through scanning PAPI questionnaires, errors or missing data fields as well as falsely interpreted handwriting remain a risk (World Bank 2020b). Sample processing is more time-consuming and error-prone than with CAI. Second, a PAPI questionnaire has limited range control possibilities regarding outlier values during the interview. It cannot include accurately adapted questions based on respondents' earlier answers. Third, adequate data archiving can pose a challenge for PAPI questionnaires as physical storage is required (Lavrakas 2008: 573–574).

**Computer-assisted personalized interviewing.** For realizing a CAPI survey, a digital device such as a tablet, mobile phone, or computer is used. Data is collected by an in-person interviewer to administer the questionnaire to the respondent. The enumerator records the respondent's information directly into a questionnaire application software on the digital device during the interview. The use of CAPI questionnaire surveys started in the late 1980s. It has since become the standard method for face-to-face digital data collection (Lavrakas 2008: 118–119). The main advantages of using a CAPI tool are its efficiency and facilitation of logic checks, validations, requirement options, and skip patterns during an interview. These assure a higher quality dataset. They allow for easier data validation and cleaning during and after the interview process. The collected data can immediately be uploaded and stored – if an internet connection is available – in an electronic format. Furthermore, enumerators can be monitored on a regular basis to avoid misunderstandings, erroneous data entry points, and other possible mistakes (World Bank 2020c). CAPI questionnaires generally allow more complexity than PAPI questionnaires. Therefore, they require a greater amount of preparation rather than post-processing (Lavrakas 2008: 69). Depending on the objective of the survey, this can be an advantage or disadvantage. CAPI-based questionnaire surveys are generally more efficient for quantitative data collection, while a PAPI questionnaire would be a better option for qualitative data collection (World Bank 2020c).

The main considerations for using a CAPI tool are the preparation time, technological and programming knowledge of the survey developers and enumerators, and wireless connection as well as the access to CAPI-appropriate devices. Preparing a questionnaire for a CAPI tool requires an exact survey design preparation and an elaborate questionnaire progression plan. This is due to the complex levels which can be programmed into the CAPI application. Therefore, the preparation time of a CAPI-based survey questionnaire takes considerably longer in most cases than preparing a PAPI survey questionnaire. Often enumerators require technical training before interviewing the respondents to prevent problems during the interview process. Another possible difficulty in using CAPI questionnaire tools is the need for electricity and internet connectivity. This is not possible under every circumstance. In the case of an uncertain technical setting in the field, a PAPI questionnaire survey would be a better option. Finally, the cost of acquisition of digital devices for conducting a CAPI questionnaire survey and the risk of theft during the interview process could be a potential disadvantage for using this method (World Bank 2020c).

**Surveybe.** For the CORIGAP household baseline surveys in Indonesia, Thailand, and Vietnam, the CAPI tool Surveybe was selected to conduct the surveys. It was introduced to allow for enhanced time efficiency during the interview process, save costs for data encoding, and increase data quality (IRRI 2014: 19).

**Dimagi CommCare.** The CommCare application was used for conducting the household endline surveys in Indonesia, Myanmar, Thailand, and Vietnam. It was also employed for the perception surveys in China and Vietnam. This CAPI platform developed by Dimagi, Inc. allowed building a more complex digital survey questionnaire application compared to Surveybe. It increased the efficiency during the interview process and facilitated the data cleaning and validation activities. The creation of the survey questionnaire in the CommCare application dashboard was faster and more user-friendly. Pretesting of the application and correcting errors could be done immediately in the app-building program. The CommCare application offered several possibilities to reduce input mistakes during the interview process, data validation procedure, and export of the final dataset. Thus, it was possible to strongly decrease the risk of missing data and unrealistic values. In addition, the time for data validation was reduced to a minimum. Quantitative limits were programmed as part of data quality assurance for the numerical questions. Furthermore, the CommCare tool was especially beneficial for managing multiple questionnaires in different languages. It could be deployed in several countries. CommCare also offered the possibility to be used offline. This was a major advantage in remote survey areas. It allowed for a quick survey procedure from start to finish within a couple of months with the result of higher quality datasets for subsequent data analysis.

### 6.2.1 Questionnaire Structure

For this thesis, two types of questionnaires were used to collect farmer data. First, a household baseline and endline questionnaire including detailed agronomic questions was used in each phase of the CORIGAP project. Second, a perception questionnaire was created in Phase II to collect data on farmers' adoption behavior and perceptions of the recommended best management practices and technologies.

**Household survey questionnaire.** The household questionnaire consisted of a consent form plus five categories and included multiple-choice and single-choice questions, matrix questions, as well as closed-ended and open-ended questions (Appendix). It was used twice in each CORIGAP country, except China. In CORIGAP Phase 1, household baseline data were collected from 2012 to 2015 to analyze farmers' situation before the introduction of best management practices and related technologies. In CORIGAP-Pro, agronomic information after the introduction of the recommended practices and technologies from 2017 to 2019 was collected.

In the first part of the questionnaire, farmers answered sociodemographic questions, including age, gender, marital status, education, and household composition as well as their membership in farming organizations. Moreover, questions about non-rice income sources and amounts were included. Farmers described their involvement in national agricultural programs in their respective countries. In the endline survey, they were also asked if they had practiced the recommended best management practices for at least two seasons.

In the second section, questions on farm characteristics and cropping pattern were included. Farmers were asked to fill out a question matrix covering topics such as the cultivated area in hectare, tenure status, land rental, method of crop establishment, date of planting and harvesting, seed type and quantity in kilogram as well as topography and soil type. This section was filled out for the dry and wet season separately.

The third part of the questionnaire concerned farmers' rice production and sale. Farmers indicated their area of rice production in hectares, the total gross production of paddy rice in kilograms, and the moisture content in percent. Then farmers were asked to fill out a question matrix, including quantities in kilograms and price for sold rice and for stored rice to sell later, as well as quantities in kilograms for rice kept for home consumption and kept for seeds. This section was filled out separately for the dry and wet season.

In the fourth part of the questionnaire, farmers indicated their farming practices, input types and quantities, and costs for rice production. First, information on seed and seedbed preparation was requested. If farmers performed transplanting, they were asked specific questions on the method of seedbed preparation and the required input use (fertilizer, insecticide, herbicide). Farmers were also asked about who had done the transplanting activity and the respective labor costs. Second, farmers filled out a question matrix on their land preparation, including labor quantities and wages as well as power used for rice straw management, soil preparation, leveling, and canal maintenance. Third, farmers answered a question matrix on their crop establishment method and the respective activities, such as transport of seedlings, transplanting, or broadcasting. Farmers also indicated the labor hours and wages for each activity. Fourth and fifth, farmers were asked to fill out a question matrix on their fertilizer application as well as irrigation and water management activities with respective timing, amount, cost, labor hours, and wages. Finally, a question matrix on pest management, including the type of pest control, application times, quantities, and cost as well as labor hours and wages was answered by the farmers. This section was filled out separately for the dry and wet season.

For the final part of the questionnaire, farmers indicated their harvest and postharvest activities in a question matrix. Power used, labor hours, and wages were asked for specific activities, such as harvesting, cleaning, hauling, drying, milling, and storing. Farmers also answered questions about their drying regime, seed storage, and milling activities. Furthermore, they gave information about their seed storage activities and postharvest equipment. This section was filled out for the dry and wet season separately.

**Perception survey questionnaire.** This questionnaire was employed in China and Vietnam in 2019 to collect data on farmers' perceptions of change since the introduction of new practices and technologies. It evolved from an earlier survey questionnaire utilized in Indonesia and Thailand in 2018. The questionnaire focused specifically on farmers' adoption behavior, perceived benefits, and barriers to the recommended practices and technologies. It consisted of single-choice and multiple-choice questions, Likert-type scale questions in a matrix format with pictures, and open-ended questions. It was adapted to the Chinese and Vietnamese contexts. Country-specific sections and practice-specific questions related to the national agricultural programs of each country were added. The following sections were included in both questionnaires. The country-specific sections are highlighted in the methods chapters of each case study (Chapter 8.2.1, 13.2.1, and Appendix).

The questionnaire started with consent information. Farmers were informed that the participation is voluntary, that anonymity will be ensured, and that they can terminate the survey at any time without penalty. Furthermore, they received a brief introduction to the topic of the questionnaire. In the end, they were asked to sign the consent form before proceeding to the next part.

The first section included sociodemographic questions such as age, gender, marital status, household composition, and years of farming. Farmers also described their children's education and possible farm succession. Furthermore, they were asked if they earned income from non-farming activities. If they answered yes, they indicated the percentage it constitutes of their total income, from which sources the non-farming income comes from, and which household member owns the income. Farmers were further asked if they borrowed money for agricultural production purposes. If so, questions about the origin, duration, and purpose of the financial support were added. If applicable, farmers would also indicate if they availed of crop insurance and how much the premium is. Lastly, farmers described their total cultivated area, including rented land with associated costs, seed quantities, production of other crops, and total paddy rice production quantities with the associated selling price. Economic data on input costs, such as pesticides and fertilizer, irrigation, machine rental, and labor were also collected.

In the next section, farmers were asked about their adoption of specific farming practices and technologies. This included questions on the introduction and adoption year, if they are still practicing and plan on continuing the use of the practice or technology, or if not, why they decided to disadopt it. The farmers also rated the benefits and disadvantages of the best management practices and technologies. For this, farmers evaluated statements on a 6-point Likert-type scale (1 = not applicable at all, 6 = very applicable) indicating the reasons for continuing the use of a practice or technology or its disadoption.

The questionnaire continued with questions on farmers' perceived changes since adopting the recommended best management practices and technologies. Farmers expressed if they perceived an increase, decrease, or no change in their cultivated area, yield, and input costs as well as seed rate for Vietnamese farmers. They proceeded to quantify in percent how much the perceived change was for each category. Subsequently, they rated 21 Likert-type questions on a 6-point scale indicating their level of agreement (1 = completely disagree, 6 = fully agree) about the changes they have made in their rice farming management. These questions included perceived changes in seed rate, fertilizer and pesticide input, irrigation and machinery use, postharvest activities as well as the application of environmental management measures. Furthermore, farmers were asked about their subjective knowledge, satisfaction, and expectations regarding the practices and technologies using 6-point Likert-type scale statements (1 = completely disagree, 6 = fully agree). Subjective knowledge was evaluated using an adapted version of the Flynn and Goldsmith subjective knowledge scale (1999: 59). The satisfaction and expectation questions were adapted from Meakin and Weinman (2002: 263). They were adjusted to account for the geographical and agricultural context.

The final part of the perception questionnaire included questions on several dimensions of change to examine the different aspects of farmers' perceived social, economic, and environmental changes. All dimensions were evaluated on 6-point Likert-type scales (1 = completely disagree, 6 = fully agree). These dimensions were assessed using an adapted version of the twelve livelihood dimensions described in Blundo-Canto et al. (2018: 164–166). They were created for the analysis of livelihood impacts of payments for environmental services. The twelve dimensions are divided into an 'economic or monetary' and a 'non-monetary or material' group. In the first group, the six dimensions are as follows: 1) financial capital and flows, 2) employment, 3) agricultural production, 4) physical capital, 5) poverty, and 6) land tenure. In the second category, the six dimensions are: 7) social capital, 8) human capital, 9) natural capital and flows, 10) food security, 11) cultural capital, and 12) health. The natural capital items were selected based on information gathered in the 'Illustrated Guide to Integrated Pest Management in Rice in Tropical Asia' by Reissig et al. (1986). The items included beneficial indicator species, pest species, and plants found in rice ecosystems in Southeast Asia. The advice of entomologists specialized in rice ecosystems was further included to select the relevant species in the regions. Considering that farmers may not be familiar with the names of the species, pictures of the selected indicator species were shown to the farmers during the survey interviews.

### 6.2.2 Datasets

Overall, different datasets were available for the country analyses. For China, only the data on farmers' perceptions of 3CT were available since no household baseline and endline survey was conducted. For Myanmar, household baseline and endline survey data were available. However, no data on farmers' perceptions of the best management practices and technologies could be collected. This was due to the canceling of the planned perception survey in 2020 because of the COVID19 pandemic restrictions. Lastly, for Vietnam, the datasets of the household baseline and endline survey as well as the perception survey were available. Thus, a more detailed analysis was possible for this country analysis (Figure 6.2).

The household data for the Myanmar and Vietnam country analyses were collected twice per project phase. The baseline survey was conducted in Myanmar in 2012 and Vietnam in 2015. The surveyed farmers were separated into two groups, namely, a treatment and a control group. The treatment farmers were the ones who received information and training about sustainable rice farming technologies and practices. The control farmers did not receive specific information and training. They were expected to continue rice farming using their traditional practices. The endline survey took place in Myanmar in 2017 and Vietnam in 2019. Due to farmers in the treatment and control groups mixing, specifically in Myanmar, the groups were reclassified into an adopter and non-adopter group. The adopter farmers were defined as the ones who adopted the recommended technologies during the CORIGAP project period. The non-adopter farmers were the farmers who decided not to adopt any recommended technology or practice during the project phase. For the data analysis, the data were examined by the adopter group as listed in the household endline survey. The farmer perception data were collected in China and Vietnam in 2019. The surveyed farmers in China were randomly chosen based on the introduction year of 3CT. The farmers in Vietnam were randomly selected on the basis of having received an introduction to the 1M5R program through the CORIGAP project or other sources.

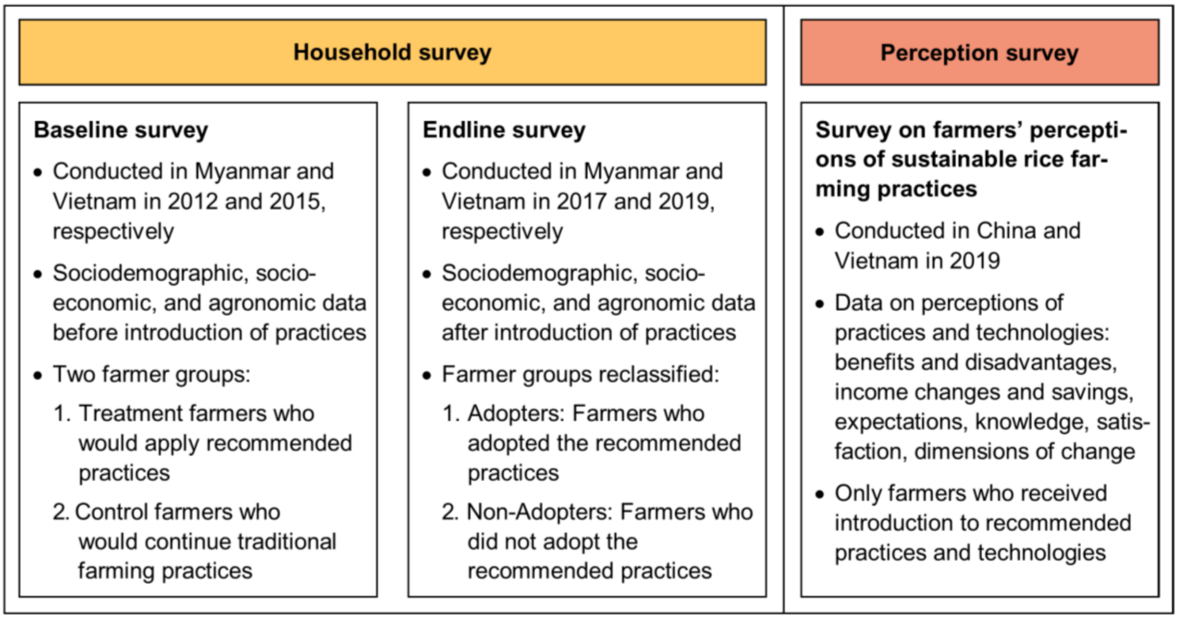



Figure 6.2 Data collection survey types
Concept: H. Wehmeyer (2021)

# Part III

# Country Analyses

## Published work

The present chapters 7 and 8 are based on the following published peer-reviewed publication.

**Wehmeyer H.**, de Guia A. H., Connor M. (2020): Reduction of Fertilizer Use in South China – Impacts and Implications on Smallholder Rice Farmers. In: Sustainability 12 (6), p. 1–21. https://doi.org/10.3390/su12062240

Weblink: https://www.mdpi.com/2071-1050/12/6/2240

Supplementary material: China perception survey questionnaire in Appendix

# 7 China – Fertilizer Consumption and Rice Farming

Due to long-term input overuse, China has been experiencing environmental degradation. In particular, high fertilizer consumption in rice production has led to agronomic challenges and ecological problems. Therefore, 3CT was developed to counteract the negative consequences of intensive rice farming. This chapter first illustrates the historical development and policy-related context of fertilizer consumption in China with a specific focus on rice agriculture in South China. In the second part, 3CT is described and its adoption-diffusion strategy is presented.

## 7.1 Fertilizer Consumption in China

China has been the largest user of fertilizer in the world since 1993. Presently it consumes over a fourth of global fertilizer quantities applied in agriculture (Jin 2012: 1006; Heffer, Gruère, Roberts 2017: 10). This development started in the 1950s when the goal of being food self-sufficient and avoiding a food crisis had become the highest priority of the Chinese government. Establishing and sustaining food security has since played a key role in agricultural policy decisions (Ghose 2014: 87; Huang et al. 2015: 105–106). Starting in the 1970s, the government introduced economic and agricultural reforms. These accelerated China's rapid agricultural growth in the early 1980s. During this period, improved seeds and fertilizer as well as modern irrigation systems were introduced (Guo et al. 2010: 1008; Nin-Pratt, Yu, Fan 2010: 210,212). In the second half of the 20th century, China's population doubled while total grain production tripled, and fertilizer consumption increased five-fold from 1980 to 2015 (Li et al. 2013: 972–973; National Bureau of Statistics of China 2020a). Today, the challenge of sustaining food security and steadily increasing agricultural output for one fifth of the world's population remains prominently on the political agenda. Only about 9 % of the world's cultivated land is located in China (Chen 2007: 2; Li et al. 2013: 973; Ghose 2014: 87,92). The scarcity of agricultural land is further aggravated because of the decline of farmland due to accelerated urbanization and rapid economic growth. From 1978 to 2006, the surface of total land allocated for agriculture in China decreased by 11 % (Christiansen 2009: 557; Ghose 2014: 87). In this context, increasing production quantities and farming efficiency as well as improving the quality of agricultural products are becoming an even more central matter to ensure food security (Ghose 2014: 87).

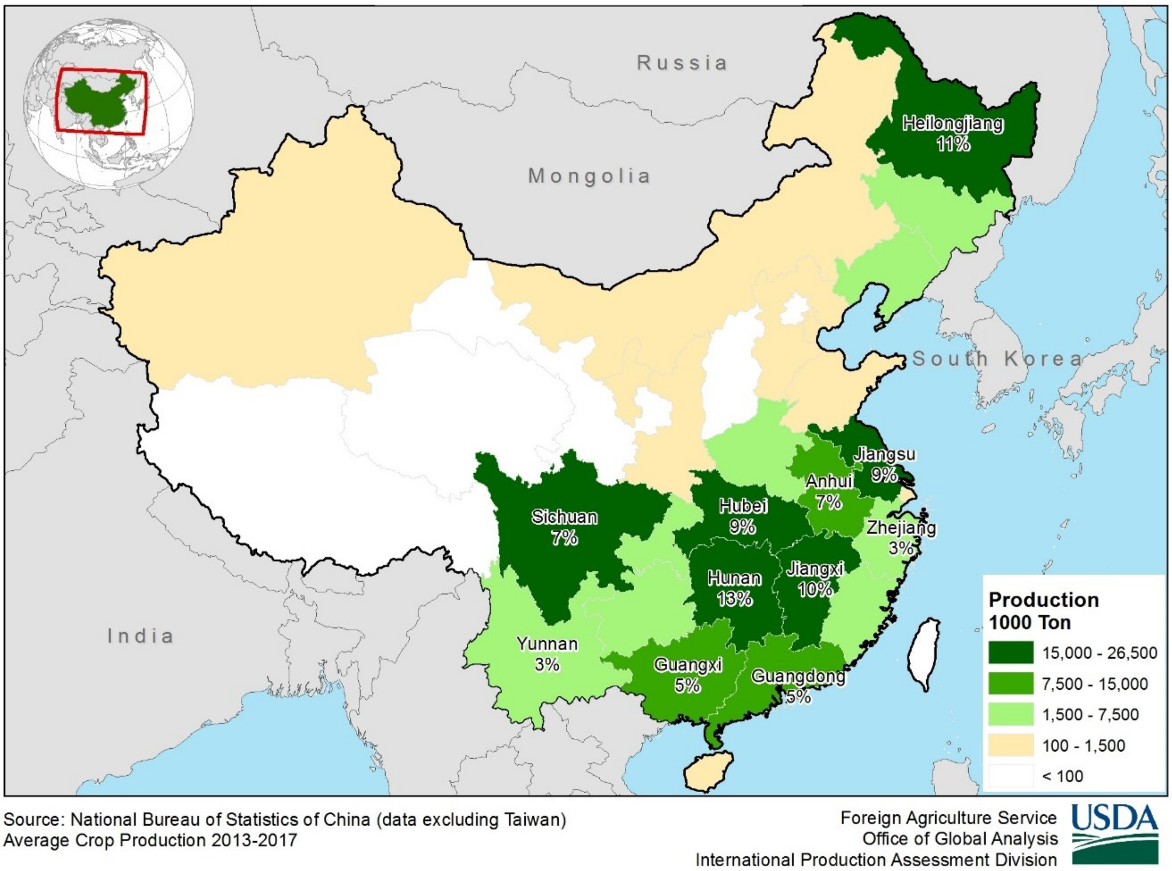
Given these geopolitical circumstances, heavy fertilizer application has become an environmental problem due to ongoing overuse over the past decades. Soil acidification, polluted rivers, and eutrophic lakes caused by agriculture increase ecological degradation (Guo et al. 2010: 1008; Ghose 2014: 93; Cai et al. 2018: 9). Chinese farmers apply high amounts of fertilizer, often exceeding 200 kg/ha of nitrogen-phosphorus-potassium (NPK) nutrients. Thus, they largely surpass the averages of industrialized countries (ca. 130 kg/ha) and India (ca. 165 kg/ha) (Huang et al. 2015: 105; World Bank 2019a; National Bureau of Statistics of China 2020a). In 2016, the Chinese average fertilizer NPK rate reached 503 kg/ha compared to the global average of 140 kg/ha (World Bank 2019a). Of the fertilizer applied, about 61 % is nitrogen fertilizer, 22 % is phosphate, and 17 % is potash (Li et al. 2013: 973; National Bureau of Statistics of China 2020a).

Within China, regional disparities of fertilizer consumption are present and demonstrate different climatic and economic circumstances. Generally, the western provinces are economically poorer than the eastern provinces, and the northern provinces are poorer than the southern provinces. High-consuming provinces such as Guangdong and Hubei report nitrogen application rates of over 180 kg N/ha (Wang et al. 2011: 2015; GRiSP 2013: 24; National Bureau of Statistics of China 2020a). Nevertheless, nutrient use efficiency, in particular nitrogen use efficiency, remains relatively low in China compared to the European Union and USA. This leads to fertilizer application not being agronomically efficient and increasing non-point source pollution (Li et al. 2013: 977). A reason for the high rate of nitrogen fertilizer is farmers' lack of knowledge on the application of fertilizer quantities. Other reasons include an inefficient public extension system and misguided government policies.

The public extension agents are often driven by commercial sales of fertilizer rather than giving farmers proper instructions on how to use chemical fertilizer correctly. Additionally, the Chinese government has not strongly warned against the excessive use of fertilizer because of the objective to ensure food security through increased productivity (Huang et al. 2008: 165, 2015: 106).

## 7.2 Rice Cultivation in China

Rice is one of the major staple food crops in China. It accounts for about a third of the total cultivation area for grains and over 40 % of total grain production (Yousaf et al. 2017: 1). China is also the principal paddy rice producer in the world in terms of production quantity. In 2017, the country's total rice production quantity amounted to 214.4 million tonnes (Mt) before India (168.5 Mt) and Indonesia (59.4 Mt) (GRiSP 2013: 25,30,33; FAO 2018: 3; FAO Statistics Division 2020). Globally, a record amount of 759.6 Mt of rice was produced in 2017 with more than a quarter being produced in China (FAO 2018: 3; Yin, Huang, Zou 2018: 1). Although China's rice cultivation area (30.9 Mha) is significantly lower than India's (43.4 Mha), Chinese farmers have been able to attain higher yields due to three important factors. First, over 95 % of China's rice cultivation areas are irrigated (Defeng 2000: 72; Peng, Tang, Zou 2009: 3; Zhu et al. 2013: 147A; Ricepedia 2019). Second, Chinese farmers have widely adopted HYVs. Especially the semi-dwarf rice varieties introduced since the end of the 1950s have been successful (Yin, Huang, Zou 2018: 1; IRRI 2019b; Ricepedia 2019). Third, applying more fertilizer over the past decades, in particular nitrogen fertilizer, has helped rice farmers to experience yearly increases in their yields (Peng, Tang, Zou 2009: 3; Yin, Huang, Zou 2018: 1; Ricepedia 2019). Accordingly, Chinese rice yields have tripled since 1961 although annual production quantities have been fluctuating and the total rice cultivation area has been steadily decreasing over the past 40 years. The average rice yields reached 6.9 t/ha in 2017 (Ricepedia 2019; World Rice Statistics 2019).




Map 7.1 Main rice cultivation areas in China by production quantity
Source: United States Department of Agriculture (USDA) - Foreign Agricultural Service (2020)

In China, rice is cultivated predominantly in the south and east, the Yangtze River valley, and in the northeast (Map 7.1). Rice production from the areas close to the Yangtze River is characterized by rice-wheat rotation. In the south and east, a rice-rice cropping pattern is preferred due to favorable climatic conditions and a suitable topography. The ideal environment allowing for long growth periods is present in southeastern China. High average temperatures and rainfall allow farmers to have two rice cropping seasons per year, an early and late rice season, in which rice is grown as a monoculture (GRiSP 2013: 17; Ricepedia 2019). In this regard, about 80 % of China's rice cultivation area is located in the south, including Guangdong Province. The South of China, therefore, plays a critical role in assuring food security (Yin, Huang, Zou 2018: 1; World Rice Statistics 2019). However, yields and production quantities have been barely increasing in the past decade. The southern provinces have become more vulnerable to the effects of climate change compared to the north and northeast of China (Peng, Tang, Zou 2009: 3; Yin, Huang, Zou 2018: 1; World Rice Statistics 2019). As a response to these environmental difficulties, the main objective of rice production has shifted from increasing yields to improving yield stability. Yield stability is the ability of a crop to maintain an appropriate yield performance while experiencing changing environments over time (Rosenzweig et al. 2001: 99; Rakshit et al. 2014: 1572; Yin, Huang, Zou 2018: 1). Calculations have shown that fertilizer-driven intensification can improve crop yields but also increases the risk of yield variability due to multiple negative effects associated with nitrogen pollution (Müller et al. 2018: 10). Thus, it is being suggested that progressive development in agricultural productivity should rather be attained by increasing grain yield per unit area. This should be achieved by disseminating practices and technologies to reduce the risk of yield variability (Yousaf et al. 2017: 1; Müller et al. 2018: 10).

**Fertilizer use for rice cultivation.** Fertilizer consumption for rice farming in China is high and attained a record in 2009 with 587'380 t of NPK fertilizer applied. Although the overall consumption of fertilizer decreased to 366'280 t in 2013, the average rate of 559.8 kg/ha NPK fertilizer remains exceedingly high (Ricepedia 2019; World Rice Statistics 2019). Particularly nitrogen fertilizer input for rice production often exceeds 180 kg/ha. This is about 75 % higher than the global average (GRiSP 2013: 108). Rice production in China consumes 36 % of nitrogen fertilizer used for rice cultivation worldwide. The highest quantities of nitrogen fertilizer are applied in South China and can reach up to 250 kg/ha (Box 7.1) (Peng et al. 2010: 650; GRiSP 2013: 24). For example, the average nitrogen input rate for rice production in Guangdong Province is approximately 200 kg/ha (Zhong et al. 2010: 222). Nonetheless, the rice plants can only take up 20-30 % of the added nitrogen fertilizer. This significantly lowers the nitrogen use efficiency (Hu et al. 2007: 331; GRiSP 2013: 108; Wang et al. 2011: 2014). Hence, much of the nitrogen is lost to the environment. Moreover, the overconsumption of nitrogen fertilizer can decrease rice yields because the plants are becoming more susceptible to lodging and pests as well as diseases (Hu et al. 2007: 331; GRiSP 2013: 108; Peng et al. 2010: 650; Zhong et al. 2010: 222–223).

**Box 7.1. Farm Size and Fertilizer Application**

Farm size has been found to significantly affect the amount of fertilizer and other chemicals applied. In China, still 70 % of farms are below two hectares. The average farm size is 0.4 ha (Ju et al. 2016: 29; Wu et al. 2018: 7012). This is due to governmental farmland allocation. The 'household contract responsibility system' has been in place since 1978. Since 1990, small farms have been demonstrating lower average yields than larger farms. This is explained by the stark increase of fertilizer usage. This in turn has led to loss of nutrient use efficiency and environmental degradation (Ju et al. 2016: 29). Studies have shown that there is an inverse relationship between farm size and fertilizer use intensity in China (Zhou et al. 2010: 92; Pan et al. 2017: 137; Wu et al. 2018: 7011). Small farms show higher fertilizer intensities than larger farms but with an increase of 1 % in farm size a decrease of fertilizer application per hectare by 0.3 % would be possible (Wu et al. 2018: 7011). Two explanations were found for this correlation. First, farmers' input quantities depend on the farm size due to effects of economies of scale associated with the adoption of best management practices. Substantial costs for adopting new technologies does not change with farm size. Hence, the majority of adoption costs is fixed and there is an upscale effect of technology adoption with farm size. Smaller farms have to invest a proportionately larger amount into the same technology or practice than larger ones. In this regard, small-scale farmers aiming for higher income would find it easier to focus on increased inputs to achieve better agricultural productivity and profitability (Ju et al. 2016: 30–31; Wu et al. 2018: 7011). Second, large-scale farmers typically have better farming knowledge and management skills. This can be seen through higher agricultural labor productivity and, thus, better use efficiency of agricultural inputs such as fertilizers and pesticides (Wu et al. 2018: 7011).

Ultimately, much of China's arable land could become unsuitable and permanently damaged for agricultural purposes if the overconsumption of nitrogen fertilizer and other inputs remains high (Ghose 2014: 92). It is suggested that 150 kg/ha to 180 kg/ha is the average optimal nitrogen fertilizer rate in South China to minimize the accumulation of residual nitrogen in the soil (Wang et al. 2011: 2018). Field trials have shown that fertilizer rates could be reduced by 20-30 % and up to even 60 % depending on the area without the reduction of yields (Ju et al. 2009: 3045; Kahrl et al. 2010: 7).

**Rice production in Guangdong Province.** Guangdong Province is one of the main producers of rice in China and rice makes up over 90 % of all food production. The province covers 1.8 Mha of rice planted area, produces over 1 Mt of paddy rice annually, and reaches an average yield of 5.7 t/ha (National Bureau of Statistics of China 2020b). Due to its subtropical, monsoon-influenced climate and vast river plains, the conditions are ideal for irrigated lowland rice cultivation. There are two rice growing and one non-rice growing season. The early rice season lasts from March to July, the late rice season from July to November, and the non-rice season from December to February (Zhong et al. 2010: 222). Furthermore, Guangdong Province has become a highly economically developed region in the past decades. This is due to its productive agriculture, a strong population increase, and a rapidly developing urban and rural economy (World Bank 2013a: 29–30). Nevertheless, with the rapid economic and agricultural development, agricultural non-point source pollution has increased severely. This not only affects the quality of the agricultural land, water, and atmosphere but also hinders the enhancement of agricultural efficiency (World Bank 2013a: 4). Moreover, it affects food safety and human health as well as rural livelihoods. Ammonia nitrogen discharge has become the main problem in the region and has led to malfunctioning regional river bodies, namely, the Pearl River, Dong River, and the Han River. Parts of these rivers and tributaries of their river basins suffer from severe eutrophication (World Bank 2013a: 4–5). These issues are a possible explanation for the province's 17.3 % lower rice yields compared to the national average of 6.9 t/ha (National Bureau of Statistics of China 2020b). Yield losses due to unproductive tillers, pests, and diseases as well as lodging can range from 10 % up to 30 % (Zhong et al. 2010: 223) (Figure 7.1).

Figure 7.1 Lodging of rice plants after strong winds
Source: System of Rice Intensification International Network and Resources Center (SRI-Rice) (2014)

A survey with 500 farmers in ten counties of Guangdong Province focusing on fertilizer practices pointed out four main problems in rice farming around the Pearl River Delta. First, farmers' nitrogen input is too high in both rice seasons, reaching rates of over 220 kg/ha of nitrogen fertilizer. Correspondingly, the nitrogen use efficiency is low at 23 %. In addition, because of the nitrogen runoff and leakage, water pollution has led to eutrophication of the nearby water bodies. Second, the high amounts of nitrogen fertilizer are mainly used at the early growth stage of the rice plants in a short timeframe. In the course of the first 15 days, farmers often apply nitrogen fertilizer two to three times. This constitutes already more than 80 % of their total application quantities in one season resulting in low nitrogen use efficiency and a large number of unproductive tillers. Third, the unproductive tillers often make up more than 50 % of the canopy. Many die during the panicle initiation stage. This results in productive tillers becoming more susceptible to lodging. These have thin and weak stems because of the high density of tillers in the field, which in turn impedes a normal growth process. Furthermore, after a lodging incident, farmers have to harvest by hand instead of using a contractor with a mechanical harvester. This necessitates more labor, time, and cost. Fourth, farmers apply too much fungicide and other pesticides. The development of diseases and insects is stimulated due to the dense canopy caused by the high number of unproductive tillers. This creates conditions of low light intensity and high humidity that become a breeding ground for multiple pests and diseases (Zhong et al. 2010: 222–223; Wang et al. 2017: 681–682).

## 7.3 The ‘Three Controls’ Technology

By reason of fertilizer overuse in rice production, 3CT was developed by the Rice Research Institute of the Guangdong Academy of Agricultural Sciences (GDRRI) and IRRI. This nutrient management technology focuses on improving sustainable farming and reducing negative environmental effects while increasing grain yields and reducing the risk of yield variability (Zhong et al. 2010: 223). The technology promotes the application of nitrogen at later growth stages. Hence, postponing the nutrient uptake of the rice plants from the early growth stage to the middle and late growth stages (Figure 7.2). This approach is called ‘nitrogen fertilizer retrusion’ (Wang et al. 2017: 682). Furthermore, the diffusion strategy also promotes a specific slow-release fertilizer that is adapted to the regional nutrient deficits of the soils for improving rice productivity (World Bank 2013b: 7). The technology aims to incentivize farmers to apply less nitrogen fertilizer on their rice fields and only at specific times per season. 3CT promotes awareness of the economic and ecological benefits of a reduced fertilizer rate (Zhong et al. 2010: 223; Wang et al. 2017: 682).

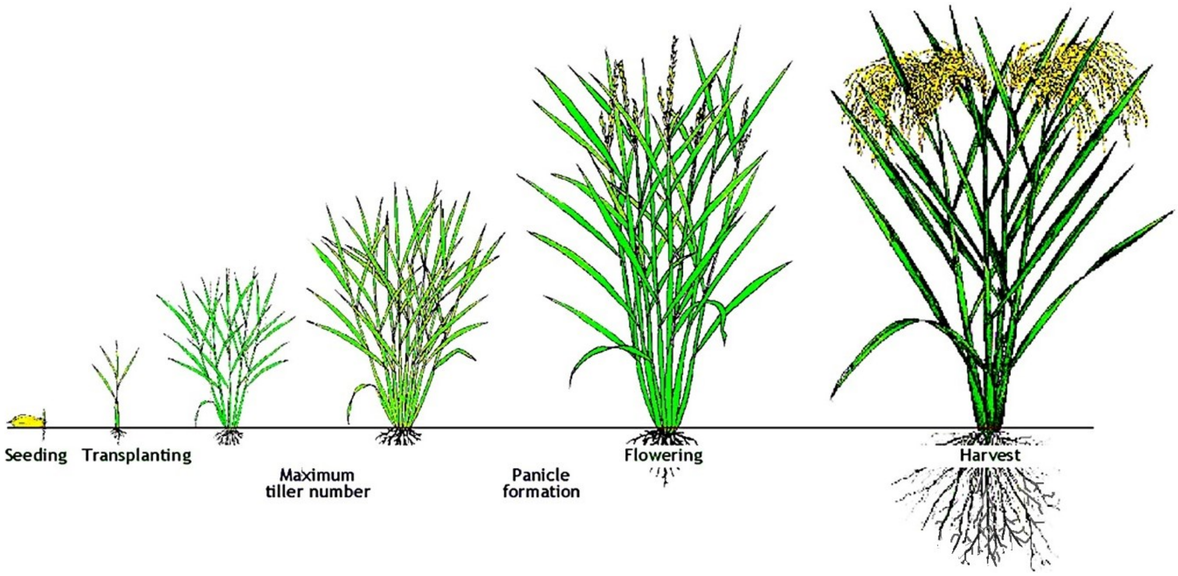



Figure 7.2 Rice crop growth stages
Source: Nelson et al. (2014: 10779)

‘Three controls’ refers to the three components 3CT (Figure 7.3). The first component is the control of nitrogen fertilizer application quantity and timing. This is crucial for improving nitrogen use efficiency and reducing environmental pollution. In particular, the control of nitrogen application during the early growth stages of the rice plants needs to be monitored. Farmers are therefore incentivized to apply their nitrogen fertilizer in the following way: 40 % at the basal stage, 20 % at the mid-tillering stage, 30 % at panicle initiation, and 10 % at heading. Moreover, the improved distribution of nitrogen input is accompanied by a reduction of 10-30 % of the total nitrogen fertilizer input (Zhong et al. 2010: 223; Wang et al. 2017: 682). The second component is the control of unproductive tillers and a set number of maximum tillers. This improves the percentage of productive tillers as well as the health of the entire canopy. It reduces the risk of lodging, diseases, and pests. Subsequently, this leads to the third component, namely, the better control of fungicide and other pesticide applications. This can be achieved through improved crop management (Zhong et al. 2010: 223–224). 3CT field trials have shown that farmers can attain a 20 % decrease in their nitrogen fertilizer input if they adopt 3CT fully. Furthermore, they can save one to two days of fungicide or other pesticide applications and increase their yields by 5-10 %. The technology also improves farmers' income by approximately 220 USD/ha (Zhong et al. 2010: 230). 3CT was developed on the basis of site-specific nutrient management (SSNM) introduced by IRRI in the 1990s. SSNM promotes a reduced application of nitrogen inputs according to the site-specific conditions (Zhong et al. 2010: 225–226). The application rate of nitrogen is based on the crop's demand which depends on climatic factors, indigenous nitrogen supply, and its growth stage. Young rice plants do not require much nitrogen and grow slowly. Hence, during the first two weeks after rice transplanting, the use of moderate amounts of nitrogen fertilizer is advised. More nitrogen is needed by the crop during the tillering and panicle initiation stages to support the plant's fast growth. During these stages, the amount and the dosage frequency are increased according to the plant's leaf color, which indicates their nitrogen status (Hu et al. 2007: 332). Field trials have resulted in SSNM leading to 11 % higher yields while having reduced nitrogen input. SSNM achieved reductions of NPK fertilizer inputs by 10-30 % in multiple Chinese provinces, including Guangdong Province. Also, the nitrogen recovery rate attained more than 50 % recovery efficiency (Hu et al. 2007: 332; Peng et al. 2010: 650–651; Zhong et al. 2010: 226; Huang et al. 2015: 106).

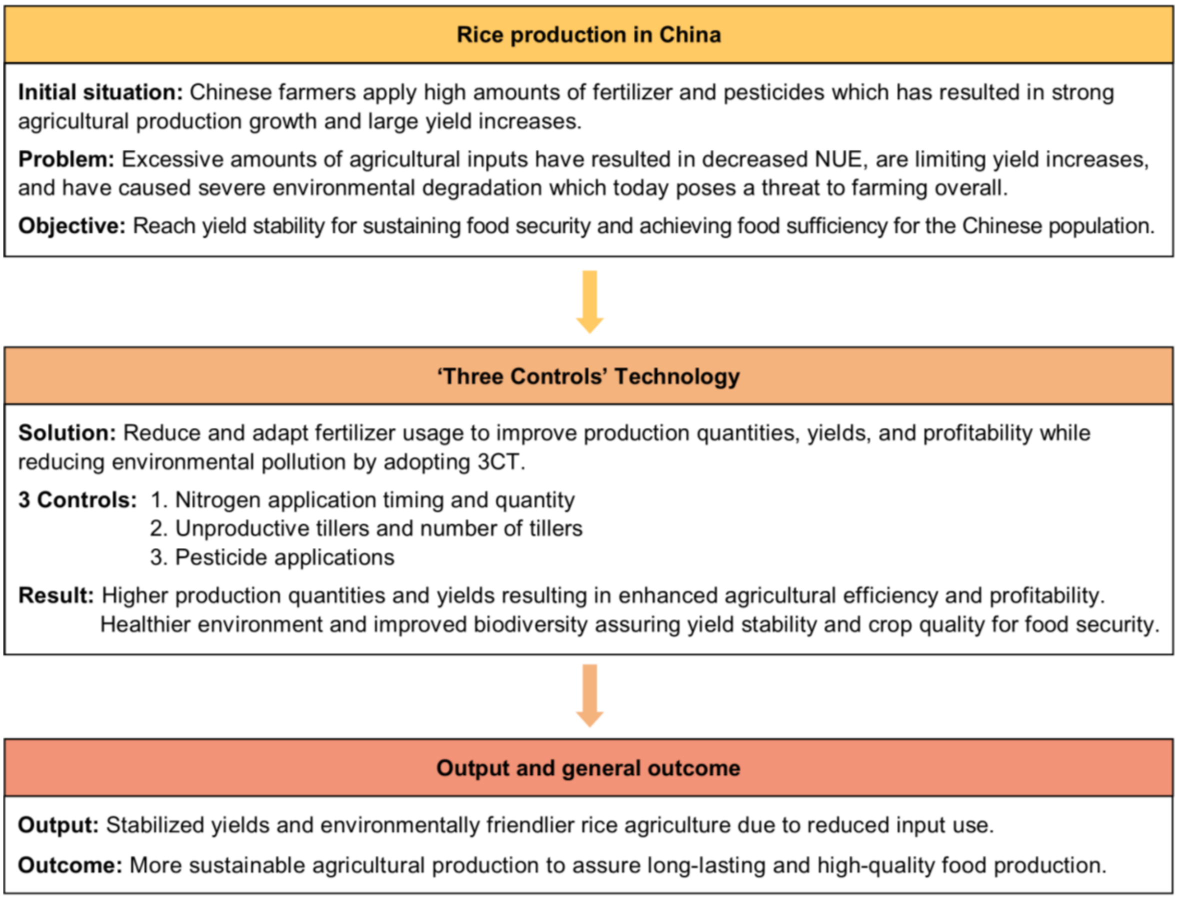



Figure 7.3 Overview of China's rice production challenges and 3CT's potential impact on China's agricultural development
Concept: H. Wehmeyer (2021)

**Adoption-diffusion strategy.** In 2007, 3CT was released in Guangdong Province. The promotion and dissemination took place in four steps. First, a program design was created to demonstrate the technology. This included choosing land parcels and villages as well as randomly selecting farmers willing to participate in the early stages of the diffusion and use 3CT in their fields (Wang et al. 2017: 683). On-farm demonstrations took place starting in 2007. For the training, two fields, a 3CT field and a farmer's traditional practice field, were separated. The early adopter farmers were given specific instructions on how to apply 3CT. Then, fertilizer rates, frequencies, and final grain yield were recorded for each field during each season (Zhong et al. 2010: 229). Second, these fields were continuously used as demonstration sites for innovation diffusion. They were monitored regularly by scientists and served as a basis for demonstrating the impact of the technology directly to the farmers in the villages (Wang et al. 2017: 683). The farmers received an easy rule of thumb to calculate the necessary nitrogen input: per one tonne of yield, about 50 kg/ha of nitrogen fertilizer should be applied. This rule sets the yield target at 80-90 % of the yield potential (Zhong et al. 2010: 224). Third, the feedback of the farmers was considered to improve the demonstration and promotion strategies. This was significant to continue with the fourth and final step, namely, focusing on large-scale diffusion. This was conducted through extension activities, increasing the number of demonstration farmers. This mechanism spread the information about the new technology and encouraged other farmers to adopt 3CT (Wang et al. 2017: 683; World Bank 2013b: 61,63).

The diffusion of 3CT was further amplified by its inclusion in a project loan from the World Bank for the 'Guangdong Agricultural Non-Point Source Pollution Control Project' from 2014 to 2018. The project area was located in the rural parts of the city prefectures of Huizhou, Jiangmen, and Heyuan in Guangdong Province. Demonstration sites for pesticide and fertilizer pollution control as well as the implementation of pollution control measures were performed in the prefectures of Huizhou City and Jiangmen City (World Bank 2013a: 290). Farmers applying 3CT were given a 25 % price reduction on fertilizer and other inputs when purchasing them from registered input suppliers. Furthermore, farmers could buy a specific slow-release fertilizer for 3CT. This fertilizer was developed precisely for the technology application in each city prefectures so farmers would not need to calculate the exact NPK fertilizer ratios. Additionally, each purchase at a registered input supplier was recorded through an electronic farmer purchasing system. Farmers would use a blue badge for buying a limited amount of inputs that was allowed under 3CT. If farmers forgot how to apply 3CT correctly or how to calculate their fertilizer input, technical boards, and posters were positioned in the villages (Figure 7.4) (World Bank 2013b: 39-40,60; IRRI 2019a: 13; Personal notes taken during meeting with GDRRI in April 2019).


Figure 7.4 Technical board explaining the steps of 3CT with the NPK fertilizer ratios and number of tillers, blue badge on the right side
Source: H. Wehmeyer (2019)

# 8 China – Farmers' Perceptions of the 'Three Controls' Technology

In this chapter, the study on farmers' perceptions of 3CT is presented. First, the rationale and research gaps are discussed, followed by the research objectives. Second, the methodological approach using a CAPI-based survey questionnaire is explained. This is followed by the results on farmers' perceived benefits, satisfaction levels, subjective knowledge, and expectations of the technology. Furthermore, agronomic changes and eight livelihood dimensions are analyzed. Finally, a structural equation modelling impact model is discussed for examining the overall impact of 3CT on farmers' economic, social, and environmental livelihoods.

## 8.1 Rationale of the Study

Several internal and external factors play a role for farmers to adopt a new practice in their fields. Internal factors include, for example, farm household income from farming and non-farming activities, the quantity of labor from farm household members, agricultural input use and effectiveness, risk aversion of the farmer, age of the household head, or the number of years of education received by the household head. External factors can be, for instance, the size of the agricultural production area, soil type and quality of cultivated land, type of water source and degree of water scarcity, or the level of government support (Dai et al. 2015: 582). So that a new agricultural practice is widely adopted by farmers, it must apply to the farmers' needs and demonstrate its profitability. Risk aversion is considered foremost as a crucial factor for non-adoption (Babcock 1992: 272; Stuart, Schewe, McDermott 2014: 211; Smith, Siciliano 2015: 22). In particular, economic risk plays an important role in the decision-making stage of the adoption process. Especially small-scale farmers with low incomes will be rather unwilling to take economic risks if the new technology could result in yield losses, and thus profit reduction (Stuart, Schewe, McDermott 2014: 211; Smith, Siciliano 2015: 22). However, the economic optimum often does not coincide with the fertilizer rate for reaching the agronomic optimum (Yang et al. 2012: 960; Smith, Siciliano 2015: 22). Therefore, the high application rate of fertilizer in China demonstrates a mechanism for farmers to reduce their economic risk and potential yield losses (Babcock 1992: 272; Stuart, Schewe, McDermott 2014: 211; Smith, Siciliano 2015: 22).

Other risks, such as environmental risks, are less dominant in farmers' risk aversion decision-making process, but high fertilizer consumption has already adversely impacted the environment (Stuart, Schewe, McDermott 2014: 210; Smith, Siciliano 2015: 22). Studies have demonstrated a negative relationship between fertilizer application, farmers' level of education, and environmental knowledge (Han, Zhao 2009: 1242; Smith, Siciliano 2015: 22). Moreover, if farmers are uncertain about soil nitrogen concentrations and weather conditions, they tend to apply higher rates of nitrogen fertilizer (Babcock 1992: 271; Smith, Siciliano 2015: 22). Another reason for high agrochemical use is the low quality of extension advisory services, and hence the lack of knowledge about sustainable farming practices (Huang et al. 2008: 165; Pan et al. 2017: 130–131; Guo et al. 2015: 100). Chinese farmers often still rely on the information given to them during the period of the Green Revolution (Jia et al. 2013: 365; Guo et al. 2015: 100). This is due to low funding for public extension services since the late 1980s (Guo et al. 2015: 100). Also, how a farmer perceives agronomic advice and the level of trust in this recommendation will influence the rate of fertilizer usage. Regarding fertilizer use reduction, farmers rather prefer to overapply relative to the suggested input amount. They tend to overestimate the impact of additional nitrogen on their yields. Hence, they systematically set aside agronomists' recommendations. Consequently, key factors influencing the high fertilizer application rates in China are farmers' perception and knowledge of fertilizer use as well as profitability expectations (Sheriff 2005: 543; Smith, Siciliano 2015: 22).

In the case of 3CT, the positive effects of the technology are well-documented for monitored field trials. The increase in rice yields has been shown in several field studies such as Peng et al. 2006, Zhong et al. 2010, and Liang et al. 2019. However, these studies have been executed under experimental conditions (Wang et al. 2017: 683). Few survey-based studies have focused on the degree to which farmers have adopted the technology in their fields for large-scale rice production. One study by Wang et al. assessed farmers' 3CT adoption through survey interviews in 2012 (2017: 683). They observed that not all farmers followed the exact 3CT guidelines. Farmers' implementation of the technology varied. For example, farmers applied fertilizer at another timing and in different amounts than recommended. They also used other varieties for rice production than suggested. These variations affect the reliability of the evidence of 3CT's effective impact. Similar results have also been found in studies about SSNM adoption. Farmers modified SSNM recommendations to fit their personal needs rather than applying the exact way of practice. Thus, the technology was often adopted sequentially and only partially (Byerlee, de Polanco 1986: 526; Khanna 2001: 35; Jia et al. 2013: 365; Huang et al. 2015: 106). Therefore, the gap between 3CT studies under controlled conditions and actual application by farmers needs to be studied more in-depth. Surveys on the effects of 3CT adoption on farmers' agronomic and social development as well as on environmental change have not been conducted yet. This study aims to address this gap by investigating farmers' perception, knowledge, and satisfaction levels of 3CT to analyze the adoption behavior. The main objective is to examine farmers' perceived economic, environmental, and social changes due to the adoption of 3CT. In particular, three aspects are explored: 1) farmers' perception of 3CT by evaluating levels of satisfaction, expectations, and knowledge about the technology, 2) perceived impacts on the environment and farmers' livelihoods by investigating multiple dimensions of change, and 3) effect of 3CT on rice production quantities and yields, financial development, and inputs use.

## 8.2 Materials and Methods

### 8.2.1 Survey Questionnaire and Data Collection Approach

The 'Farmers' Perceptions on Sustainable Development' survey questionnaire was implemented to investigate farmers' adoption behavior. Data on farmers' perceptions of 3CT and the related changes they have experienced since the technology's introduction were collected. Likert-type scale questions were mostly used. Farmers were asked to rate statements on 6-point Likert-type scales indicating their level of agreement or if a statement is applicable or not. The scales were set up as follows: 1 = completely disagree and 6 = fully agree, or 1 = not applicable at all and 6 = very applicable. In general, the items were adjusted to account for the Chinese rural and agricultural context.

The survey questionnaire was divided into an information and consent form followed by five thematic categories described in Chapter 6.2.1. The first section of the questionnaire used concerned farmers' adoption of 3CT and their current cropping schedule for the early (March–July) and late (July–November) rice season of 2018. Information about the time of introduction of 3CT, the start of use, and the number of seasons in which 3CT was used, was collected. Farmers further rated 16 Likert-type scale statements (1 = not applicable at all, 6 = very applicable) on the benefits of the technology (Table 8.2). If they stopped using 3CT, they answered a set of 17 statements. The second part of the questionnaire included questions on farm details and assessed farmers' economic situation for the two most recent rice cropping seasons. Farm details, such as the cultivated area in mu (Chinese area unit: 1 mu = 0.067 ha), total rice paddy production in kilogram, cropping pattern, and land tenure status with associated costs in Chinese Yuan (1 USD = 6.329 Yuan) (XE.com 2019) were asked. The third section examined farmers' perceived changes since adopting 3CT. They rated 15 Likert-type scale statements (1 = completely disagree, 6 = fully agree) their rice farming practices (Table 8.5). In addition, farmers rated statements on subjective knowledge (5 items), satisfaction (7 items), and expectations (4 items) regarding 3CT on a 6-point Likert-type scale (1 = completely disagree, 6 = fully agree) (Table 8.3). Eight dimensions of change were selected to examine the different aspects of the farmers' perceived social, economic, and environmental changes. All dimensions were evaluated using 6-point Likert-type scales (1 = completely disagree, 6 = fully agree). Some were renamed for the purpose of better comprehension during the interviews. The dimensions included in the questionnaire were: 1) agricultural production (8 items) (Table 8.6), 2) physical capital (renamed facilities and equipment, 5 items) (Table 8.7), 3) food security (5 items) (Table 8.10), 4) human capital (renamed knowledge and knowledge sharing, 4 items) (Table 8.8), 5) social capital (renamed social recognition, 3 items) (Table 8.9), 6) poverty (renamed wealth change, 5 items) (Table 8.12), 7) health (renamed health change, 3 items) (Table 8.11), and 8) natural capital (19 items) (Table 8.13). For this study, three dimensions from Blundo-Canto et al. (2018) were not included (employment, financial capital and flows, and land tenure). They were not considered relevant in the Chinese context and for the specific research objectives. The dimensions poverty and cultural capital were compiled into one for this study. The fourth part of the questionnaire included questions about the farmers' non-rice income. Finally, in the fifth part, demographic information such as age, gender, marital status, and household composition was asked. Questions about children's education and possible farm succession were also included.

The survey questionnaire was created in English and translated into Chinese. To ensure content validity, the Chinese questionnaire was independently back-translated into English and reviewed for possible imparities. Data were collected by means of face-to-face interviews using the mobile data collection application CommCare (Version: Dimagi 2.44.3). The questionnaire was built online in the CommCare program and consisted of both languages. The CommCare application was installed on Samsung Galaxy Tablets A 7.0 (2016) LTE SM-T285 and deployed offline in the villages (Figure 8.1). The study was approved by the IRRI Research Ethics Committee (2019-0003-A-2016-61).

Figure 8.1 Enumerator interviewing a farmer in Ruhu Township pointing at a picture in the natural capital dimension section
Source: H. Wehmeyer (2019)

### 8.2.2 Sampling and Survey Implementation

Purposive sampling was chosen in terms of geographic location. The district of Huicheng in the prefecture of Huizhou City in Guangdong Province was selected by GDRRI as the study area due to its importance as a key agriculture production zone in the province. Moreover, the district of Huicheng in Huizhou City Prefecture participated in the World Bank's 'Guangdong Agricultural Non-Point Source Pollution Control Project'. The farmers in the district of Huicheng received promotion and demonstration of 3CT starting in 2014 (World Bank 2013a: 31, b: 7). In this regard, the 3CT perception survey was conducted in three townships of Huicheng District: Hengli, Luzhou, and Ruhu (Map 8.1). Two villages per township were visited for the farmer interviews. Farmers were selected by local staff from the commune office. They were contacted by the village heads and asked for participation in the survey. Farmers who agreed to participate in the survey were invited to come to the village center on the day of the survey to conduct the interviews. Each farmer received compensation for their travel cost. All interviews were conducted in a central village location where selected farmers were invited to attend. Farmers' information was collected by local enumerators, who received special interviewing training before the data collection took place. Enumerators completed the questionnaire with the farmer. Depending on farmers' literacy levels and their eyesight, enumerators would read the questions to the farmers, or farmers would read the questions themselves. The enumerators would insert the answers into the questionnaire application. Data collection took place over three days in April 2019 (17.-19.04.2019). The questionnaire was completed in approximately 35-45 minutes.


Map 8.1 Location of the selected townships for the 3CT perception survey in Huizhou City Prefecture, Guangdong Province
Concept: H. Wehmeyer; Cartography: M. Brunner; Cartographic base: GADM (2020)

### 8.2.3 Data Analysis

Raw data were exported from the CommCare dashboard and imported into Microsoft Excel (version 1910). The raw data exports in Microsoft Excel were merged by farmer ID and imported to the statistical package IBM SPSS 26 for data analysis. Regional units such as the Chinese surface unit 'mu' and China's currency 'Yuan' were converted to hectare (1 mu = 0.067 ha) and USD (USD 1.0 = CNY 6.329) (XE.com 2019), respectively. Descriptive statistics were conducted to provide sample descriptions of the demographic, socioeconomic, and financial as well as agricultural data of the entire sample. Furthermore, farmers' agricultural performance was analyzed by computing total production quantities (t), yield (t/ha), and inputs (USD/ha) to calculate the estimated average income from rice (USD/ha). A partial budget analysis was performed to examine farmers' perceived change in profitability. Parametric tests, namely, Pearson correlations, t-Test including Cohen's d effect size, and analysis of variance (ANOVA), were executed. Exploratory and confirmatory factor analyses were used to analyze farmers' perceived benefits of 3CT and the dimensions of change to identify underlying relationships between items. This approach was chosen because the perceived changes can be multifactorial. It can be assumed that the items are not fully independent from each other. The chosen extraction method was principal components based on eigenvalues >1 and varimax rotation. To assess the reliability of the Likert-type scale measures, Cronbach's alpha (α) was computed to analyze the internal consistency of items forming a scale. Lastly, structural equation modeling (SEM) procedures were performed to test the relationship between the economic, social, and environmental impact and the effect of each parameter. SEM was performed using the statistical software package AMOS 26. Maximum likelihood method of estimation was applied to calculate the SEM coefficients (Byrne 2013: 141). The model fit was assessed using the Comparative Fit Index (CFI) and the root mean square error of approximation (RMSEA). CFI with values higher than 0.90 represent an acceptable fit, values above 0.95 a good fit. RSMEA values lower than 0.08 signify an acceptable fit; values below 0.05 are a good fit (Byrne 2013: 78–81; Connor, Siegrist 2016: 465). The SEM analysis was conducted in three steps. First, the relevant impact variables were selected. Second, the data were fitted to the structural model. Third, modification indices were used to identify parameter additions to reach a model with a better fit. For testing the model, all participants were included (n = 142). Overall, statistical significance was set to p = ≤0.05.

## 8.3 Results

The results of this study are structured as follows. Sociodemographic characteristics of the sample are described. This is followed by the presentation of farmers' 3CT adoption and perceived benefits. Next, farmers' levels of satisfaction, subjective knowledge, and expectations are demonstrated, and the agronomic results are shown. Lastly, farmers' perceptions of change in rice farming practices and dimensions of change as well as the structural equation modelling conceptual model are presented.

In total, 142 farmers participated in the study, 79.6 % (n = 113) were male and 20.4 % were female (n = 29). The participants' mean age was 58.8 years (standard deviation (SD) = 9.3). They had been farming for an average of 35.0 years (SD = 12.8) with a minimum of four years and a maximum of 62 years. All participants were married. The average number of household members was 7.1 (SD = 3.3), of which 3.0 (SD = 1.6) were children 15 years and younger. Two-thirds (66.2 %, n = 94) of the farmers indicated having at least one non-rice income source. The distribution between the three townships was similar. On average, farmers' non-farming income constituted 72.0 % (SD = 25.4) of their total income. About a quarter of the farmers (23.4 %, n = 22) said that they received 10-50 % of their total income from non-farming activities, 35.1 % (n = 33) said 60-89 %, and 41.5 % (n = 39) answered that over 90 % of their total income came from non-farming activities. The most mentioned sources of non-rice income were salary earner at a private firm (47.1 %, n = 57), casual wage earner (25.6 %, n = 31), and salary earner at public facilities (5.8 %, n = 7). Farmers were also asked about their plans regarding their farm succession, concretely, what would happen to their farm if they were not able to farm anymore. Most farmers said that their children might continue farming on it (46.1 %, n = 65) or that they might rent it out (35.5 %, n = 50). Some farmers had not taken a decision yet (6.4 %, n = 9) and replied that it depends on the situation (7.8 %, n = 11). Farmers indicated that most of their children above the age of 16 were doing non-farm work (73.6%, n = 103) and some were doing farming (17.9 %, n = 25). However, only 17.1 % (n = 24) of the farmers' children were living in a city while the majority still lives in the countryside (82.9 %, n = 116).

### 8.3.1 3CT Adoption and Farmers' Perceived Benefits of 3CT

3CT was introduced to the farmers from 2011 onwards. Most farmers reported that they were introduced to the technology between 2014 to 2017 (83.2 %, n = 118). More than half of the farmers (56.3 %, n = 80) adopted 3CT in 2014. In the following years, all participants started using 3CT in their fields. The average time from introduction to adoption was 0.3 years (SD = 0.70) (Table 8.1). The adoption timing differed between townships. Farmers in Hengli Township showed the highest adoption rate in 2014 (86.7 %, n = 39), followed by the farmers in Luzhou Township who mainly adopted 3CT in 2014 (56.0 %, n = 28) and 2016 (34.0 %, n = 17). In Ruhu Township, most farmers adopted the technology in 2017 (53.2 %, n = 25), with some farmers already adopting 3CT in 2014

(27.7 %, n = 13). In general, all 142 farmers reported wanting to continue 3CT in the upcoming seasons. Farmers' main source of information about farming practices and new technologies, such as 3CT, were the government (78.9 %, n = 112) and village farmers groups (66.2 %, n = 94), followed by the village head (19.0 %, n = 27) and television (8.5 %, n = 12). Few farmers also mentioned the internet (2.1 %, n = 3), WeChat (2.1 %, n = 3), and neighboring farmers (1.4 %, n = 2) as a source of information on agricultural practices and technologies.

Table 8.1 Frequencies (n, %) of introduction and adoption of 3CT

| | Introduction year of 3CT | | Adoption year of 3CT | |
|---|---|---|---|---|
| Year | Frequency | Percent (%) | Frequency | Percent (%) |
| 2011 | 4 | 2.8 | - | - |
| 2012 | 5 | 3.5 | - | - |
| 2013 | 12 | 8.5 | - | - |
| 2014 | 62 | 43.7 | 80 | 56.3 |
| 2015 | 16 | 11.3 | 14 | 9.9 |
| 2016 | 19 | 13.4 | 19 | 13.4 |
| 2017 | 21 | 14.8 | 26 | 18.3 |
| 2018 | 3 | 2.1 | 3 | 2.1 |
| Total | 142 | 100.0 | 142 | 100.0 |

**Benefits of 3CT.** Since all farmers responded yes to continuing the use of 3CT, they were asked to rate 16 items concerning the benefits of 3CT adoption on a 6-point Likert-type scale (Table 8.2). The ratings ranged from 3.75 to 5.71, with a mean of 5.30 (SD = 0.40). Overall, farmers perceived the positive aspects of the technology. The five most highly rated statements were "Easy to apply", "Satisfies my preferences", "Fits my cropping pattern", "Less lodging", and "High yield". A confirmatory factor analysis over two factors was conducted to find out about the critical attributes that are necessary for the adoption of innovation (Chapter 4.1). The two factors explained 41.2 % of the variance and concerned the two main benefits of adopting a new technology such as 3CT. Factor 1 (m = 5.58, SD = 0.44, n = 8) describes the positive application experiences with 3CT and the technology's compatibility. Hence, this is the compatibility factor of 3CT. Reliability analysis of 3CT compatibility resulted in a Cronbach's α of 0.837 (n = 8). Factor 2 describes the positive reductions and farming practice changes farmers experienced since adopting the technology, in particular regarding labor. Therefore, this factor can be interpreted as the relative advantage that farmers gained from 3CT adoption, which facilitated their farming. Thus, this is the facility factor. Reliability analysis 3CT facility resulted in a Cronbach's α of 0.529 (n = 8). However, excluding the item "Labor shortage" increased Cronbach's α to 0.651 (m = 5.21, SD = 0.54, n = 7). This item showed a small (<0.300) positive and negative factor loading on both factors. It further indicated that this item does not fit in either factor category. Therefore, this item was not included for further analysis.

No significant differences between the three townships in the rating of the two benefit factors were detected (compatibility: $F(2,139) = 3.019$, $p = 0.052$), facility: $F(2,139) = 2.072$, $p = 0.130$). Significant differences between male and female farmers were present for the compatibility factor ($t(140) = 3.263$, $p = 0.001$, $d = 0.426$). Male farmers (m = 5.64, SD = 0.35, n = 113) generally rated the benefits higher than the female farmers (m = 5.35, SD = 0.64, n = 29). In particular, female farmers rated the items "Satisfies my preferences" ($t(140) = 2.749$, $p = 0.007$, $d = 0.499$), "Fits my cropping pattern" ($t(140) = 3.435$, $p = 0.001$, $d = 0.530$), "Less lodging" ($t(140) = 2.240$, $p = 0.027$, $d = 0.646$), "Technology is easily available" ($t(140) = 3.217$, $p = 0.002$, $d = 0.734$), and "Labor costs are lower" ($t(140) = 3.047$, $p = 0.003$, $d = 0.768$) significantly lower than the male farmers. The facility factor did not show significant differences between gender ($t(140) = 1.461$, $p = 0.146$).

Table 8.2 Mean ratings of the perceived 3CT benefits and factor loadings of the rotated component matrix of the confirmatory factor analysis

| **Benefits of 3CT** | **Mean rating (SD)** | **Factor loadings** | |
|---|---|---|---|
| | | **1** | **2** |
| Easy to apply | 5.71 (0.55) | **.614** | .294 |
| Satisfies my preferences | 5.64 (0.51) | **.629** | .147 |
| Fits my cropping pattern | 5.58 (0.55) | **.705** | .170 |
| Less lodging | 5.58 (0.65) | **.623** | -.081 |
| High yield | 5.57 (0.74 | **.544** | .314 |
| Technology is easily available | 5.56 (0.76) | **.734** | .189 |
| Technology is suitable for my field conditions | 5.55 (0.76) | **.726** | .176 |
| Less damages (pest, drought) | 5.49 (0.60) | .301 | **.477** |
| Weather conditions allowed the use | 5.44 (0.61) | **.705** | .150 |
| Less expensive | 5.34 (0.81) | .345 | **.462** |
| More free time | 5.27 (0.81) | .197 | **.596** |
| Replaced different technology(ies) | 5.24 (1.36) | .076 | **.320** |
| Labor hours are lower | 5.08 (0.79) | .283 | **.762** |
| Plants die less | 5.08 (1.10) | -.075 | **.457** |
| Labor costs are lower | 4.95 (1.02) | .119 | **.758** |
| Labor shortage * | 3.75 (1.70) | -.260 | **.247** |

Note: N = 142; 6-point Likert-type scale: 1 = not applicable at all, 6 = very applicable; * item deleted for further analysis; highest factor loadings are bold; Cronbach's α factor 1 = 0.837, factor 2 = 0.651

### 8.3.2 Farmers' Satisfaction, Subjective Knowledge, and Expectations Regarding 3CT

Seven items were used for analyzing farmers' level of satisfaction with 3CT (Table 8.3). Reliability analysis resulted in a Cronbach's α of 0.678 (n = 7), but by removing the item "I am not sure the technology was worth the trouble it took to implement it" it increased to 0.824 (m = 5.41, SD = 0.58, n = 6). No significant gender differences were detected (t(140) = 0.962, p = 0.338). Likewise, ratings between the townships did not result in statistically significant differences (F(2,139) = 2.943, p = 0.056). Nevertheless, a strong positive correlation between satisfaction and subjective knowledge was found (r = 0.769, p = <0.001). This indicates that farmers who perceived themselves to have high knowledge about 3CT were also highly satisfied with the technology. Five items were used to assess farmers' subjective knowledge on 3CT. Reliability was high with a Cronbach's α of 0.889 (m = 5.25, SD = 0.82, n = 5). There were no statistically significant differences between male and female farmers (t(140) = 0.546, p = 0.586). However, significant differences between townships were found (F(2,139) = 3.294, p = 0.040). Hengli farmers expressed significantly higher levels of subjective knowledge (m = 5.48, SD = 0.57, n = 45) than the farmers in Ruhu Township (m = 5.05, SD = 0.84, n = 47) (t(90) = 2.842, p = 0.006; d = 0.723). Lastly, farmers were asked four questions to evaluate their expectations of 3CT. Reliability analysis resulted in a Cronbach's α of 0.725 (n = 4) with a mean score for expectations of 5.25 (SD = 0.81). There were no significant differences between male and female farmers (t(140) = -0.375, p = 0.708) as well as between the three townships (F(2, 139) = 0.746, p = 0.476). Nevertheless, a strong positive correlation between 3CT expectations and satisfaction was found (r = 0.700, p = <0.001). Farmers whose expectations on a successful implementation of the technology were met, were also highly satisfied with it.

Table 8.3 Mean ratings of the items for satisfaction, subjective knowledge, and expectations of 3CT

| | Mean | Std. Deviation |
|---|---|---|
| **Satisfaction** | | |
| I expected that it would be easy for me to follow the technology. | 5.18 | 0.84 |
| It has been easy for me to follow the technology exactly. | 5.49 | 0.76 |
| I received a good explanation of the technology. | 5.08 | 1.04 |
| I am not sure the technology was worth the trouble it took to implement it. + | 1.67 | 1.07 |
| The technology has been great for the environment. | 5.58 | 0.66 |
| My fellow farmers are just as happy using the technology as me. | 5.56 | 0.71 |
| The technology has become standard practice for me. | 5.55 | 0.69 |
| **Subjective knowledge** | | |
| I know pretty much about the technology. | 5.26 | 0.86 |
| I do not feel very knowledgeable about the technology. * | 1.14 | 0.83 |
| Among my circle of fellow farmers, I am one of the experts on the technology. | 4.78 | 1.05 |
| Compared to most other people, I know less about the technology. * | 1.73 | 1.10 |
| When it comes to the technology, I really do not know a lot. * | 1.68 | 1.03 |
| **Expectations** | | |
| The technology did not work out the way I expected it to. * | 1.85 | 1.35 |
| My expectations for my financial development since using the technology have been met. | 5.12 | 0.81 |
| The technology exceeded my expectations of productivity increase. | 5.25 | 0.86 |
| I expect to see more positive changes when I continue using the technology. | 5.32 | 0.83 |

Note: N = 142; 6-point Likert-type scale: 1 = completely disagree, 6 = fully agree; * item was reverse coded for mean calculation; + item was deleted for further analysis

### 8.3.3 Agricultural Performance

Farmers were generally cultivating small rice fields ranging from 0.07 ha to 2.40 ha with an average of 0.35 ha (SD = 0.28). Most farmers' cropping pattern was rice-rice-fallow (99.3 %, n = 141). More than half of the farmers used inbred and hybrid rice varieties (56.3 %, n = 80), while 30.3 % (n = 43) only grew inbred varieties and 13.4 % (n = 19) planted only hybrid varieties. Some farmers (35.9 %, n = 51) indicated that they also cultivated vegetables, maize, peanuts, watermelon, sweet potato, guava, soybean, or a combination of these crops next to rice during the 2018/2019 non-rice season from December to February.

In the 2018 early rice season, farmers spent an average of USD 233.3 (SD = 154.6) on input costs corresponding to an average of 944.6 USD/ha (SD = 321.3). Farmers' mean yields reached 6.2 t/ha (SD = 0.6). Most farmers kept some or all their rice production for home consumption (89.4 %, n = 127). Seventy-five farmers (52.8 %) also sold their rice partially or fully, and 88 farmers (61.9 %) kept seeds for seed stock. On average, farmers sold 67.7 % (SD = 26.3) of their harvest and their mean rice income was USD 679.9 (SD = 557.9). Hengli farmers had significantly higher rice incomes ($F(2,71) = 3.653$, $p = 0.031$) and yields ($F(2,139) = 15.955$, $p = <0.001$) than the other farmers. They also spent significantly less per hectare in input cost than Luzhou and Ruhu farmers ($F(2,139) = 6.351$, $p = 0.002$). In the 2018 late rice season, farmers spent USD 360.7 (SD = 273.7) on inputs equating to mean input costs of 1153.1 USD/ha (SD = 359.3). Their mean yield was 6.7 t/ha (SD = 0.6). Most kept their rice production for their own consumption (99.2 %, n = 139). Fifty-two farmers (37.1 %) also sold some of their rice and 21 (15.0 %) kept seeds for stock. Farmers sold 48.1 % (SD = 22.1) of their harvest on average and generated a mean rice income of USD 841.5 (SD = 691.5). No significant differences between the townships were detected for rice income ($F(2,45) = 0.121$, $p = 0.886$). However, significant variations in yield ($F(2,137) = 8.204$, $p = <0.001$, total input cost ($F(2,127) = 3.414$, $p = 0.036$), and input cost per hectare ($F(2,127) = 14.133$, $p = <0.001$) were found. Farmers in Hengli Township had significantly higher yields ($t(91) = 3.289$, $p = 0.001$, $d = 0.589$) than Luzhou farmers. Also, Luzhou ($t(81) = -5.315$, $p = <0.001$, $d = -0.321$) and Ruhu farmers ($t(82) = -4.291$, $p = <0.001$, $d = 0.286$) had considerably higher input cost per hectare than Hengli farmers. In addition, notable differences between farmers in Luzhou and Ruhu Township were present for yield ($t(94) = -3.724$, $p = <0.001$, $d = 0.613$) and total input cost per season ($t(91) = 2.235$, $p = 0.028$, $d = 0.294$).

In 2018, farmers spent an average of USD 612.3 (SD = 390.9) on rice production and attained a mean yield of 6.5 t/ha (SD = 0.6). They sold on average 44.0 % (SD = 21.7) of their production and had a mean rice income of USD 1079.8 (SD = 1001.8). Significant differences between the townships were found for yield and inputs cost. Hengli farmers reached significantly higher yields than Luzhou ($t(91) = 4.613$, $p = <0.001$, $d = 518$) and Ruhu farmers ($t(89) = 2.248$, $p = 0.027$, $d = 0.529$). There were also significant yield ($t(94) = -2.185$, $p = 0.031$, $d = 0.553$) and input cost differences ($t(91) = 2.283$, $p = 0.\ 25$, $d = 0.474$) between farmers in Luzhou and Ruhu Township (Table 8.4). Partial budget analysis resulted in a mean added income from increased rice production of 915.5 USD/ha (SD = 1010.6) since adopting 3CT. Farmers' have avoided spending 718.4 USD/ha (SD = 694.0) input costs since using 3CT. They perceived input cost savings of 57.5 % (SD = 19.2) on average. Hengli farmers mentioned significantly higher average savings of 64.7 % (n = 43) compared to farmers in Luzhou (51.8 %, n = 48) and Ruhu Township (56.6 %, n = 17) ($F(2,139 = 5.576$, $p = 0.005)$. Furthermore, most farmers (97.9 %, n = 139) perceived a positive change in their rice income and a mean increase in yield of 1.1 t (SD = 0.9) since adopting the technology. Before the adoption, farmers' average yield was 5.6 t/ha (SD = 1.0).

Table 8.4 Agronomic results per season and year 2018 by township

| | Township | Rice yield (t/ha) [1] | Input cost (USD/ha) [2] | Total input cost (USD) [2] | Total rice income (USD) [3] |
|---|---|---|---|---|---|
| Early season 2018 | Hengli | 6.6 (SD = 0.5) | 816.2 (SD = 221.0) | 206.1 (SD = 146.9) | 897.1 (SD = 546.9) |
| | Luzhou | 6.0 (SD = 0.6) | 1056.0 (SD = 459.3) | 265.6 (SD = 183.0) | 638.1 (SD = 649.0) |
| | Ruhu | 6.1 (SD = 0.7) | 937.1 (SD = 131.7) | 225.2 (SD = 122.6) | 469.0 (SD = 293.3) |
| Late season 2018 | Hengli | 6.9 (SD = 0.6) | 921.9 (SD = 203.0) | 326.3 (SD = 190.4) | 866.9 (SD = 725.2) |
| | Luzhou | 6.5 (SD = 0.6) | 1299.3 (SD = 391.3) | 443.3 (SD = 375.4) | 889.4 (SD = 784.6) |
| | Ruhu | 6.9 (SD = 0.7) | 1192.1 (SD = 337.8) | 306.9 (SD = 182.1) | 768.0 (SD =579.3) |
| Year 2018 | Hengli | 6.8 (SD = 0.5) | 867.9 (SD = 195.6) | 572.0 (SD=309.0) | 1376.4 (SD = 1138.5) |
| | Luzhou | 6.3 (SD = 0.5) | 1178.8 (SD = 359.3) | 726.4 (SD = 507.9) | 1019.9 (SD = 984.2) |
| | Ruhu | 6.5 (SD = 0.6) | 1042.8 (SD = 192.8) | 532.2 (SD = 283.8) | 836.0 (SD = 806.2) |

Note: [1] n = 140, [2] n = 134, [3] n = 84

### 8.3.4 Farmers' Perceived Changes in Rice Farming and Dimensions of Change

**Perceived farming practices changes.** Farmers were asked to answer a set of 15 questions to find out about the positive and negative changes in their agricultural practices since adopting 3CT (Table 8.5). The questions included items on input use, especially change in fertilizer use and pesticide application as well as adapted irrigation and machinery practices. Additionally, farmers rated their postharvest activities related to rice straw and soil handling. Questions related to measures for enhancing biodiversity, such as the planting of trees and other plants, were also included in the set of questions. Reliability analysis of the scale resulted in a Cronbach's α of 0.785 (n = 15). Farmers strongly agreed to have used less inorganic fertilizer and pesticide, which signals a proper application of 3CT. They rather disagreed with having used more organic fertilizer and only slightly agreed to have used less herbicide. Other inputs such as irrigation and machinery use did not change much, according to the farmers. Significant differences between the townships were found for the items on "I have used less chemical fertilizer" ($F(2,139) = 11.335$, $p = <0.001$) and "I have used less pesticide" ($F(2,139) = 13.230$, $p = <0.001$). Farmers in Hengli Township (n = 45; chemical fertilizer: m = 5.93, SD = 0.25; pesticides: m = 5.82, SD = 0.39) rated the two statements significantly higher than farmers in Luzhou (n = 50; chemical fertilizer: m = 5.28, SD = 1.03, pesticides: m = 4.86, SD = 1.26) and Ruhu Township (n = 47; chemical fertilizer: m = 4.96, SD = 1.00, pesticides: m = 4.94, SD = 0.99).

Table 8.5 Mean ratings of the perceived farming practice changes since the adoption of 3CT

| Perceived changes in farming practice since the adoption of 3CT | Mean | Std. Deviation |
|---|---|---|
| I have used more seeds per mu. | 2.40 | 1.29 |
| I have used less chemical fertilizer. | 5.38 | 0.94 |
| I have used more organic fertilizer. | 2.35 | 1.20 |
| I have used less herbicide. | 3.23 | 1.20 |
| I have used less pesticide (such as insecticide, fungicide, etc.). | 5.19 | 1.05 |
| I have used more water for irrigation. | 2.80 | 1.01 |
| I have been doing fewer irrigation hours. | 2.80 | 1.03 |
| I have used more fuel for my agricultural machinery. | 2.59 | 1.05 |
| I have used less electricity for my agricultural practices. | 2.70 | 1.04 |
| My soils have been more prone to erosion. | 2.19 | 1.21 |
| I leave my fields fallow during the non-rice season. | 5.41 | 1.17 |
| I have been collecting my rice straw. | 5.65 | 0.61 |
| I have used my rice straw for mulching, cattle fee, mushroom production, biogas production, or others. | 5.01 | 1.53 |
| I have planted trees and/or shrubs. | 1.85 | 1.07 |
| I have also planted other plants – not rice – between or alongside my fields. | 1.96 | 1.13 |

Note: N = 142, 6-point Likert-type scale: 1 = completely disagree, 6 = fully agree

In order to find out about the many aspects of change that may have occurred since using 3CT, the farmers were asked to rate questions of eight dimensions of change. These questions aim to examine farmers' perceived changes in different aspects of their livelihoods since having adopted the technology.

**Agricultural production.** Changes in agricultural production were evaluated using eight items (Table 8.6). Farmers indicated a lot of changes concerning their rice production. The mean score for agricultural production was 5.35 (SD = 0.49, n = 7). Farmers strongly agreed to have experienced increased yields and decreased their fertilizer use. They also reported having spent less on inputs and other production costs. An exploratory factor analysis was conducted and revealed three factors that concern specific aspects of farmers' experience with 3CT. The three factors explained 66.8 % of the variance. Factor 1 describes the positive changes in agricultural production that the farmers have perceived and demonstrates 3CT's key benefits. Thus, this factor can be regarded as the production outcome factor. Cronbach's α was 0.766. However, reliability analysis suggested removing the item "I now apply more fertilizer at a later growth stage" to increase Cronbach's α to 0.827. The context of the item is rather specific compared to the rest of the scale but lacks an exact description of the time when fertilizer should be applied. Thus, this item was excluded for further analysis. Farmers perceived a strong change in their overall production outcome (m = 5.40, SD = 0.66, n = 3). No significant gender differences were found (t(140) = 0.392, p = 0.696). However, significant differences between the three townships were found (F(2,139) = 8.365, p = <0.001). Hengli farmers (m = 5.71, SD = 0.39, n = 45) rated the items in the production outcome factor significantly higher than the farmers in Luzhou (m = 5.29, SD = 0.79, n = 50) and Ruhu Township (m = 5.22, SD = 0.61, n = 47). Factors 2 and 3 were not further analyzed because they both comprised of just two items which does not allow for a conclusive interpretation. Hence, they were not further discussed.

Table 8.6 Mean ratings of the agricultural production dimension and factor loadings of the rotated component matrix of the exploratory factor analysis

| **Agricultural production** | **Mean rating (SD)** | **Factor loadings** | | |
|---|---|---|---|---|
| | | **1** | **2** | **3** |
| My yield has increased a lot. | 5.46 (0.79) | **.809** | -.033 | .111 |
| I have produced higher-quality rice. | 4.63 (1.01) | .225 | .028 | **.683** |
| Rice farming has become more difficult. * | 1.24 (0.60) | -.007 | **.853** | -.034 |
| Working on the farm is not as hard anymore. | 5.07 (1.21) | .044 | -.273 | **.759** |
| I have been able to save money due to avoided production costs. | 5.28 (5.28) | **.843** | -.045 | .255 |
| I spent more money to pay for production costs. * | 1.25 (0.76) | -.152 | **.781** | -.144 |
| My fertilizer use has decreased. | 5.45 (0.74) | **.801** | -.044 | .228 |
| I now apply more fertilizer at a later growth stage. | 5.45 (1.13) | **.665** | -.265 | -.372 |

Note: N = 142; 6-point Likert-type scale: 1 = not applicable at all, 6 = very applicable; * item was reverse coded for factor mean calculation; Cronbach's α for factor 1 = 0.766; highest factor loadings are bold

**Physical capital.** This dimension includes the changes farmers have perceived in their facilities, machinery, and equipment since having adopted 3CT (Table 8.7). Reliability analysis resulted in Cronbach's α of 0.625 (n = 5). Farmers perceived little changes in physical capital (m = 2.69, SD = 1.05). There were no significant differences between male and female farmers (t(140) = 0.097, p = 0.923). Nonetheless, significant differences between the three townships were found (F(2,139) = 22.004, p = <0.001). Farmers in Hengli Township (m = 3.43, SD = 0.88, n = 45) perceived the most changes in their physical capital and consistently rated the questions higher than the other farmers in Luzhou (m = 2.44, SD = 0.91, n = 50) and Ruhu Township (m = 2.23, SD = 0.98, n = 47).

Table 8.7 Mean ratings of the items in the dimension physical capital

| **Physical capital** | **Mean** | **Std. Deviation** |
|---|---|---|
| I have been able to buy new farming equipment. | 3.15 | 1.80 |
| I have been able to upgrade or build new farm buildings. | 2.28 | 1.48 |
| I rent more land for rice production. | 2.47 | 1.40 |
| I was able to have my house renovated and improved. | 2.47 | 1.63 |
| I have been able to build a new house. | 3.05 | 1.96 |

Note: N = 142, 6-point Likert-type scale: 1 = completely disagree, 6 = fully agree

**Human capital.** Reliability analysis of the human capital scale demonstrated a Cronbach's α of 0.625 (n = 4) (Table 8.8). However, the results of the reliability analysis suggested excluding the item "I am now able to express concerns about my farming practices". Thus, by excluding this item, Cronbach's α increased to 0.760

(n = 3). Farmers perceived a lot of changes in their human capital (m = 5.07, SD = 0.79). No statistically significant gender differences in perceptions of human capital were found (t(140) = 0.065, p = 0.948). There were also no significant differences between the three townships (F(2,139) = 2.89, p = 0.059).

Table 8.8 Mean ratings of the items in the dimension human capital

| Human capital | Mean | Std. Deviation |
|---|---|---|
| I have gained a lot of knowledge. | 5.25 | 0.76 |
| I have been able to provide a better workforce. | 5.01 | 0.88 |
| I have changed my farming habits. | 4.97 | 1.19 |
| I am now able to express concerns about my farming practices. * | 4.68 | 1.34 |

Note: N = 142, 6-point Likert-type scale: 1 = completely disagree, 6 = fully agree, * deleted for further analysis

**Social capital.** Farmers perceived positive changes in their social capital (m = 4.98, SD = 0.91) (Table 8.9). Reliability analysis resulted in a Cronbach's α of 0.840 (n = 3). There were no significant differences between male and female farmers in the perception of social capital change (t(140) = 0.855, p = 0.388). However, significant differences were found between the townships (F(2,139) = 3.130, p = 0.047). Farmers in Hengli Township (m = 5.24, SD = 0.73, n = 45) perceived significantly higher social capital changes compared to the farmers in Ruhu Township (m = 4.79, SD = 0.82, n = 47).

Table 8.9 Mean ratings of the items in the dimension social capital

| Social capital | Mean | Std. Deviation |
|---|---|---|
| I can now provide advice to fellow farmers on how to improve their farming practices. | 4.89 | 1.06 |
| I can now organize farmers into groups to work together to improve farming practices. | 4.76 | 1.25 |
| I can now communicate with other farmers about my experience in using best management practices. | 5.29 | 0.77 |

Note: N = 142, 6-point Likert-type scale: 1 = completely disagree, 6 = fully agree

**Food security.** Reliability analysis resulted in a Cronbach's α of 0.780 (n = 5) (Table 8.10). Deleting "My family's eating habits have not changed at all" increase it to 0.850 (m = 4.08, SD = 1.07, n = 4). Significant differences between male (m = 4.24, SD = 0.91) and female (m = 3.43, SD = 1.38) farmers were found (t(140) = 3.814, p = <0.001). Male farmers showed significantly higher ratings than female farmers. Moreover, there were significant differences between the three townships (F(2, 139) = 3.877, p = 0.023). In particular, the differences were present between the townships of Hengli (m = 4.27, SD = 0.58, n = 45) and Luzhou (m = 3.75, SD = 1.51, n = 50) as well as between the townships Luzhou and Ruhu (m = 4.24, SD = 0.76, n = 47). Farmers in Luzhou Township rated the changes significantly lower than the farmers in the other two townships.

Table 8.10 Mean ratings of the items in the dimension food security

| Food security | Mean | Std. Deviation |
|---|---|---|
| My family's eating habits have not changed at all. * | 3.70 | 1.64 |
| My family can eat more meat. | 3.75 | 1.27 |
| My family can eat more fruit. | 4.12 | 1.25 |
| My family can eat more vegetables. | 4.11 | 1.25 |
| My family eats more kinds of food. | 4.33 | 1.38 |

Note: N = 142, 6-point Likert-type scale: 1 = completely disagree, 6 = fully agree, * reverse coded item and deleted for further analysis

**Health.** The farmers were asked three questions on the changes they have experienced in their levels of health since they have adopted 3CT (Table 8.11). On average, they gave a very high mean rating of 5.30 (SD = 0.71). The reliability analysis of the items demonstrated a Cronbach's α of 0.775 (n = 3). There were no significant gender differences between male and female farmers (t(140) = 0.856, p = 0.393) as well as between the three townships (F(2,139) = 1.91, p = 0.151).

Table 8.11 Mean ratings of the items in the health dimension

| Health | Mean | Std. Deviation |
|---|---|---|
| My health has improved a lot. | 5.03 | 1.02 |
| I have more health issues. * | 1.23 | 0.68 |
| My family members have become healthier. | 5.10 | 0.82 |

Note: N = 142, 6-point Likert-type scale: 1 = completely disagree, 6 = fully agree, * reverse coded item

**Poverty.** The reliability analysis of the poverty dimension resulted in a Cronbach's α of 0.571 (n = 5) (Table 8.12). However, removing the item "I have lost a lot of money" increased Cronbach's α to 0.604 (n = 4). Compared to the other items, this item was rather unspecific. Thus, it was excluded from further analyses. The mean rating of the four remaining items was 4.49 (SD = 0.80). There were no gender differences (t(140) = 0.374, p = 0.709). However, significant differences between the three townships were found (F(2,139) = 5.45, p = 0.005). Farmers in Hengli Township (m = 4.81, SD = 0.62, n = 45) showed significantly higher ratings compared to the farmers in Luzhou (m = 4.35, SD = 0.95, n = 50) and Ruhu Township (m = 4.34, SD = 0.71, n = 47).

Table 8.12 Mean ratings of the items in the poverty dimension

| Poverty | Mean | Std. Deviation |
|---|---|---|
| I can buy fashionable clothes for my children. | 4.47 | 1.08 |
| I was able to buy a mobile phone. | 4.81 | 1.20 |
| I was able to buy new furniture for the family home. | 3.79 | 1.60 |
| I have more money than before. | 4.89 | 0.68 |
| I have lost a lot of money. * | 1.20 | 0.60 |

Note: N = 142, 6-point Likert-type scale: 1 = completely disagree, 6 = fully agree, * reverse coded item and deleted for further analysis

**Natural capital.** Farmers rated the presence of different insects and vertebrate animals in their rice fields (Table 8.13). They were shown pictures of beneficial indicator species and pest species in rice fields to have a clearer picture of biodiversity changes since their adoption of 3CT. Furthermore, two items asking about plant biodiversity were also included. The farmers indicated that they had not seen many impactful changes in the presence of beneficial rice field-specific species. Reliability analysis of the beneficial species scale revealed a Cronbach's α of 0.501 (n = 11). It suggested excluding the item "I have seen fewer frogs" to increase Cronbach's α to 0.588 (m = 3.27, SD = 0.67 n = 10). Since frogs and toads can be both beneficial and pest species, farmers may not have been able to distinguish or recognize the species shown in the picture and, therefore, were not sure about which types of frogs they have seen in their fields. This item was excluded from further analyses.

There were significant differences between male (m = 3.33, SD = 0.65, n = 113) and female (m = 3.02, SD = 0.70, n = 29) farmers (t(140) = 2.241, p = 0.027, d = 0.659). Male farmers rated the perceived changes greater than the female farmers. There were also significant differences between the three townships (F(2,139) = 17.193, p = <0.001). Hengli farmers (m = 3.66, SD = 0.65, n = 45) rated the items significantly higher than the farmers in Luzhou (m = 2.93, SD = 0.71, n = 50) and Ruhu (m = 3.25, SD = 0.38, n = 47) Township. A significant difference was also found between the farmers in Luzhou and Ruhu Township ($t(95) = -2.663$, $p = 0.009$, $d = 0.578$). The pest species scale's Cronbach's α was 0.673 ($n = 8$) and its mean rating was 2.49 ($SD = 0.73$). No significant differences were found for gender ($t(140) = 0.332$, $p = 0.740$; male: $m = 2.49$, $SD = 0.74$; female: $m = 2.45$, $SD = 0.70$) and between the townships ($F(2,139) = 0.209$, $p = 0.679$). For further analysis, the beneficial indicator species scale was separated into beneficial vertebrates ($n = 4$) and beneficial invertebrates ($n = 4$) because humans tend to perceive these differently (Batt 2009: 180; Taylor, Signal 2009: 134). Also, the two elements for beneficial plant management, "there are more trees and shrubs on my farm" and "there are more wildflowers around my fields", were included in further analyses as individual factors.

Table 8.13 Mean ratings of the items in the dimension natural capital

| **Natural capital** | **Mean** | **Std. Deviation** |
|---|---|---|
| I see more wasps in my fields. [1] | 2.71 | 1.55 |
| I see fewer flies in my fields. [*, 1] | 4.58 | 1.37 |
| There are more dragonflies in my fields. [1] | 2.93 | 1.48 |
| I have seen fewer birds around my fields. [*, 1] | 2.39 | 1.68 |
| I have seen fewer frogs in my fields. [*, 1] | 3.64 | 1.64 |
| There are more fish in my fields. [1] | 3.11 | 1.70 |
| I have seen fewer rats in my fields. [*, 2] | 3.21 | 1.65 |
| There are more crickets in my fields. [2] | 2.37 | 1.19 |
| I have seen more bats in my fields. [1] | 3.69 | 1.33 |
| I have seen more bugs in my fields. [2] | 2.19 | 1.32 |
| There are fewer beetles in my fields. [*, 2] | 4.11 | 1.44 |
| I have seen more butterflies in my fields. [2] | 2.68 | 1.32 |
| I have seen fewer snakes in my fields. [*, 1] | 3.62 | 1.45 |
| There are more stemborers in my fields. [2] | 1.77 | 1.22 |
| I have seen fewer moths in my fields. [*, 2] | 4.40 | 1.33 |
| I have seen fewer spiders in my fields. [*, 1] | 4.24 | 1.31 |
| I see more planthoppers in my fields. [2] | 1.63 | 1.04 |
| There are more trees and shrubs on my farm. [1] | 2.59 | 1.24 |
| There are more wildflowers around my fields. [1] | 2.80 | 1.31 |

Note: N = 142, 6-point Likert-type scale question format with species corresponding pictures, * reverse coded item, 1 beneficial indicator species, 2 pest indicator species

### 8.3.5 Structural Equation Modelling Conceptual Model

For testing the relationship between three latent variables (economic, social, and environmental impact) based on the concept of sustainable development, a model was created using the dimensions of change presented and analyzed in this study. The economic impact was examined using the factors production outcome, physical capital, and poverty. The social impact was analyzed using seven dimensions: social capital, human capital, health, compatibility, facility, satisfaction, and expectations. Lastly, the environmental impact was evaluated using four factors, namely beneficial vertebrates, beneficial invertebrates, more trees and shrubs, and more wildflowers along with the farmers' rice fields (Figure 8.2).

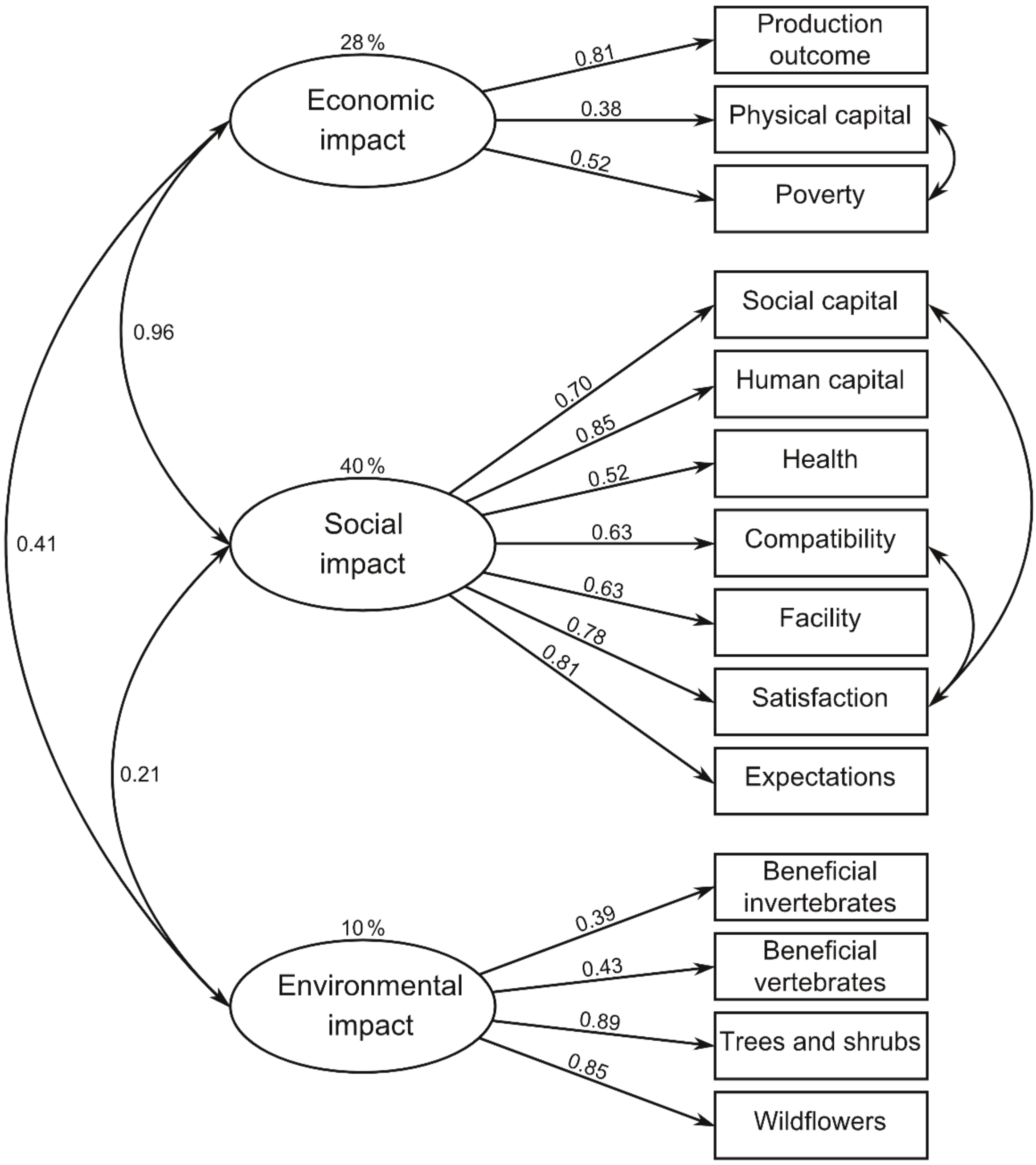



Figure 8.2 Final model for the impact of 3CT on three sustainability pillars
Note: N = 142; Values represent standardized estimates; the initial model does not have correlations between error terms.

The initial model resulted in a suboptimal fit with a CFI = 0.856 and RMSEA = 0.113. With the modification indices applied, the fit was improved by allowing additional correlations between the error terms of the observed variables "physical capital" and "poverty", "social capital" and "satisfaction" as well as between "compatibility" and "satisfaction". The first additional correlation indicated that financial assets for the farming business and personal expenses are related. If farmers earn more, they will be likely to invest in both factors for their economic development. The two following correlations highlighted the link between satisfaction with 3CT and the effects it has had on farmers' social capital and farming practice compatibility. The more farmers were able to share with their fellow farmers, the more satisfied they were with 3CT. Hence, the correlation between social capital and satisfaction concerned the beneficial social element of the technology. The correlation between satisfaction and compatibility highlighted how well 3CT is adapted to the farmers' needs. Hence, this correlation demonstrated the link between ease of use and positive adoption experience. The revised model showed an improved overall fit with a CFI = 0.914 and RMSEA = 0.089. The structural model explained 28 % of the variance of 3CT's economic impact. Furthermore, 40% of the variance could be explained for the social impact of the technology, and 10 % of the variance of the environmental impact was explained in the model. The standardized coefficients are represented along each path.

## 8.4 Discussion

The present study examined farmers' perception of changes related to the three pillars of sustainability, including economic, environmental, and social impacts, in a non-experimental setting of 3CT. For each impact, different factors of change were selected. The structural model showed good model fit indices after reducing structural constraints and allowing covariance relationships between error terms. The model and the structural path analysis are discussed in detail using the framework of the Agenda 21 sustainability targets (Bell, Morse 2008: 30; United Nations Sustainable Development 1992).

Farmers perceived a lot of changes regarding the economic impact of 3CT. The three dimensions for evaluating the economic impact of 3CT – production outcome, physical capital, and poverty – showed high to medium-high regression weights with the latent construct economic impact and good reliabilities of the scales ($\alpha > 0.600$). The production outcome factor had the highest regression weight ($r = 0.81$), with economic impact indicating to be a strong explanatory variable for economic impact. Farmers perceived positive changes in their production outcome. This could be due to the positive impact of 3CT on farmers' yields and financial situation. The results also showed that since the adoption of 3CT, farmers have been attaining mean yields of above 6 t/ha (min. = 5.1 t/ha, max. = 7.8 t/ha), approaching the national average of 7.0 t/ha (National Bureau of Statistics of China 2020a). Whereas before adopting 3CT, farmers reached average yields of 5.6 t/ha (SD = 1.0). This is in line with experimental studies, which also showed a significant yield increase of 1-1.5 t/ha when using the 3CT compared to farmer's practice (Zhong et al. 2010: 230; Wang et al. 2017: 687–689). Furthermore, these results also indicate that 3CT increases nutrient use efficiency under non-experimental conditions (Wang et al. 2017: 682–683). All participants responded that they have adopted 3CT fully and have not changed the timings of fertilizer application which is crucial for improving nitrogen use efficiency and reducing environmental pollution (Zhong et al. 2010: 224–225; Wang et al. 2017: 688). Overall, the farmers in the present study perceived a positive influence of 3CT adoption on the reduction of fertilizer and pesticide use as well as reduced labor hours and input costs. In 2018, farmers perceived savings of input costs of on average 389.4 USD/ha (SD = 344.6) which includes both fertilizer and pesticide costs and is in line with results shown in experimental field trial studies (Zhong et al. 2010: 230).

The findings of this study showed that farmers, on average, had an added revenue from an increase in yield of on average 915.5 USD/ha (SD = 1010.6) since using 3CT. However, it needs to be noted that there is high variability in these data. A possible explanation could be different times of introduction and adoption. Hengli Township was the first of the three townships to introduce 3CT. Hence, farmers adopted the technology two to three years earlier than farmers in Ruhu and Luzhou Township. This means that these farmers had time to get used to the new technology, mastered its application, and perceived more positive effects over a longer period. In fact, results showed that farmers from Hengli Township attained higher yields and higher total gross income from rice than farmers in the other two townships. Studies investigating the adoption of farming technologies and practices have shown that the duration of adoption plays a crucial role in perceiving positive effects (Liu, Bruins, Heberling 2018: 19; Baumgart-Getz, Prokopy, Floress 2012: 23). Taking all production outcome results of the present study into account, it can be interpreted that participants' farming business has improved profitability due to increases in production quantities and decreased input costs. These results are consistent with the elements needed for successful and long-term adoption of new agricultural practices and technologies (Pannell et al. 2005: 8–9; Prokopy et al. 2008: 308–309). Participants also perceived changes in poverty reduction which can be further translated into positive financial development. Results of the SEM model showed that poverty had a medium high regression weight ($r = 0.52$) and can, therefore, be seen as a good predictor of economic impact. Farmers from Hengli Township, who have adopted 3CT the longest and reached the highest average yields, indicated a significantly higher reduction of poverty levels compared to the farmers in other townships. Poverty reduction could be attributed to the adoption of 3CT but could also be due to China having raised its efforts to reduce poverty nationwide and boost economic development (Liu et al. 2019a: 1). Most Chinese farmers are not living in conditions of extreme poverty anymore and have been benefiting from significant improvements in infrastructure, public services, and living conditions (Liu et al. 2019a: 4).

Correspondingly, the findings of the present study demonstrated that farmers do not invest much in physical capital (m = 2.69, SD = 1.05) for their agricultural production. This could be due to the fact that the farmers in Guangdong Province are rather wealthy compared to other regions in China and have been able to already establish their farm business, including the necessary physical capital (National Bureau of Statistics of China 2020c). Consequently, the influence of physical capital on the economic impact of 3CT seems to be rather limited in the Chinese context, which was also shown in the lower regression weight (r = 0.38). Furthermore, results also indicated an association between the variables poverty and physical capital, which was shown by the modification indices allowing a covariance between the error terms. This means that both dimensions share some parts of the variance; in other words, they are related or are not distinct concepts. Hence, increasing farmers' physical capital could have a direct effect on their perception of poverty reduction since poverty is defined as a lack of assets (Woolard, Klasen 2005: 884). In total, all three variables explained 28% of the variance of economic impact. It needs to be noted that the present study did not include aspects related to regional and national economic policy developments, non-farming income, or other financial elements that may also have explanatory value.

The second pillar, social impact, was evaluated using seven different variables encompassing internal as well as external social factors. All scales used as variables showed good reliabilities (α > 0.600) and had high regression weights (r > 0.500), indicating to be of great importance for explaining the latent construct. In fact, all seven variables together explained 40% of the variance of social impact. Results showed that farmers in general perceived high benefits from adopting 3CT. These benefits included saving labor hours and having more free time, which are included in the facility factor. Furthermore, participating farmers also considered 3CT easy to apply and to be fitting to their cropping pattern, which are incorporated in the compatibility factor. The variables satisfaction and expectations were also included in the model. The findings demonstrated that farmers had high expectations but also indicated that they were highly satisfied with 3CT. Both variables had high regression weights (r > 0.780) and can be interpreted as important predictors of social capital. Therefore, 3CT not only accounts for compatibility and facility, which gives the technology a relative advantage compared to others but also makes farmers feel satisfied when adopting it. These are important components for adoption in the long term. It has been shown that successful adoption of a new technology or practice has to be compatible with farmers' local circumstances and the environment (Stuart, Schewe, McDermott 2014: 216; Smith, Siciliano 2015: 15; Mottaleb 2018: 126). Based on the literature, subjective knowledge, as well as social and human capital were also included in the model as predictors of social impact (Blundo-Canto et al. 2018: 164–166; Connor, San 2021: 55–56). Participants perceived to have a great amount of knowledge about 3CT. They also evaluated their perceived social capital to be high. Both variables concerned knowledge and knowledge dissemination and were highly correlated (r = 0.683). This means that participants who perceive that they are highly knowledgeable about 3CT are also able to pass this knowledge on to other farmers. If a knowledgeable, trustworthy farmer in the community speaks highly of a new technology or practice, other farmers are more likely to follow (Liu, Bruins, Heberling 2018: 13). Hence, the diffusion of the new technology or practice through the community will be accelerated. Studies have suggested that education and social capital are important elements for the successful adoption of sustainable agricultural practices (Liu, Bruins, Heberling 2018: 13; Prokopy et al. 2008: 303). Networking with peers, businesses, and agencies as well as interpersonal contact have also shown to be important factors influencing the adoption of sustainable agricultural practices. Especially farmer-to-farmer communication has been described to be a significant predictor of technology adoption (Liu, Bruins, Heberling 2018: 12; Prokopy et al. 2008: 303; Lubell, Fulton 2007: 676). The variable human capital focused on farmers' knowledge acquisition and the use of this additional knowledge. Farmers generally evaluated their gain in human capital highly. Human capital also had a very high regression weight (r = 0.85) and is, therefore, an important factor for social impact. Other studies have also shown that the adoption of best management practices can have a positive effect on acquiring human capital (Connor, San 2021: 55–56). Another aspect of social impact is the change in farmers' health. Participants of the present study perceived positive changes in their health status. Reductions of fertilizer and especially pesticides have been shown to have a positive effect on farmers' health (Nicolopoulou-Stamati et al. 2016: 4). It can be concluded that the adoption of 3CT has had a positive social impact and has improved farmers' livelihoods considerably.

The third pillar of sustainability concerns the environment. The present study focused on biodiversity to explain the latent construct of environmental impact. Faunal variables (beneficial vertebrates and invertebrates) had lower regression weights than the floral variables (wildflowers, and trees and shrubs). Nonetheless, since both types of biodiversity are important for ecosystem services, it can be reasoned to include them in impact assessment but possibly refining them further. Farmers perceived more beneficial vertebrates and invertebrates since adopting 3CT. However, farmers in Hengli Township, who used 3CT the longest, perceived more beneficial vertebrates and invertebrates. This result suggests that the longer farmers practice 3CT, the more beneficial biodiversity changes they perceive. Additionally, this finding further suggests that more time is needed to evaluate the technology's full effect on biodiversity changes and that species need time to re-enter less polluted ecosystems. Farmers of the present study generally did not perceive many changes in floral biodiversity. However, it needs to be noted that farmers were provided with pictures for faunal biodiversity but not for floral biodiversity. Therefore, it is not clear if they were not sure about what was meant by wildflowers, trees, and shrubs, and hence, were not able to evaluate them correctly. Another aspect that was not accounted for in this study was herbicide use. If farmers used herbicides, this could have had a negative effect on the floral biodiversity (FAO 2019: 101; Gaba et al. 2016: 7; Egan, Mortensen 2012: 1030). The four variables for environmental impact explained 10% of its variance. It could be argued that this is rather low. However, the selected environmental factors used in the present study focused solely on biodiversity changes, and thus excluded other environmental changes related to water, soil, and the atmosphere. These environmental aspects should not be neglected in a rigorous impact assessment but would have been out of the scope of the present study since perceptions of these elements are difficult to assess. Therefore, these findings only indicate a partial view of the environmental impact of 3CT. Nevertheless, it is important to point out that biodiversity is vital to deliver ecosystem services to humanity. It makes agricultural production and farmer livelihoods more resilient to shocks and stresses, particularly to the effects of climate change. Therefore, a central effort to protect biodiversity is the reduction of environmentally harmful external inputs such as chemical fertilizers and pesticides (Liu et al. 2003: 530; FAO 2019: 3–4). Recently efforts to conserve biodiversity in China have been started because the majority of Chinese ecosystems are estimated to be of low habitat quality (FAO 2019: 155). In this context, biodiversity levels need to be further monitored to create evidence on the effects of 3CT and the recovery process of rice field biodiversity levels.

The present study outlined and tested a conceptual model to investigate the three aspects of sustainable development described in the Agenda 21 sustainability targets (Bell, Morse 2008: 30; United Nations Sustainable Development 1992). It became clear that economic and social impact are closely related, which was shown by the very strong correlation between the two latent constructs, economic and social impact ($r = 0.960$). However, it is important to analyze these two impact areas separately to also focus on aspects that are not solely related to economic matters to have a more holistic view of the different aspects of sustainable development. Most impact studies focus on economic impact, which is important to assess the economic value of new technologies and practices, but neglect other parts of sustainable development such as social and environmental aspects (Liu, Bruins, Heberling 2018: 13–14; Pannell et al. 2005: 6–7; Hunecke et al. 2017: 227). Nonetheless, sustainable development is a holistic concept integrating economic, social, environmental aspects as well as institutional elements (Bell, Morse 2008: 30; United Nations Sustainable Development 1992). Accordingly, social factors such as health, human and social capital, and environmental factors such as biodiversity, soil health, water, and atmospheric conditions, which are not necessarily driven by attaining an economic goal, need to be assessed to ensure sustainable development (Pannell et al. 2005: 1). Social factors are particularly important for the adoption of conservation technologies. Social processes take place for farmers to decide on the adoption of a new technology or practice. Hence, the adoption of agricultural practices is strongly driven by feedback from the family, the community, and personal perceptions of the social environment (Liu, Bruins, Heberling 2018: 13; Pannell et al. 2005: 4; Haghjou, Hayati, Momeni Choleki 2014: 964). Lastly, the World Bank non-point source pollution project ended in 2018. Hence, this poses the question if the subsidies related to 3CT will remain or not. For example, the fertilizer subsidy can be seen as a strong motivation for the farmers to use the 3CT specific fertilizer. However, if the 3CT fertilizer becomes more expensive, some farmers might opt for other options that are not as well suited for their fields. Moreover, if they change the fertilizer they apply in their fields and do not see positive results, farmers might perceive 3CT not to work well and disadaopt the technology. This could be the case particularly for the farmers who have only started the technology recently. Therefore, keeping a close relationship with the farmers through a functioning extension network is crucial for the continuation of further dissemination and broader application of the technology.

**Limitations.** The present study was conducted in a small part of China, in the district of Huicheng, Guangdong Province. The results represent farmers benefitting from the World Bank's non-point source pollution project. The sample size was limited, and sampling was not conducted randomly. Furthermore, the average age of farmers was high; farmers had high incomes and diversified income sources. Therefore, the results may not represent the entire Chinese rice farming population. It also needs to be noted that all data rely on recall and self-reported measures, and thus are susceptible to biases, such as recall bias and social desirability bias.

## Published work

The present chapters 9 and 10 are based on the following published peer-reviewed publication.

**Wehmeyer H.**, Malabayabas A., San S. S., Thu A. M., Tun M. S., Thant A. A., Connor M. (2022). Rural development and transformation of the rice sector in Myanmar: Introduction of best management practices for sustainable rice agriculture. In: Outlook on Agriculture, 51 (2), p. 223–237. https://doi.org/10.1177/00307270221086008

Weblink: https://journals.sagepub.com/doi/10.1177/00307270221086008

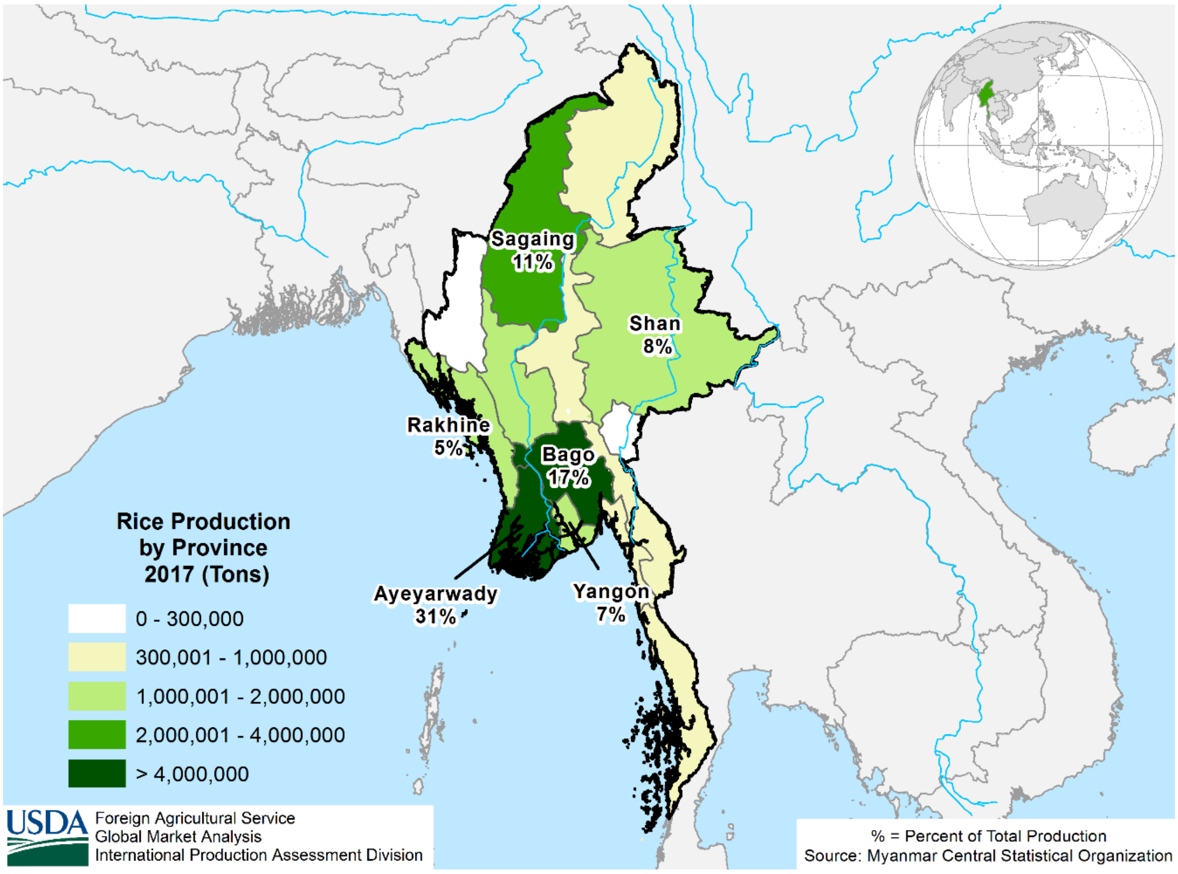
Supplementary material: Household baseline and endline survey questionnaire in Appendix

# 9 Myanmar – Rural Development and Transformation of the Rice Sector

In this chapter, the importance of rice cultivation for rural development in Myanmar and the transformation of the rice sector over time is discussed. First, the current state of rice production and the historical development of the rice sector is presented. Second, the constraints and opportunities for rural development in Myanmar are reviewed. Lastly, CORIGAP's Myanmar activities are described.

## 9.1 Rice Cultivation in Myanmar

Rice farming in Myanmar is characterized by subsistence-oriented agriculture in the lowlands, predominantly in the Ayeyarwady Delta (Map 9.1). In total, less than 20 % of agricultural land is artificially irrigated. The major irrigated zones lie within the Ayeyarwady Delta, near the Bago Yoma dams. In the delta region, more than 60 % of arable land is cultivated with rainfed rice (GRiSP 2013: 130–131; Aye Aye et al. 2017: 104).




Map 9.1 Main rice cultivation areas in Myanmar by production quantity
Source: USDA - Foreign Agricultural Service (2020)

Myanmar is still lagging regarding the use of modern agricultural practices and technologies compared to its neighboring countries, especially in the application of farm mechanization. Agricultural production remains strongly influenced by traditional farming practices. These are generally highly labor-intensive with low labor efficiency due to a low degree of mechanization and agricultural productivity (Figure 9.1). In order to modernize and improve the development of the agricultural sector in Myanmar, farmers would need to use farm mechanization tools more efficiently. Training on the utilization of machinery from land preparation to harvesting and postharvest activities is necessary to advance agricultural productivity and cropping intensity. National policy efforts have not been entirely successful due to the lack of skills, education, and training of the farmers as well as insufficient extension activities. The governmental mechanization scheme involving the distribution of farm machinery to farmers has been rather deficient (YuYu, Hye-Jung 2015: 169).

Figure 9.1 Rice farmer in Myanmar working in the rice fields
Source: M. Connor (2018)

Rice has been a staple food in Myanmar for centuries and remains the most important agricultural crop of the country. Myanmar is the world's seventh-largest rice-producing country behind Vietnam and Thailand (GRiSP 2013: 130–131; FAO Statistics Division 2020). More than half of the agricultural area is used for rice cultivation. It contributes over 30 % to the country's gross agricultural output. Moreover, rice contributes to 95 % of the total cereal output. In this respect, rice is Myanmar's main agricultural product and the second most important exported agricultural commodity after pulses. From 1995 to 2010, total rice production increased from 18 Mt to over 32 Mt. In the 2010s, total rice production ranged between 26 Mt and 28 Mt annually (GRiSP 2013: 130; Aye Aye et al. 2017: 104; FAO Statistics Division 2020). Average rice yields rose from below 3 t/ha in the 1990s to around 3.7 t/ha in the 2010s. Nonetheless, yields have been stagnating over the past decade (Figure 9.2). In general, rice farmers use modern varieties extensively but apply rather low amounts of inputs. As a result, they are not achieving the yield potential. Thus, Myanmar has considerably lower rice yields than other Southeast Asian countries (GRiSP 2013: 130–131; Michigan State University (MSU), Myanmar Development Resource Institute's Center for Economic and Social Development (MRDI/CESD) 2013: 7; FAO Statistics Division 2020; Ricepedia 2020b). The area harvested grew from 4.7 Mha to 8.0 Mha between 1990 and 2010. Area expansion and yield growth mainly accounted for the increased rice production resulting in area growth contributing 58 % and yield growth 42 % to the overall production rises. In 1992, the government introduced a summer paddy production program to facilitate double cropping during the dry season, including irrigation infrastructure upgrading. Additionally, HYVs started being produced nationally through the establishment of seed farms. This has led to annual rice output growth rates ranging between 1-3% over the past two and a half decades (Nay 2011: 5; GRiSP 2013: 130–131; MSU,MRDI/CESD 2013: 6; Raitzer, Wong, Samson 2015: 6; Chen, Lu 2018: 6).

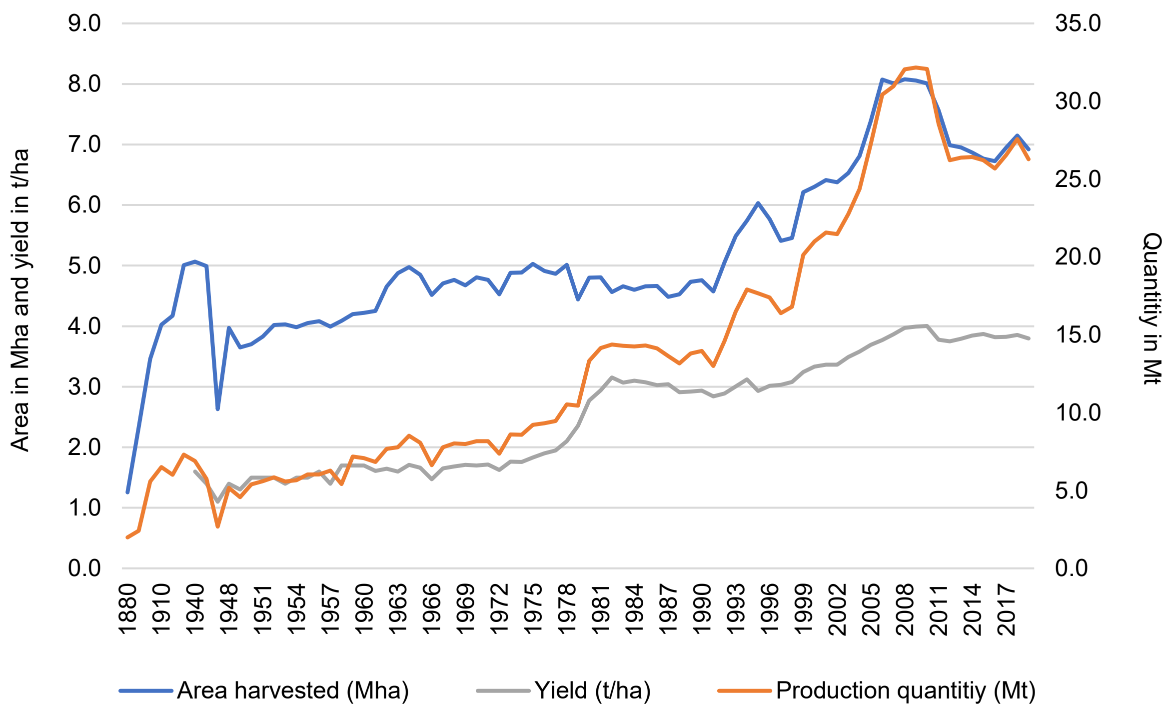



Figure 9.2 Historical development of rice area, yield, and production quantity from 1880 to 2019
Source: Win (1991); FAO Statistics Division (2021a); Concept: H. Wehmeyer (2021)

Rice is a vital income source for farmers and very important for Myanmar's food security. Over half of the poverty reduction between 2005 and 2015 can be directly related to the progress of the agricultural sector (World Bank 2019b: 1). The agricultural sector's contribution to the state's GDP is 38 % and over 25 % of total export earnings constitute of agricultural exports. Furthermore, the sector employs approximately 70 % of all workers in the country. The majority of the farmer households in Myanmar are considered subsistence smallholders; 63 % cultivate on less than two hectares. The remaining 25 % have between two and four hectares and 13 % have more than four hectares (GRiSP 2013: 130; Aye Aye et al. 2017: 104; FAO 2020b). Overall, Myanmar has reached food sufficiency on a national level, as reflected in the export of pulses, rice, and other food items, but many rural households have limited purchasing power that results in indebtedness and malnutrition (Raitzer, Wong, Samson 2015: 4). Consequently, national self-sufficiency has not translated into food security for the poor, with about 30 % of rural households falling below the national poverty line (MSU, MRDI/CESD 2013: 7). Despite major investments in the rice sector by the government, rice remains an unprofitable crop for farmers. Profits are low while input costs for fertilizer and pesticides as well as labor costs are high. In addition, farmers receive little information and often have limited knowledge about how to use a variety of agricultural inputs. Specifically, pesticides are misused due to a lack of education and training (MSU, MRDI/DESD 2013: 7,16). Another issue for farmers is adverse weather conditions such as irregular rainfall coupled with poor water control due to climate change. This has become more prevalent over the past years, with flood and drought frequencies increasing (Nay 2011: 5; MSU, MRDI/CESD 2013: 7). Small farmers have been searching for alternatives such as switching to the cultivation of beans and pulses during the winter season because it is more profitable. This is mostly due to fewer labor requirements and fewer input costs. Nonetheless, prices for beans and pulses are especially volatile since the majority is being exported (MSU, MRDI/CESD 2013: 7).

**Historical development of Myanmar's rice sector.** In the 1850s, the British colonizers established agricultural policies to boost rice production in Myanmar. The essential element to the strong rice productivity in the late 19th century was the areal expansion in the forested area of the Ayeyarwady Delta. The second important element was the shift to growing rice as a monoculture. Technological innovation was not prioritized; thus, rice farming was highly dependent on the weather due to a lack of appropriate irrigation infrastructure (Perry 2008:

51–52; Fujita 2016: 100–101). Rice trade continually expanded until the 1930s and Myanmar became the world's leading rice exporter before WWII. Nevertheless, expansion began to stall in the great economic depression of the 1930s. It would recover by the 1950s through improved infrastructure and modernization efforts. In the early 1950s, Myanmar was one of the big three rice producers in the world, with a global market share of 28 %. But in 1962, the procurement system was changed. New monopolistic policies were introduced that hindered rice trade. Between 1962 and 1967, exports collapsed by 80 %. By 1970 Myanmar's share in the global rice market was only 2 % and reached 0.7 % in 1980. As a consequence, Myanmar's rice sector was stagnating, production levels were determined by seasonal fluctuations, and average rice yields from 1962 to 1975 remained at approximately 1 t/ha. Green Revolution technologies, such as HYVs, were introduced from the late 1960s on but started to show effect only in the early 1980s when the government reduced some control over the rice market. Rice yields rose continuously from an average of 1.3 t/ha in 1980 to 1.8 t/ha in 1987. By the late 1980s, the spread of the Green Revolution was halted when export market prices collapsed, inputs became scarce, and the government regained strict control of the rice trade (Perry 2008: 51-55,75).

The government introduced a national extension program, the 'Summer Paddy Program', in 1992. The objective was to promote double cropping of rice and expand the summer paddy cultivation area with HYVs focusing specifically on the Ayeyarwady Delta. Therefore, technical guidance and investments in agricultural infrastructure, particularly for irrigation and drainage projects, were made. Subsidies for inputs, such as diesel oil for irrigation pumps, were also provided to farmers. Additionally, the government set sown area targets (Matsuda 2009: 23; Fujita 2016: 107,118). This system of compulsory cropping forced farmers to grow rice in the rainy season on land classified as paddy fields. Furthermore, if the paddy field was irrigable, summer paddy in the dry season had to be grown regardless of environmental or economic considerations (Fujita 2016: 116). The government monopolized rice exports until 2003 (Kubo 2013: 185). As a result of these governmental policies, rice has remained the most important crop in Myanmar until today. Deplorably, the overemphasis on rice production has been preventing crop diversification, and hence large-scale agricultural growth and rural development (Lagerqvist, Connell 2018: 302–303).

### 9.1.1 Reorganization of the Rice Industry in Myanmar

Political restructuring and the concomitant political and economic reforms passed after 2010 have aimed to improve Myanmar's infrastructure, promote the private sector, and attract direct foreign investment (Aye Aye et al. 2017: 13). Since 2011, strong efforts have been made to resolve issues related to the country's history of isolation and restrictive policies. A major focus has been put on economic reforms, including profound changes to the agriculture sector. Institutional changes to the agricultural sector have been pursued through the implementation of a comprehensive development plan (Min, Kudo 2013: 40; Aye Aye et al. 2017: 13). The economic reforms are centered around the removal of economic distortions, such as price controls and subsidies, the rationalization of taxes, and the development of the private sector. They further promote the decentralization of administrative and institutional functions, the diversification of the export sector as well as the improvement of import and export procedures. A particular focus lies on farmers' increased freedom of choice in terms of the crops they cultivate and the processing, transport, and trading of their output (Myanmar Ministry of Agriculture and Irrigation 2015: 12–15; Aye Aye et al. 2017: 13).

In this context, the Myanmar Rice Industry Association was established in 2010 with the objective of reorganizing and modernizing the domestic rice sector. It includes multiple stakeholders such as rice producers, traders, and exporters who intend to make Myanmar's rice industry more competitive, specifically regarding countries such as Thailand and Vietnam. The following set of interventions aims to support the improvement of Myanmar's agricultural economy. First, farmers, traders, and millers require increased access to credit. The government has started establishing credit programs for low-income farmers to enable farmers to buy the inputs for higher productivity. Second, raising the farm-gate price of paddy can encourage farmers to produce more through better-adapted inputs and technologies. This results in increased profitability and incentivizes farmers to continue rice cultivation. Third, the financing of small-scale village infrastructure projects is necessary to raise the demand for wage labor for the rural poor. This includes adequate irrigation facilities, better rice mills and storage facilities as well as improved roads for farm-to-market transportation. These ensure high-quality rice for export and reduce transportation costs and time. Additionally, the government has started to help private companies providing microfinancing solutions in order for farmers to buy high-quality seeds and inputs (GRiSP 2013: 131–132).

The Myanmar Rice Sector Development Strategy was launched in 2015. It was jointly conceptualized by the Ministry of Agriculture and Irrigation of Myanmar, IRRI, the FAO Regional Office Asia-Pacific, and the World Bank. Its objective is to boost agricultural productivity to transform rural areas that are highly dependent on rice farming. The strategy contextualizes the need for developing the rice industry, its position in the agriculture sector, and its importance to drive rural transformation. Overall, the global demand for rice is increasing and Myanmar has great potential in the international rice trade. The national strategy puts a strong emphasis on the improved performance and branding of Myanmar rice for the international market (Myanmar Ministry of Agriculture and Irrigation 2015: 12–15). Nevertheless, the greatest obstacles to the modernization of the agriculture sector are related to the ongoing problems of macro-economic stability, widespread infrastructural deficits, economic diversification, and restrictions on the transfer of foreign capital and profits (Aye Aye et al. 2017: 13).

## 9.2 Constraints and Opportunities for Rural Development in Myanmar

Myanmar's economy is being converted from an agrarian economy to an economy based on a mix of activities, specifically manufacturing and services. Agricultural modernization is seen as the catalyst for transforming the wider economy and Myanmar has the possibility to become an agri-food trade hub in Southeast Asia (OECD 2015: 49, OECD 2016a: 34; OECD, FAO 2017: 71). The OECD and FAO emphasize in their Agricultural Outlook 2017-2026 that the reduction of overall poverty through increased incomes in rural areas necessitates raising agricultural efficiency and diversifying to high-value crops. The expansion of the agri-food sector's linkages to non-agricultural activities is important to stimulate employment in non-farm sectors. Hence, the key to this transformation is expanding agricultural exports along the value chain (2017: 71).

**Constraints.** One of the main difficulties in rural areas is poor infrastructure. Producers and traders are forced to substitute the lack of public infrastructure by paying private companies, e.g., for fuel-based generators in place of national electricity supplies. These are high-cost expenses that lower profits, hinder exports, and dampen incentives for other investments (World Bank 2014: 22; OEDC 2015: 54; Snoxell, Lyne 2019: 222). This issue is exacerbated by the rural sector's generally underdeveloped financial system. Smallholders farmers, who dominate agricultural production in Myanmar, mostly do not have the financial means to save and reinvest adequately in their farm enterprises. This problem is intensified by the constraints farmers face to receive formal credit (OECD 2015: 54–55; Snoxell, Lyne 2019: 225). The government has adapted its credit system. It now provides more services to farmers. However, many still resort to loans from relatives and friends or moneylenders at high interest rates (Tun, Kennedy, Nischan 2015: 9–10; Myanmar National Portal 2019; Snoxell, Lyne 2019: 225). In this regard, a negative feedback loop is present. Due to farmers' problems of low liquidity and lack of credit, they are constrained from accumulating productive assets and invest in their farms. This leads to low levels of commercialization and household income. Thus, the factors of liquidity, access to credit, and ownership of productive assets are strongly interrelated (Snoxell, Lyne 2019: 225).

Land tenure security and mandatory cropping regulations affect farmers' incentive to improve agricultural efficiency. In Myanmar, the state retains ownership of all land; farmers are granted land use rights. This perpetuates the vulnerability of smallholders who avoid changes to their practice and cultivate land only to the minimum required (World Bank 2014: 22; OECD 2015: 56–57; Tun, Kennedy, Nischan 2015: 7). It has been shown that investments in farm development are generally positively correlated with land tenure. Secure land tenure incentivizes farmers to invest in their farm enterprise. Hence, commercialization is higher amongst farm households that have more secure land tenure (Place, Roth, Hazell 1994: 38–39; Snoxell, Lyne 2019: 224).

Increasing yields and improving product quality requires solving the problem of access to good seeds. Most farmers use their own seeds, which are becoming less efficient over time. Many farmers simply cannot regularly buy new seeds either because they cannot afford them or because they are not easily accessible (World Bank 2014: 18; OECD 2015: 55). In addition, poor quality control and weak extension support to seed multiplication farms have led to low-quality outputs. Hence, seed quality continuously deteriorates due to bad storage conditions and so does the output from those seeds (OECD 2015: 55). Another barrier to increasing productivity levels is the little use of SSNM, low mechanization, and constraints in postharvest processing. For example, in rice production, there is a lack of dryers, storage facilities, modern milling machinery, and efficient transportation to markets after harvest. This contributes to high postharvest losses and rice contamination resulting in reduced market prices up to 30 % (GRiSP 2013: 132; Myanmar Ministry of Commerce, International Trade Centre 2015: 7). This is related to the issue of a weak agricultural extension system. Also, there is little interaction between extension staff, researchers, and farmers. Agricultural extension programs are underfinanced. Extension workers have little practical knowledge to share with farmers. Thus, only very few farmers benefit from these services resulting in limited access to information and inputs for most farmers (MSU, MRDI/CESD 2013: 9; World Bank 2014: 21). Consequently, rice farmers in Myanmar often lack adequate levels of agronomic knowledge and skills to produce high-quality products and increase productivity levels (OECD, FAO 2017: 71). Lastly, the challenges of climate change expose the vulnerability of farmers to drought, flooding, and extreme weather events. Thus, reducing agricultural productivity and endangering food security. As a consequence, it has become urgent to improve farmers' knowledge on climate-smart agriculture practices to help them become more resilient and adapt to climate change (Myanmar Ministry of Agriculture and Irrigation 2015: 34–35; Lar et al. 2018: 45–46).

**Opportunities.** Despite its difficulties, Myanmar remains a country with a large potential. Given the country's relatively low level of rural development, it can establish a robust development strategy based on its assets and in line with the SDG targets. It can implement efficient rural development strategies while avoiding development mistakes and current issues of neighboring countries. These include, for example, agricultural input overconsumption, soil degradation, strong rural-urban migration, and subsequent urban poverty (OECD 2016b: 17,30; Aung 2019: 335). Myanmar can become a leading example of genuine development, working towards independence from foreign aid and incorporating practical and well-adapted solutions (Aung 2019: 335). It benefits from an advantageous geostrategic position bordering India and China as well as being part of ASEAN. The country can benefit from exporting and trading with its neighbors to serve the growing Asian markets and become a more important global exporter. Therefore, economic policies focusing on the improvement of domestic agricultural production systems, export and pricing regulations as well as reducing trade barriers and tariffs have to be set in place (Myanmar Ministry of Agriculture and Irrigation 2015: 50; OECD 2016b: 17; Aung 2019: 335–336).

The public sector's efforts for agricultural development have been intensified. The budget of the Myanmar Ministry of Agriculture and Irrigation has been increasing steadily since 2013. Spending has been focusing on agricultural research, extension programs, and the development and promotion of seeds. The reallocation of public expenditures from rice to programs supporting other crops, livestock, and fisheries could support the agricultural diversification process (MSU, MRDI/CESD 2013: 15; World Bank Myanmar 2016: 8). Additionally, reforming the Myanmar Agricultural Development Bank could provide incentives for commercial banks to operate in the sector as well as support farmers to develop their farm enterprises and access necessary services to expand (OECD 2015: 54, OEDC 2016b: 49). In this regard, establishing an enabling environment for the private sector could become a driving force of Myanmar's economic development. Investments in critical public services (e.g., road and electricity infrastructure, education and research, health services, and social protection) and investments in key public goods, especially seeds and extension services, play an important role in improving agricultural productivity. This, in turn, accelerates rural development. In particular, expanding agricultural extension services and farmer education can help spread modern farming practices using better quality inputs, increasing levels of mechanization, and reducing postharvest problems (OECD 2016b: 28,34; World Bank Myanmar 2016: 8; OECD, FAO 2017: 71).

In the rice sector, a shift towards a highly productive and more competitive productivity growth trajectory will require the further restructuring of agricultural support institutions. To satisfy the increasing global demand for rice Myanmar can use its advantageous position and concentrate on the expected rise in demand from growth markets. It has the opportunity to position itself prominently and as a close neighbor to China. Hence, it can respond to this demand and gain a significant share in the international market (MSU, MRDI/CESD 2013: 14,17; Myanmar Ministry of Agriculture and Irrigation 2015: 48; Kubo 2016: 1). Furthermore, branding Myanmar's rice as coming from a rich diversity of traditional farming practices or local rice varieties offers marketing potential. Because rice farmers use fewer chemical inputs compared to other countries, marketing can focus on rice production being more respectful towards the environment. Myanmar can create quality-defined branded products, such as rice grown with traditional rice-farming methods. As a result, low-input farming practices can be encouraged to continue and used as an opportunity to add value to the rice produced (Myanmar Ministry of Agriculture and Irrigation 2015: 46; OECD 2016b: 39).

## 9.3 CORIGAP Activities in Myanmar

The CORIGAP activities in Myanmar started in 2013 with the objective of introducing sustainable best management practices in rice production. These aim to reduce rice yield gaps due to unfavorable environments and high postharvest losses. The recommended best management practices primarily include the introduction of balanced nutrient management and postharvest technologies. These help farmers increase their rice yields and improve agricultural efficiency (IRRI 2018c). The CORIGAP targets were added to the adaptive research activities of IRRI in Myanmar on the basis of the MyRice project. The MyRice project conducted adaptive research on cropping options to increase and sustain productivity in rice production systems in the Ayeyarwady Delta. The project was funded by the Australian Centre for International Agricultural Research and lasted from 2012 to 2017. In this context, CORIGAP and MyRice actively collaborated, aiming to increase farmers' income and field productivity as well as ensure sustainable rice farming. In particular, both projects focused on promoting learning alliances, developing business models, establishing joint in-country training activities, and supporting gender research (Singleton, Labios 2019: 4,12,95; Connor, San 2021: 49). Under the two projects, more than 10'000 farmers were reached. The projects introduced farmers to new varieties through extensive seed distribution, supported efficient pest monitoring, and the implementation of sustainable postharvest management practices as well as demonstrations of agricultural best management practices. These include various practices and technologies, notably, improved rice and pulse varieties and adapted inputs for better nutrient use management, ecological rodent management, and specific machinery, such as drum seeder, mechanical transplanter, combine harvester, lightweight thresher, flat-bed dryer, and storage bags for rice seed (Singleton, Labios 2019: 5-9,26; Connor, San 2021: 50; Connor et al. 2021b: 3). In addition, CORIGAP's focus on reducing yield gaps added an environmental aspect to avoid negative environmental consequences by promoting sustainable farming practices and technologies (Connor, San 2021: 50; Connor et al. 2021b: 3).

In order to facilitate knowledge exchange for rural development, farmers and various stakeholders were invited to participate in learning alliances. These village-level learning alliances were established to help farmers produce better quality rice by getting directly in touch with millers, traders, government officials, and NGO staff (IRRI 2018d; Singleton, Labios 2019: 34–36). For example, the members of the learning alliance in Maubin Township, Bago Region, were introduced to lightweight threshers and new varieties. Subsequently, farmers participated in field trials where they learned about suitable new rice varieties as options to improve their agricultural productivity (Quilloy, Gummert, Flor 2014). Additionally, a focus on livelihood improvement through good-quality seeds, reduced postharvest losses, and the development of business models concentrating on postharvest technologies were included in the activities. The learning alliances facilitated the active participation from both public and private sectors and the subsequent formation of a network between farmers and providers. This resulted in the technical improvement of a market model for mechanical dryers, in particular the solar bubble dryer (Figure 9.3), and supported a local manufacturer in making lightweight threshers (IRRI 2018d; Singleton, Labios 2019: 9,19). Over 200 farmers and national as well as international staff participated in postharvest demonstration trials where principles of grain quality, drying, and hermetic storage were discussed. Additionally, participants were introduced to postharvest techniques to maintain good-quality grains regarding threshing, drying, and storing (Quilloy, Cabardo, Flor 2014; Singleton, Labios 2019: 19).

Another element of the CORIGAP and MyRice projects in Myanmar were participatory varietal selection trials. Experimental and farmers' fields were established to provide opportunities for farmers to distinguish different rice varieties and select the most suitable ones. Farmers also assessed the eating quality of their preferred varieties based on field performance. More than 50 HYVs for salt-prone and flood-prone areas were tested. In total, over 3200 farmers participated in these trials from 2013 to 2017. Furthermore, the participatory varietal selection field trials focused on making best management practices more accessible to farmers including. Practices included sustainable pre-and postharvest activities such as direct seeding, proper fertilizer, weed and herbicide management (Mendoza 2014; IRRI 2018d; Singleton, Labios 2019: 6). Lastly, a household survey was conducted in eight villages of Daik-U Township, Bago Region, in August 2012 and repeated in August 2017. The survey was stratified between rice-rice and rice-pulse cropping systems with 100 farmers per system. For each pattern, 50 farmers each were interviewed from the project or non-project villages. The villages were identified with the help of the local Department of Agriculture partners in Daik-U Township. The survey objective was to compare productivity and income before and after the implementation of best practices and new varieties to provide a clearer picture of the changes that occurred by introducing new management practices (Singleton, Labios 2019: 36–37).

Figure 9.3 Solar Bubble Dryer (center) next to traditional drying of rice on the side of the street (left)
Source: IRRI Rice Knowledge Bank (2021e)

# 10 Myanmar – Best Management Practices for Sustainable Rice Farming

In this chapter, the study on farmers' agronomic changes due to the introduction of best management practices under the CORIGAP project is presented. First, the rationale and the research objectives are described. This is followed by the methodological approach and the results of farmers' agronomic development. These are discussed, specifically focusing on differences between farmer groups and cropping patterns.

## 10.1 Rationale of the Study

Major challenges in the agricultural sector persist in Myanmar. These include Infrastructural deficits, a lack of financing, and a slow institutional transformation. Coupled with insufficient government services, this accentuates Myanmar's lagging agricultural modernization and diversification process (OECD 2015: 21–22; Aye Aye et al. 2017: 13). Although the government has determined the transformation of the rice sector as a priority, yields continue to stagnate around 3.5 t/ha. Today, over 70 % of rice varieties planted in the lowlands are HYVs, but these efforts have not shown their impact on productivity in spite of their wide circulation (Naing et al. 2008: 152–153; Haggblade et al. 2014: 59; FAO Statistics Division 2020). First, this is due to farmers using inadequate amounts of inputs, especially fertilizer, and unsuitable practices to obtain the full potential of HYVs. Second, the quality of the seeds farmers use is generally low because they mostly come from the harvested paddy. This is repeated for many years and deteriorates the performance of HYVs (Naing et al. 2008: 165; GRiSP 2013: 131; Kubo 2013: 9; Myanmar Ministry of Agriculture and Irrigation 2015: 44). These issues are not only caused by economic constraints but also by rice farmers' low level of agricultural education and technical skills. Thus, crucial knowledge on how to effectively increase yields is missing (Aung 2011: 20; World Bank 2019b: 8). Furthermore, rice growers receive no or just little support from extension services. Extension officers often only have little knowledge to provide to farmers. As a result, the rates of knowledge and technology transfer in Myanmar are low. This further perpetuates the difficulties to improve and transform the rice (Dapice et al. 2011: 19; Haggblade et al. 2014: 63–64; World Bank 2019b: 29).

It has been shown that the quality of advisory and extension is an important determinant for knowledge transfer (Aung 2011: 73; Danso-Abbeam, Ehiakpor, Aidoo 2018: 7; Linn, Maenhout 2019: 21). Therefore, investigating farmers' rice productivity and profitability before and after the introduction of best management practices is necessary. In the context of an extension program such as CORIGAP, the impact of the knowledge transfer for sustainable rice farming in Myanmar can be determined. CORIGAP studies in Myanmar have generally focused on discussing issues in rice production, e.g., yield gaps and stagnating productivity growth, rice value chain deficiencies, and structural weaknesses (Naing et al. 2008; Dapice et al. 2011; Stuart et al. 2016; Linn, Maenhout 2019). Furthermore, other relevant studies have analyzed specific factors separately, such as the impact of mechanization or postharvest activities on rice production efficiency (YuYu, Hye-Jung 2015; Gummert et al. 2020). All of these investigations pointed out substantial elements for the agricultural inefficiency in rice farming in Myanmar considering one specific factor. There has been limited empirical attention on long-term operations with a broad set of interventions in the same region. Especially concentrating on the same farmers and their evolution over time has not been studied. The few existing research from other projects is based on field data or onetime surveys (YuYu, Hye-Jung 2015: 168). In general, limited information on the overall development of rice farmers in Myanmar is present compared to other Southeast Asian countries. For instance, in Vietnam or Indonesia, longitudinal studies using household surveys, adoption surveys, and market studies have been realized (Stür, Khanh, Duncan 2013; Moeis et al. 2020). Such studies are missing for Myanmar and information on rice farmers' long-term development is not present except for limited national data. Thus, a clearer understanding of the development of rice farming in Myanmar is necessary.

The present study aims to examine the effect of rice farmers' application of sustainable farming practices on productivity and profitability over an extended period under the CORIGAP project. The particularity of this study is the timely setting from 2012 to 2017, when Myanmar's political transition had just recently started. Therefore, analyzing how rice farmer's productivity has evolved over the course of these five years also indicates an overall development horizon for the entire country. It provides a sound basis for further research and development, including policy considerations. The main purpose of the study is to analyze the socioeconomic and agronomic development of rice farmers. These were divided into an adopter and non-adopter group concerning the introduction of best management practices under the CORIGAP project. In this regard, three research objectives will be investigated: 1) assess the changes in rice farmers' sociodemographic, socioeconomic, and agronomic situation from 2012 to 2017, 2) evaluate the socioeconomic and agronomic differences between adopters and non-adopters from 2012 to 2017, and 3) analyze the effects of the introduction of sustainable farming practices through the CORIGAP project on farmers' rice yields.

## 10.2 Materials and Methods

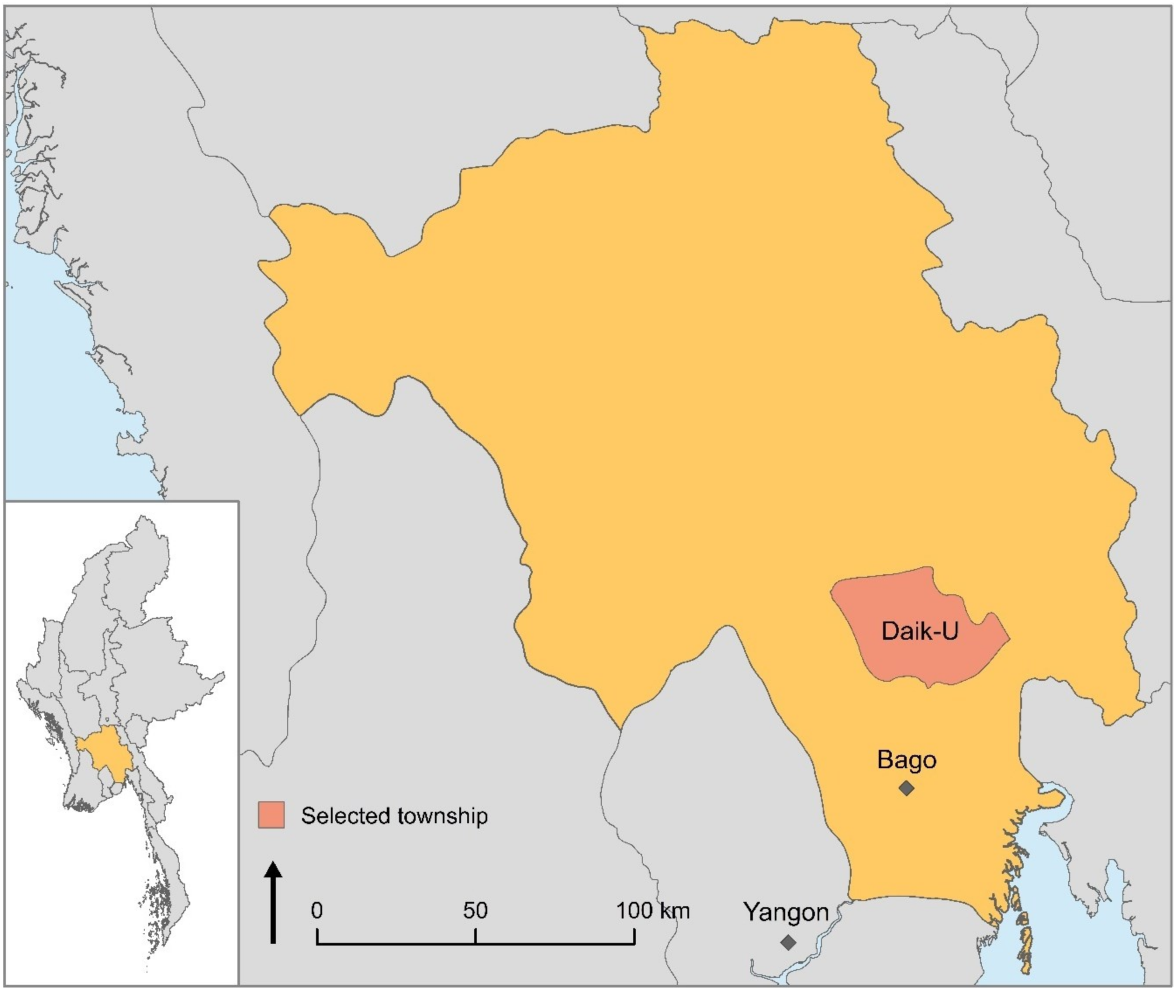
### 10.2.1 Survey Questionnaire and Data Collection Approach

A household survey questionnaire was used for the collection of baseline and endline agronomic data on rice farmers in Myanmar in 2012 and 2017. The questionnaire was subdivided into five sections, namely 1) socioeconomic to farm characteristics, 2) cropping pattern and land preparation, 3) information on production output, fertilizer, pesticide, 4) irrigation application, and 5) harvest and postharvest practices activities. A detailed description of the questionnaire is presented in Chapter 6.2.1. For the baseline questionnaire survey, farmers answered questions related to their farming activities executed during the cropping seasons of 2011-2012. For the endline questionnaire survey, they described their farming practices during the cropping seasons of 2016-2017. Generally, one main rice season during the monsoon time – wet season – from May to November is common in Myanmar. This is followed by a second cropping season during the drier months – dry season – between November and April. A second rice season can be accomplished through irrigation or another crop, such as pulses, is cultivated (Torbick et al. 2017: 4). During the first part of the baseline survey interviews, farmers answered questions related to their agronomic practices used in the wet season from May to November 2011. In the second half of the interview, they answered the same set of questions for the dry season of November 2011 to April 2012. This process was repeated for the endline questionnaire survey. Farmers were asked about their wet season practices from May to November 2016 and their dry season practices from November 2016 to April 2017. Additionally, the endline questionnaire included a section to collect data on farmers' experience with pesticide training and application methods. These were introduced as best management practices during the CORIGAP interventions between 2013 and 2016.

The survey questionnaire was created in English and translated into Burmese. It was back-translated to English to ensure content validity. Data were collected by means of face-to-face interviews using a PAPI and CAPI system. A detailed description of the PAPI and CAPI systems is presented in Chapter 6.2. The 2012 baseline survey questionnaire was paper-based. The paper questionnaire was filled out manually by the local extension workers interviewing the farmers. Afterward, the data were manually entered into a database and cleaned for further analysis. In 2017, the collection of the endline household data took place after all the CORIGAP interventions had been introduced. The data collection was performed using the CAPI tool CommCare (Version: Dimagi 2.35.2) installed on Samsung Galaxy Tablets A 7.0 (2016) LTE SM-T285. Farmers' answers were typed into the CommCare application by the local extension workers during the interview. The information was automatically synchronized with the CommCare dashboard without requiring post-data entry.

### 10.2.2 Sampling and Survey Implementation

The survey included the collection of data from treatment and non-treatment farmers. In 2012, the Myanmar Department of Agriculture, in collaboration with local agencies in Bago Region, defined the treatment villages. The treatment farmers were randomly selected from the list of farmers in each geographical unit (village or commune) obtained from the local agricultural extension office. The treatment villages were defined as sites that would receive training on the application of best management practices for rice cultivation. This included CORIGAP activities. The treatment farmer selection criteria were based on agricultural characteristics, e.g., existing irrigation and water management infrastructure, use of fertilizer and pesticides, level of technology use, and access to farming machinery. An additional criterion was farmers' cropping pattern. Farmers were separated into two cropping patterns, namely, a rice-rice group and a rice-pulse group. The treatment farmers would be the ones obtaining regular trainings on recommended sustainable rice practices and inputs. Farmers received, for example, HYVs and specific information on sustainable irrigation and land management techniques. In relation to this, the non-treatment villages were purposively selected based on environmental criteria and village location. Characteristics such as soil type, cropping pattern, and topography matched the treatment villages. This was necessary to compare the farmer groups. The non-treatment farmers would not receive any training, materials, or inputs as well as other resources. Overall, four treatment villages and four non-treatment villages were selected to conduct the CORIGAP household survey. In the end, there would be two villages per farmer group and cropping pattern (Map 10.1).




Map 10.1 Survey location of household baseline and endline survey in Daik-U Township in Bago Region, Myanmar
Concept: H. Wehmeyer; Cartography: M. Brunner; Cartographic base: GADM (2020)

Before conducting the household baseline survey, an organizational needs assessment in the eight selected survey villages in Daik-U Township was accomplished. Afterward, a pre-test of the survey questionnaire was conducted in two villages. Farmers who agreed to participate in the survey were invited to come to the village center on the day of the survey to conduct the interviews. Each farmer received compensation for their travel cost. The baseline survey was conducted with the help of eight staff members of the Myanmar Department of Agriculture of East Bago Region. They served as the interviewers and filled out the paper-based questionnaire. They received a two-day training on the content of the questionnaire and interview skills. The questionnaire was completed in approximately 1.5 hours. In total, 200 farmers – 100 treatment and 100 non-treatment farmers – were surveyed in eight villages. In each village, 25 farmers were interviewed from August 15 to 30, 2012, for the household baseline survey. Each farmer group included 50 rice-rice farmers and 50 rice-pulse farmers. The treatment villages were Kyaik Sa Kaw, Ka Dote Phaya Gyi, Oat Shit Kone, and Phaung Kwe. The control villages were Doe Tan, Ma U Tann, Myo Ma, and Shwe Inn Done. All geographical units were located within a 25 km radius. The household endline survey took place from September 1 to 12, 2017. The same farmers who participated in the baseline survey were interviewed for the endline survey. However, this was not possible in a few instances because farmers had moved or deceased. In those cases, the closest family member would be interviewed if they were still farming. Ten staff members of the Myanmar Department of Agriculture of East Bago Region collected the data by interviewing farmers using a tablet questionnaire. They received a two-day training on the background of the project, contents of the questionnaire, the use of the survey questionnaire application. A farmer interview was finished in approximately one hour.

### 10.2.3 Data Analysis

**Reclassification of farmer groups and cropping patterns.** After five years, a significant number of farmers had shifted from one farmer group to another or switched to another cropping pattern. Some farmers changed from being a treatment farmer to being a control farmer and vice-versa. Others switched from rice-rice to rice-pulse and vice-versa. Hence, the separation between treatment and control villages as well as between cropping patterns was not in place anymore. The farmers had to be reclassified for further analysis. Therefore, the farmer group and cropping pattern mentioned by the respondents in the 2017 endline survey was chosen to reclassify the farmers into an adopter (formerly treatment) and non-adopter (formerly control) group. This was because the CORIGAP project interventions happened after the 2012 baseline survey. In 2012, farmers were all at the baseline level and had not yet received an introduction to CORIGAP practices. In addition, due to the long timespan of five years between the two household surveys, only farmers who responded to both survey questionnaires were analyzed for this study.

**Data validation and cleaning.** The data collected in 2012 using a paper-based survey questionnaire were digitalized manually in IBM SPSS. They were subsequently validated by checking for outliers and missing information in IBM SPSS and Microsoft Excel. The 2017 data were automatically digitalized in the CommCare application. The 2017 raw dataset was subsequently imported into Microsoft Excel from the CommCare dashboard. The two raw data exports were merged by farmer ID. For the following data analysis, Microsoft Excel (version 2101, Redmond, WA, USA), IBM SPSS (version 27, Armonk, NY, USA), and IBM SPSS AMOS (version 27, Amos Development Corporation, Wexford, PA, USA) were used.

**Data analysis.** Agronomic and socioeconomic data were checked for normal distribution. The data were not normally distributed. A detailed description of the normality distribution of the selected variables is presented in Table 10.1. The first part of the data analysis consisted of descriptive statistics to produce sample descriptions of the sociodemographic and socioeconomic data as well as agronomic data. Chi-square ($\chi^2$) test statistics were used to compare frequencies of categorical variables. Effect sizes were determined using Pearson's r. A value of 0.05 and below indicates no effect, 0.1-0.3 a small effect; 0.3-0.5 an intermediate effect, and 0.5 and higher a strong effect (Cohen 1988: 79–81).

Table 10.1 Normality test for selected socioeconomic and agronomic data

| | 2012 | | | | |
|---|---|---|---|---|---|
| Variables | **n** | **Skewness (SE)** | **Kurtosis (SE)** | **K-S test** | **Shapiro-Wilk test** |
| Annual household income (MMK) | 138 | 1.615 (0.206) | 1.784 (0.410) | KS (138) = 0.190, p = <0.001 | SW (138) = 0.783, p = <0.001 |
| Annual non-rice income (MMK) | 39 | 1.975 (0.378) | 4.322 (0.741) | KS (39) = 0.220, p = <0.001 | SW (39) = 0.766, p = <0.001 |
| Annual credit (MMK) | 106 | 3.495 (0.235) | 15.256 (0.465) | KS (106) = 0.292, p = <0.001 | SW (106) = 0.618, p = <0.001 |
| Cultivation area (ha) | 160 | 2.240 (0.192) | 5.987 (0.381) | KS (160) = 0.243, p = <0.001 | SW (160) = 0.750, p = <0.001 |
| Rice yield (t/ha) | 160 | 1.753 (0.192) | 5.963 (0.381) | KS (160) = 0.135, p = <0.001 | SW (160) = 0.871, p = <0.001 |
| Δ Yield (t/ha) | n/a | n/a | n/a | n/a | n/a |
| Rice income (MMK/ha) | 137 | 1.946 (0.207) | 8.223 (0.411) | KS (137) = 0.106, p = 0.001 | SW (137) = 0.871, p = <0.001 |
| Input cost (MMK/ha) | 159 | 3.423 (0.192) | 14.737 (0.383) | KS (159) = 0.216, p = <0.001 | SW (159) = 0.648, p = <0.001 |
| Labor cost (MMK/ha) | 159 | 3.145 (0.192) | 11.417 (0.383) | KS (159) = 0.235, p = <0.001 | SW (159) = 0.639, p = <0.001 |
| Labor (d/ha) | 160 | 3.317 (0.192) | 16.991 (0.381) | KS (160) = 0.157, p = <0.001 | SW (160) = 0.723, p = <0.001 |
| | **2017** | | | | |
| Variables | **n** | **Skewness (SE)** | **Kurtosis (SE)** | **K-S test** | **Shapiro-Wilk test** |
| Annual household income (MMK) | 156 | 2.784 (0.194) | 8.646 (0.386) | KS (156) = 0.211, p = <0.001 | SW (156) = 0.669, p = <0.001 |
| Annual non-rice income (MMK) | 58 | 1.474 (0.314) | 2.097 (0.618) | KS (58) = 0.192, p = <0.001 | SW (58) = 0.855, p = <0.001 |
| Annual credit (MMK) | 155 | 3.138 (0.195) | 8.958 (0.387) | KS (155) = 0.406, p = <0.001 | SW (155) = 0.478, p = <0.001 |
| Cultivation area (ha) | 160 | 3.243 (0.192) | 12.801 (0.381) | KS (160) = 0.241, p = <0.001 | SW (160) = 0.645, p = <0.001 |
| Rice yield (t/ha) | 160 | 0.018 (0.192) | 0.387 (0.381) | KS (160) = 0.141, p = <0.001 | SW (160) = 0.973, p = 0.003 |
| Δ Yield (t/ha) | 159 | -0.677 (0.192) | 3.056 (0.383) | KS (159) = 0.101, p = <0.001 | SW (159) = 0.951, p = <0.001 |
| Rice income (MMK/ha) | 159 | 0.521 (0.192) | -0.296 (0.383) | KS (159) = 0.081, p = 0.013 | SW (159) = 0.969, p = 0.001 |
| Input cost (MMK/ha) | 159 | 1.004 (0.192) | 1.694 (0.383) | KS (159) = 0.089, p = 0.004 | SW (159) = 0.944, p = <0.001 |
| Labor cost (MMK/ha) | 146 | 1.213 (0.201) | 1.115 (0.399) | KS (146) = 0.135, p = <0.001 | SW (146) = 0.884, p = <0.001 |
| Labor (d/ha) | 155 | 1.474 (0.195) | 2.540 (0.387) | KS (155) = 0.139, p = <0.001 | SW (155) = 0.860, p = <0.001 |

Note: SE = Standard error, K-S test = Kolmogorov-Smirnov test with Lilliefors correction test

The survey years were analyzed as independent samples due to the significant changes in farmer groups and cropping patterns. The socioeconomic and agronomic variables were evaluated by season and annually by aggregating the wet and dry season. Farmers' total annual income consisted of their rice cultivation and non-rice farming income. Rice income was computed by multiplying the sold rice harvest with the selling price mentioned by the farmer. Furthermore, labor days and labor cost, input costs, and rice income are presented per hectare. Since the selected variables for the socioeconomic and agronomic analysis were not normally distributed, the Mann Whitney U test, a nonparametric test, was utilized to determine the mean differences between the farmer groups, cropping patterns, and two survey years.

The second part of the data analysis consisted of a mediated hierarchical linear regression analysis. This was used to investigate the determinants of yield using the farmer group as a mediating variable. Farmers' yield development between the adopter and non-adopter group was examined. By performing this method, the present study aims to examine whether the CORIGAP project interventions had a mediating effect on rice yield compared to rice produced without the project interventions. In addition to the hierarchical regression analysis, a mediated structural equation modeling (SEM) model was tested in IBM SPSS AMOS. The maximum likelihood method of estimation was applied to calculate the SEM coefficients (Byrne 2013: 141). Bootstrapping was selected for testing the statistical significance due to the fact that the selected data are non-normally distributed. Statistical significance was set to $p = \leq 0.05$. The average annual exchange rates of the years 2012 and 2017 were used to convert the financial data from Burmese Kyat to US Dollar for the discussion section (2012: USD 1 = MMK 842.0; 2017: USD 1 = MMK 1360.0) (XE.com 2020).

## 10.3 Results

The results are presented by farmer group, cropping pattern, and survey year. First, sociodemographic results, as well as farm characteristics of the sample, are described. Second, the socioeconomic and agronomic findings are presented, including the results of rice-rice farmers in the wet and dry season. Third, the mediation analysis for rice yield is performed for all farmers and the two cropping patterns.

### 10.3.1 Sociodemographic Results and Farm Characteristics

For the final data analysis, 160 farmers remained. No significant sociodemographic differences between the farmer groups – adopter and non-adopter – were detected in both survey years, with one exception. In 2012, there were considerably more farmers in the adopters group who had received secondary education compared to the farmers in the non-adopters group ($\chi^2(1) = 5.158$, $p = 0.023$, $r = 0.368$). This difference was also detected in 2017 with a moderate effect ($\chi^2(1) = 3.903$, $p = 0.048$, $r = 0.355$). A detailed description of the sample by farmer group is presented in Table 10.2. Regarding the two cropping patterns, no differences were found for all sociodemographic and farm-specific variables in 2012. However, in 2017 there were significant differences between the rice-rice and the rice-pulse farmers. There were considerably more male farmers in the group of rice-pulse farmers compared to the rice-rice farmers, but the effect size remained small ($\chi^2(1) = 4.165$, $p = 0.041$, $r = 0.181$). Rice-pulse farmers demonstrated higher levels of education, with 47.3% (n = 42) having had more than basic primary education compared to 39.1 % (n = 28) of the rice-rice farmers. There was a considerably higher number of rice-pulse farmers who had an upper secondary education in 2017. The effect size was moderate ($\chi^2(1) = 6.259$, $p = 0.012$, $r = 0.481$). In the same year, significantly more rice-pulse farmers were a member of a farming organization ($\chi^2(1) = 5.769$, $p = 0.016$, $r = 0.385$). Furthermore, there were considerably more non-adopters in the group of rice-pulse farmers. Nonetheless, the effect size was small ($\chi^2(1) = 4.470$, $p = 0.033$, $r = 0.238$). Lastly, more rice-pulse farmers used transplanting as a crop establishment method in 2017 in comparison with the rice-rice farmers ($\chi^2(1) = 4.651$, $p = 0.031$, $r = 0.233$). A detailed description of the sample by cropping pattern is presented in Table 10.3.

Table 10.2 Sociodemographic results and farm characteristics by year and farmer group

| | 2012 | | | | 2017 | | | |
|---|---|---|---|---|---|---|---|---|
| | Adopter | | Non-adopter | | Adopter | | Non-adopter | |
| Variables | n | Mean (SD) | n | Mean (SD) | n | Mean (SD) | n | Mean (SD) |
| Age (years) | 81 | 48.7 (10.4) | 79 | 48.9 (11.0) | 81 | 52.2 (10.2) | 78 | 52.6 (11.6) |
| Years farming | 75 | 23.7 (11.6) | 71 | 23.7 (13.1) | 81 | 27.7 (11.1) | 78 | 28.6 (13.8) |
| Household size (headcount) | 81 | 5.3 (1.9) | 79 | 5.7 (2.1) | 81 | 4.9 (1.7) | 78 | 5.2 (1.8) |
| Gender | n | % | n | % | n | % | n | % |
| Male | 64 | 85.3 | 63 | 86.3 | 64 | 85.3 | 63 | 86.3 |
| Female | 11 | 14.7 | 10 | 13.7 | 11 | 14.7 | 10 | 13.7 |
| Civil Status | n | % | n | % | n | % | n | % |
| Married | 74 | 91.4 | 63 | 79.7 | 71 | 87.7 | 65 | 83.3 |
| Widowed | 3 | 3.7 | 7 | 8.9 | 5 | 6.2 | 5 | 6.4 |
| Single | 3 | 3.7 | 8 | 10.1 | 5 | 6.2 | 7 | 9.0 |
| Separated | 1 | 1.2 | 1 | 1.3 | n/a | n/a | 1 | 1.3 |
| Education | n | % | n | % | n | % | n | % |
| Primary school | 40 | 49.4 | 47 | 60.3 | 42 | 51.9 | 50 | 64.1 |
| Secondary school | 26 | 32.1 | 12 | 15.4 | 21 | 25.9 | 10 | 12.8 |
| Upper secondary school | 12 | 14.8 | 14 | 17.9 | 14 | 17.3 | 13 | 16.7 |
| High school or more | 3 | 3.7 | 5 | 6.4 | 4 | 4.9 | 6 | 6.4 |
| Ethnolinguistic group | n | % | n | % | n | % | n | % |
| Bamar | 68 | 87.2 | 68 | 76.1 | 68 | 87.2 | 68 | 76.1 |
| Shan | 7 | 9.0 | 9 | 11.4 | 7 | 9.0 | 9 | 11.4 |
| Karen | 3 | 3.8 | 2 | 2.5 | 3 | 3.8 | 2 | 2.5 |
| Member of an organization | 7 | 9.2 | 10 | 13.7 | 22 | 27.2 | 17 | 21.8 |
| Cropping pattern | n | % | n | % | n | % | n | % |
| Rice-Rice | 39 | 48.1 | 36 | 45.6 | 36 | 44.4 | 30 | 38.0 |
| Rice-Pulse | 42 | 51.9 | 43 | 54.4 | 45 | 55.6 | 49 | 62.0 |
| Crop establishment method | n | % | n | % | n | % | n | % |
| Transplanting | 74 | 91.4 | 73 | 92.4 | 41 | 50.6 | 45 | 57.0 |
| Direct seeding | 7 | 8.6 | 6 | 7.6 | 40 | 49.4 | 34 | 43.0 |
| Seed source | n | % | n | % | n | % | n | % |
| Own harvest | 70 | 86.4 | 71 | 89.9 | 70 | 86.4 | 66 | 83.5 |
| Farmer exchange | 4 | 4.9 | 4 | 5.1 | 1 | 1.2 | 7 | 8.9 |
| Seed grower | 3 | 3.7 | n/a | n/a | 6 | 7.4 | 1 | 1.3 |
| Input dealer | n/a | n/a | 3 | 3.8 | 3 | 3.7 | 2 | 2.6 |
| Department of Agriculture | 4 | 4.9 | 1 | 1.3 | 1 | 1.2 | 3 | 3.8 |

Note: SD = Standard deviation

Table 10.3 Sociodemographic results and farm characteristics by year and cropping pattern

| | 2012 | | | | 2017 | | | |
|---|---|---|---|---|---|---|---|---|
| | Rice-Rice | | Rice-Pulse | | Rice-Rice | | Rice-Pulse | |
| Variables | n | Mean (SD) | n | Mean (SD) | n | Mean (SD) | n | Mean (SD) |
| Age (years) | 75 | 49.4 (10.3) | 85 | 48.3 (10.9) | 65 | 53.2 (11.2) | 94 | 51.9 (10.7) |
| Years farming | 65 | 24.4 (12.5) | 81 | 23.2 (12.2) | 65 | 29.8 (12.8) | 94 | 27.0 (12.2) |
| Household size (headcount) | 75 | 5.3 (2.0) | 85 | 5.6 (2.0) | 65 | 5.0 (1.5) | 94 | 5.1 (1.9) |
| Gender | n | % | n | % | n | % | n | % |
| Male | 60 | 83.3 | 67 | 88.2 | 52 | 82.5 | 75 | 88.2 |
| Female | 12 | 16.7 | 9 | 11.8 | 11 | 17.5 | 10 | 11.8 |
| Civil Status | n | % | n | % | n | % | n | % |
| Married | 66 | 88.0 | 71 | 83.5 | 57 | 87.7 | 79 | 84.0 |
| Widowed | 4 | 5.3 | 6 | 7.1 | 3 | 4.6 | 7 | 7.4 |
| Single | 3 | 4.0 | 8 | 9.4 | 4 | 6.2 | 8 | 7.5 |
| Separated | 2 | 2.7 | n/a | n/a | 1 | 1.5 | n/a | n/a |
| Education | n | % | n | % | n | % | n | % |
| Primary school | 44 | 58.7 | 43 | 50.6 | 41 | 62.1 | 51 | 54.3 |
| Secondary school | 16 | 21.3 | 22 | 25.9 | 12 | 18.2 | 19 | 20.2 |
| Upper secondary school | 12 | 16.0 | 14 | 16.5 | 7 | 10.6 | 20 | 21.3 |
| High school or more | 3 | 4.0 | 5 | 5.9 | 5 | 7.6 | 4 | 4.3 |
| Ethnolinguistic group | n | % | n | % | n | % | n | % |
| Bamar | 75 | 100.0 | 61 | 74.4 | 66 | 100.0 | 70 | 76.9 |
| Shan | n/a | n/a | 16 | 19.5 | n/a | n/a | 16 | 17.6 |
| Karen | n/a | n/a | 5 | 6.1 | n/a | n/a | 5 | 5.5 |
| Member of an organization | 5 | 7.1 | 12 | 15.2 | 12 | 18.5 | 27 | 28.7 |
| Farmer group | n | % | n | % | n | % | n | % |
| Adopter | 39 | 52.0 | 42 | 49.4 | 36 | 54.5 | 45 | 47.9 |
| Non-adopter | 36 | 48.0 | 43 | 50.6 | 30 | 45.5 | 49 | 52.1 |
| Crop establishment method | n | % | n | % | n | % | n | % |
| Transplanting | 66 | 88.0 | 81 | 95.3 | 33 | 50.0 | 53 | 56.4 |
| Direct seeding | 9 | 12.0 | 4 | 4.7 | 33 | 50.0 | 41 | 43.6 |
| Seed source | n | % | n | % | n | % | n | % |
| Own harvest | 65 | 86.7 | 76 | 89.4 | 58 | 87.9 | 78 | 83.0 |
| Farmer exchange | 4 | 5.3 | 4 | 4.7 | 3 | 4.5 | 5 | 5.3 |
| Seed grower | n/a | n/a | 1 | 1.2 | 3 | 4.5 | 4 | 4.3 |
| Input dealer | 2 | 2.7 | 3 | 3.6 | 1 | 1.5 | 4 | 4.3 |
| Department of Agriculture | 4 | 5.3 | 1 | 1.2 | 1 | 1.5 | 3 | 3.2 |

Note: SD = Standard deviation

Differences between 2012 and 2017 were found for the total sample. Most of the surveyed farmers were male (85.8 %, n = 127). The mean age of the respondents in 2012 was 48.8 (SD = 10.6) years and 52.4 (SD = 10.9) years in 2017. The female respondents were on average 3.0 years younger than the male respondents. Most of the male respondents were married (85.6 %, n = 137). Within the group of female respondents, about half were married (2012: 52.4 %, n = 11; 2017: 57.1 %, n = 12). The remaining were widowed (2012: 23.8 %, n = 5; 2017: 19.0 %, n = 4) or single (2012: 23.8 %, n = 5; 2017: 23.8 %, n = 5). The average duration of the respondents' school education was 6.9 (SD = 3.0) years. The male respondents (7.1 years, SD = 3.1) received 1.5 years of additional school education compared to the female respondents (5.5 years, SD = 2.7). More than half (56.3 %, n = 90) of the survey participants had received up to six years of primary school education. Of these, 64.8 % (n = 58) completed primary school education in line with the education requirements in Myanmar (ASEAN Federation of Engineering Organisations 2018: 1–3). Most farmers mentioned belonging to the Bamar people (86.6 %, n = 136). Shan (10.2 %, n = 16) and Karen (3.2 %, n = 5) people were also interviewed. Overall, a minority of the interviewed farmers were a member of a farmer organization. Nevertheless, the number increased significantly from 17 (11.4 %) in 2012 to 39 (24.5 %) in 2017 and the effect size was moderate ($\chi^2(1) = 8.902$, $p = 0.003$, $r = 0.398$).

In 2012, 75 farmers were applying rice-rice as a cropping pattern and 85 were doing rice-pulse. By 2017, nine farmers changed their cropping pattern from rice-rice to rice pulse. Of these, three were classified as adopters and six were non-adopters. This shift led to a decrease in rice-rice farmers (n = 66) and an increase in rice-pulse farmers (n = 94). Overall, there were no significant differences regarding the distribution of the farmers' cropping pattern between both years ($\chi^2(1) = 1.032$, $p = 0.310$, $r = 0.056$). However, in the group of non-adopters, the discrepancy between rice-rice and rice-pulse farmers in 2017 was statistically significant. The effect size was small ($\chi^2(1) = 4.570$, $p = 0.033$, $r = 0.241$). Hence, there were considerably more rice-pulse than rice-rice farmers in the non-adopters group. The majority of farmers (98.1 %, n = 157) were the owners of the agricultural land they cultivated in both survey years. The remaining three farmers (1.9 %) indicated having a leasehold on their land and paying a fixed rent for being able to farm. In 2012, most farmers used transplanting as a crop establishment method for rice (91.9 %, n = 147). Nevertheless, in 2017 the number of farmers applying direct seeding as a method for crop establishment increased from 13 (8.1 %) to 74 (46.3 %). The remaining 86 (53.8 %) continued transplanting. Thus, the difference in numbers between the two survey years of the farmers' crop establishment method changed significantly with a strong effect ($\chi^2(1) = 58.878$, $p = <0.001$, $r = 0.822$). Most farmers used rice seeds from their own harvest in both years. The other farmers would get their rice seeds from the exchange with other farmers, seed growers, input dealers, or the Myanmar Department of Agriculture. The reclassification of the farmers resulted in approximately a 50/50 distribution of the two farmer groups. Of all 160 selected farmers, 81 (50.6 %) were considered adopters and 79 (49.4 %) farmers were non-adopters. Compared to the initial classification, half of the 160 farmers, precisely 80, changed the farmer group from being a former treatment farmer to becoming a non-adopter (n = 39) or a control farmer becoming an adopter (n = 41). Furthermore, the new distribution of the farmers led to a mostly half and half distribution within the villages except for one village (Ka Doke Phayar Gyi) where a 65 % to 35 % ratio with adopters to non-adopters, respectively, was present. This village started as a treatment village in 2012. A detailed description of the 80 reclassified farmers is presented in Table 10.4. No statistically significant differences were found for both reclassified farmer groups in 2012 and 2017 for all sociodemographic variables and farm characteristics.

Table 10.4 Sociodemographic results and farm characteristics by reclassification group and year

| | Control to adopter | | | | Treatment to non-adopter | | | |
|---|---|---|---|---|---|---|---|---|
| | 2012 | | 2017 | | 2012 | | 2017 | |
| Variables | n | Mean (SD) | n | Mean (SD) | n | Mean (SD) | n | Mean (SD) |
| Age (years) | 41 | 48.3 (10.0) | 41 | 52.1 (9.4) | 39 | 49.6 (10.0) | 38 | 54.0 (11.0) |
| Years farming | 39 | 24.0 (10.9) | 41 | 28.6 (9.2) | 33 | 24.2 (11.9) | 38 | 28.7 (14.2) |
| Household size (headcount) | 41 | 4.9 (1.8) | 41 | 4.8 (1.6) | 39 | 5.5 (2.0) | 38 | 5.3 (1.6) |
| Gender | n | % | n | % | n | % | n | % |
| Male | 31 | 79.5 | 31 | 79.5 | 32 | 86.5 | 32 | 86.5 |
| Female | 8 | 20.5 | 8 | 20.5 | 5 | 13.5 | 5 | 13.5 |
| Civil Status | n | % | n | % | n | % | n | % |
| Married | 38 | 92.7 | 37 | 90.2 | 31 | 79.5 | 33 | 86.8 |
| Widowed | n/a | n/a | 2 | 4.9 | 4 | 10.3 | 2 | 5.3 |
| Single | 2 | 4.9 | 2 | 4.9 | 3 | 7.7 | 2 | 5.3 |
| Separated | 1 | 2.4 | n/a | n/a | 1 | 2.6 | 1 | 2.6 |
| Education | n | % | n | % | n | % | n | % |
| Primary school | 19 | 46.3 | 21 | 51.2 | 22 | 56.4 | 24 | 63.2 |
| Secondary school | 14 | 34.1 | 12 | 29.3 | 6 | 15.4 | 6 | 15.8 |
| Upper secondary school | 8 | 19.5 | 8 | 19.5 | 7 | 17.9 | 5 | 13.2 |
| High school or more | n/a | n/a | n/a | n/a | 3 | 7.7 | 2 | 7.9 |
| Ethnolinguistic group | n | % | n | % | n | % | n | % |
| Bamar | 39 | 100 | 39 | 100 | 28 | 71.8 | 28 | 71.8 |
| Shan | n/a | n/a | n/a | n/a | 9 | 23.1 | 9 | 23.1 |
| Karen | n/a | n/a | n/a | n/a | 2 | 5.1 | 2 | 5.1 |
| Member of an organization | 2 | 5.3 | 8 | 19.5 | 5 | 14.3 | 9 | 23.7 |
| Cropping pattern | n | % | n | % | n | % | n | % |
| Rice-rice | 20 | 48.8 | 18 | 43.9 | 17 | 43.6 | 17 | 43.6 |
| Rice-pulse | 21 | 51.2 | 23 | 56.1 | 22 | 56.4 | 22 | 56.4 |
| Crop establishment method | n | % | n | % | n | % | n | % |
| Transplanting | 40 | 97.6 | 20 | 48.8 | 34 | 87.2 | 21 | 53.8 |
| Direct seeding | 1 | 2.4 | 21 | 51.2 | 5 | 12.8 | 18 | 46.2 |
| Seed source | n | % | n | % | n | % | n | % |
| Own harvest | 37 | 90.2 | 35 | 85.4 | 34 | 87.2 | 31 | 79.5 |
| Farmer exchange | 3 | 7.3 | n/a | n/a | 2 | 5.1 | 5 | 12.8 |
| Seed grower | 1 | 2.4 | 4 | 9.8 | n/a | n/a | 1 | 2.6 |
| Input dealer | n/a | n/a | 2 | 4.9 | 2 | 5.1 | 1 | 2.6 |
| Department of Agriculture | n/a | n/a | n/a | n/a | 1 | 2.6 | 1 | 2.6 |

Note: SD = Standard deviation

### 10.3.2 Socioeconomic and Agronomic Results

No considerable differences were found between the two farmer groups in 2012 and 2017. Adopters and non-adopters did not vary significantly from each other regarding their socioeconomic and agronomic situation in both survey years (Table 10.5). With regard to the two cropping patterns, significant differences between the groups were found in 2012 and 2017 (Table 10.6).

Table 10.5 Socioeconomic and agronomic results by farmer group per year

| | 2012 | | | | | | |
|---|---|---|---|---|---|---|---|
| | Adopter | | Non-adopter | | Comparison | | |
| Variables | n | Mean (SD) | n | Mean (SD) | U | p | r |
| Annual household income (MMK) | 72 | 1’711’636.4 (1’710’909.1) | 65 | 1’606’363.6 (1’536’181.8) | 2295.5 | 0.848 | -0.016 |
| Annual non-rice income (MMK) | 16 | 869’454.5 (1’062’000.0) | 22 | 549’636.4 (453’363.6) | 175.5 | 0.988 | -0.002 |
| Annual credit (MMK) | 59 | 803’363.6 (965’272.7) | 46 | 595’636.4 (523’636.3) | 1263.5 | 0.542 | -0.059 |
| Cultivation area (ha) | 81 | 5.0 (4.3) | 78 | 4.1 (3.2) | 2764.5 | 0.172 | -0.108 |
| Rice yield (t/ha) | 81 | 2.9 (1.1) | 78 | 3.0 (1.1) | 3115.5 | 0.880 | -0.012 |
| Δ Yield (t/ha) | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| Rice income (MMK/ha) | 73 | 319’636.4 (175’636.3) | 63 | 330’727.3 (210’363.6) | 2363.0 | 0.782 | 0.023 |
| Input cost (MMK/ha) | 80 | 72’727.3 (58’545.5) | 78 | 68’545.5 (66’818.2) | 3253.0 | 0.644 | -0.036 |
| Labor cost (MMK/ha) | 80 | 75’454.5 (87’727.2) | 78 | 73’363.6 (84’909.1) | 3073.0 | 0.870 | -0.013 |
| Labor (d/ha) | 81 | 32.6 (33.0) | 78 | 30.8 (20.4) | 2930.0 | 0.430 | -0.062 |
| | 2017 | | | | | | |
| | Adopter | | Non-adopter | | Comparison | | |
| Variables | n | Mean (SD) | n | Mean (SD) | U | p | r |
| Annual household income (MMK) | 79 | 5’761’621.6 (6’336’621.6) | 76 | 4’572’567.6 (4’618’243.2) | 2777.5 | 0.422 | -0.064 |
| Annual non-rice income (MMK) | 27 | 3’105’270.3 (2’566’891.9) | 31 | 2’689’054.1 (2’066’351.4) | 397.0 | 0.737 | -0.044 |
| Annual credit (MMK) | 78 | 1’480’270.3 (1’433’243.2) | 76 | 2’867’432.4 (4’390’675.7) | 3095.0 | 0.629 | 0.039 |
| Cultivation area (ha) | 81 | 5.5 (5.3) | 78 | 4.1 (2.8) | 2797.5 | 0.212 | -0.099 |
| Rice yield (t/ha) | 81 | 3.6 (0.8) | 78 | 3.5 (0.9) | 2827.5 | 0.251 | -0.091 |
| Δ Yield (t/ha) | 81 | 0.7 (1.1) | 78 | 0.5 (1.2) | 2815.5 | 0.236 | -0.094 |
| Rice income (MMK/ha) | 81 | 768’648.6 (258’378.4) | 77 | 731’621.6 (294’109.6) | 2764.0 | 0.217 | -0.098 |
| Input cost (MMK/ha) | 80 | 199’729.7 (110’945.9) | 78 | 205’675.7 (99’729.7) | 3312.0 | 0.504 | 0.053 |
| Labor cost (MMK/ha) | 73 | 167’702.7 (153’108.1) | 72 | 203’918.9 (168’108.1) | 2960.0 | 0.189 | 0.109 |
| Labor (d/ha) | 77 | 43.7 (42.4) | 77 | 43.2 (36.6) | 2881.0 | 0.763 | -0.024 |

Note: SD = Standard deviation; U = Mann Whitney U test

Rice-pulse farmers had significantly higher yields than rice-rice farmers in both years of the survey. The effect was moderate in 2012 and small in 2017. Considerable differences were detected for annual household income, agricultural credit, cultivation area, and labor days in 2017. Rice-rice farmers earned significantly more per year, had larger cultivation areas, and received higher agricultural credits compared to the rice-pulse farmers. Nevertheless, the effect sizes for the three variables were small. The rice-pulse farmers had significantly higher labor in days per hectare than the rice-rice farmers in 2017, but the effect size was small.

Table 10.6 Socioeconomic and agronomic results by cropping pattern per year

| | 2012 | | | | | | |
|---|---|---|---|---|---|---|---|
| | Rice-rice | | Rice-pulse | | Comparison | | |
| Variables | n | Mean (SD) | n | Mean (SD) | U | p | r |
| Annual household income (MMK) | 67 | 1’614’454.5 (1’708’636.4 | 70 | 1’706’909.1 (1’552’363.6) | 2170.0 | 0.451 | 0.064 |
| Annual non-rice income (MMK) | 24 | 594’818.2 (588’000.0) | 14 | 837’545.5 (1’026’818.2) | 156.0 | 0.731 | 0.058 |
| Annual credit (MMK) | 52 | 654.818.2 (742’181.8) | 53 | 718’727.7 (864’454.5) | 1318.5 | 0.700 | 0.037 |
| Cultivation area (ha) | 75 | 4.1 (3.5) | 84 | 4.2 (3.1) | 3042.5 | 0.710 | 0.029 |
| Rice yield (t/ha) | 75 | 2.6 (1.1) | 84 | 3.5 (1.0) | 1818.0 | <0.001 | 0.367 |
| Δ Yield (t/ha) | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| Rice income (MMK/ha) | 68 | 298’454.5 (169’727.3) | 68 | 355’636.4 (208’363.6) | 1872.5 | 0.056 | 0.164 |
| Input cost (MMK/ha) | 75 | 76’636.4 (61’181.8) | 83 | 65’727.3 (55’727.3) | 2092.0 | 0.643 | -0.055 |
| Labor cost (MMK/ha) | 75 | 66’909.1 (75’272.7) | 83 | 81’181.8 (94’727.3) | 2744.5 | 0.200 | 0.102 |
| Labor (d/ha) | 75 | 31.7 (30.6) | 84 | 33.4 (32.4) | 3103.0 | 0.871 | 0.012 |
| | 2017 | | | | | | |
| | Rice-rice | | Rice-pulse | | Comparison | | |
| Variables | n | Mean (SD) | n | Mean (SD) | U | p | r |
| Annual household income (MMK) | 65 | 6’594’729.7 (6’827’702.7) | 90 | 4’155’405.4 (4’227’162.1) | 2357.0 | 0.039 | -0.165 |
| Annual non-rice income (MMK) | 28 | 3’439’459.4 (2’488’513.5) | 30 | 2’363’108.1 (2’016’486.5) | 304.0 | 0.071 | -0.237 |
| Annual credit (MMK) | 65 | 2’660’810.8 (3’745’945.9) | 89 | 1’802’567.6 (2’923’918.9) | 2114.5 | 0.004 | -0.234 |
| Cultivation area (ha) | 66 | 4.9 (4.7) | 93 | 4.0 (2.7) | 2497.5 | 0.045 | -0.159 |
| Rice yield (t/ha) | 66 | 3.3 (0.9) | 93 | 3.7 (0.8) | 2290.0 | 0.006 | 0.217 |
| Δ Yield (t/ha) | 66 | 0.7 (1.1) | 93 | 0.6 (1.2) | 2708.0 | 0.207 | -0.100 |
| Rice income (MMK/ha) | 66 | 720’135.1 (301’351.3) | 92 | 752’973.0 (254’324.3) | 2938.5 | 0.731 | 0.025 |
| Input cost (MMK/ha) | 65 | 220’945.9 (114’594.6) | 93 | 199’324.3 (98’648.6) | 3010.0 | 0.765 | -0.003 |
| Labor cost (MMK/ha) | 55 | 178’108.1 (170’270.3) | 90 | 190’270.3 (156’081.1) | 2277.5 | 0.421 | 0.066 |
| Labor (d/ha) | 63 | 36.1 (30.9) | 91 | 50.6 (43.2) | 2198.5 | 0.014 | 0.197 |

Note: SD = Standard deviation; U = Mann Whitney U test

Table 10.7 Agronomic results by season and year for rice-rice farmers

| | Wet season | | | | | | | 2012 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2012 | | 2017 | | Comparison | | | Wet season | | Dry season | | Comparison | | |
| Variables | n | Mean (SD) | n | Mean (SD) | U | p | r | n | Mean (SD) | n | Mean (SD) | U | p | r |
| Cultivation area (ha) | 74 | 4.9 (4.7) | 66 | 5.9 (5.7) | 1817.0 | 0.099 | 0.143 | 74 | 4.9 (4.7) | 63 | 2.9 (2.0) | 1481.0 | <0.001 | -0.315 |
| Rice yield (t/ha) | 74 | 2.6 (1.2) | 66 | 3.3 (1.0) | 1219.5 | <0.001 | 0.377 | 74 | 2.6 (1.2) | 66 | 2.6 (0.9) | 2098.0 | 0.314 | -0.086 |
| Rice income (MMK/ha) | 67 | 293’636.4 (171’000.0) | 66 | 747’297.3 (301’486.5) | 1630.0 | 0.013 | 0.217 | 67 | 293’636.4 (171’000.0) | 47 | 303’454.5 (168’636.4) | 1511.0 | 0.715 | 0.034 |
| Input cost (MMK/ha) | 66 | 80’454.5 (64’454.6) | 66 | 218’378.4 (144’459.5) | 1041.0 | <0.001 | 0.437 | 66 | 80’454.5 (64’454.5) | 63 | 75’636.4 (46’272.7) | 1769.0 | 0.303 | -0.091 |
| Labor cost (MMK/ha) | 66 | 65’818.2 (78’818.2) | 66 | 201’486.5 (257’973.0) | 1304.0 | 0.003 | 0.263 | 66 | 65’818.2 (78’818.2) | 66 | 67’363.6 (39’000.0) | 1910.0 | 0.069 | 0.155 |
| Labor (d/ha) | 66 | 30.3 (21.6) | 66 | 48.9 (34.1) | 980.5 | 0.001 | 0.330 | 66 | 30.3 (21.6) | 66 | 25.1 (17.4) | 2003.0 | 0.157 | -0.121 |
| Crop establishment method | n | % | n | % | $\chi^2$ | p | r | n | % | n | % | $\chi^2$ | p | r |
| Transplanting | 65 | 87.8 | 33 | 50.0 | 6.400 | 0.011 | 0.266 | 65 | 87.8 | 35 | 55.6 | 9.000 | 0.003 | 0.300 |
| Direct seeding | 9 | 12.2 | 33 | 50.0 | 13.714 | <0.001 | 0.571 | 9 | 12.2 | 28 | 44.4 | 9.757 | 0.002 | 0.513 |
| | Dry season | | | | | | | 2017 | | | | | | |
| Cultivation area (ha) | 63 | 2.9 (2.0) | 60 | 3.8 (2.7) | 1314.5 | 0.001 | 0.291 | 66 | 5.9 (5.7) | 60 | 3.8 (2.7) | 1576.0 | 0.008 | -0.230 |
| Rice yield (t/ha) | 66 | 2.6 (0.9) | 60 | 3.2 (1.0) | 1341.0 | 0.002 | 0.278 | 66 | 3.3 (1.0) | 60 | 3.2 (1.0) | 2128.0 | 0.938 | -0.007 |
| Rice income (MMK/ha) | 47 | 303’454.5 (168’636.4) | 60 | 633’243.2 (248’783.8) | 1054.0 | <0.001 | 0.403 | 66 | 747’297.3 (301’486.5) | 60 | 633’243.2 (248’783.8) | 1817.0 | 0.131 | -0.131 |
| Input cost (MMK/ha) | 63 | 75’636.4 (46’272.7) | 56 | 223’783.8 (139’054.1) | 920.0 | <0.001 | 0.358 | 66 | 218’378.4 (144’459.5) | 56 | 223’783.8 (139’054.0) | 875.0 | 0.252 | 0.116 |
| Labor cost (MMK/ha) | 66 | 67’383.6 (39’046.8) | 37 | 163’843.5 (162’226.9) | 776.0 | 0.002 | 0.301 | 66 | 201’486.5 (257’973.0) | 37 | 163’783.8 (162’162.2) | 724.0 | 0.213 | -0.024 |
| Labor (d/ha) | 66 | 25.1 (17.4) | 37 | 24.4 (21.0) | 1075.0 | 0.316 | -0.099 | 66 | 48.9 (34.1) | 37 | 24.4 (21.0) | 285.0 | <0.001 | -0.437 |
| Crop establishment method | n | % | n | % | $\chi^2$ | p | r | n | % | n | % | $\chi^2$ | p | r |
| Transplanting | 35 | 55.6 | 21 | 32.3 | 4.741 | 0.029 | -0.296 | 33 | 50.0 | 21 | 32.3 | 2.667 | 0.102 | 0.222 |
| Direct seeding | 28 | 44.4 | 44 | 67.7 | 2.449 | 0.118 | 0.188 | 33 | 50.0 | 44 | 67.7 | 1.571 | 0.210 | 0.142 |

Note: SD = Standard deviation; U = Mann Whitney U test

Significant agronomic differences were detected for rice-rice farmers' wet and dry seasons (Table 10.7). Agronomic results in the wet season from 2012 to 2017 showed significant changes for all variables except for the cultivation area. The effect sizes for rice yield, input cost, and labor days were moderate. The number of farmers changing the cropping pattern from transplanting to direct seeding was considerable with a strong effect. Additionally, major differences for cultivation area, rice yield, rice income, input cost, and labor cost were present in the dry season from 2012 to 2017. Farmers' crop establishment method changed from less transplanting to more direct seeding with a strong effect size. The rice cultivation area was considerably smaller during the dry season. Finally, in 2017, significant differences between the two seasons were present for labor days.

Annual socioeconomic and agronomic results are presented in Table 10.8. Farmers' average annual household income significantly increased from 2012 to 2017. In 2012, 23.8 % (n = 38) of farmers indicated having additional income from other sources. In 2017, the number had increased to 36.3 % (n = 58). There were considerably more farmers having a non-rice income in the second survey year ($\chi^2(1) = 5.968$, p = 0.015, r = 0.249). Farmers' average non-rice income increased significantly from 2012 to 2017, with a strong effect. The majority of the farmers also indicated having received an agricultural credit. There was a statistically significant difference in the numbers of farmers receiving an agricultural credit between the two survey years ($\chi^2(1) = 49.965$, p = <0.001, r = 0.439). By 2017, farmers' credit amount had more than doubled with a moderate effect size. A wide distribution range was present for the cultivation area. However, there was no significant change in farmers' mean cultivation area between 2012 and 2017. Mean rice yields were 3.0 t/ha (SD = 1.1) in 2012 and increased significantly to 3.6 t/ha (SD = 0.9) in 2017. The effect was moderate. The yield difference was on average 0.6 t/ha (SD = 1.1). The distribution ranged from -4.5 to 3.5 t/ha. Farmers' mean income from rice rose significantly. Correspondingly, their input cost per hectare also significantly increased with a strong effect size. Lastly, labor cost per hectare rose considerably as well. However, labor in days per hectare did not.

Table 10.8 Socioeconomic and agronomic results by year

| | 2012 | | | 2017 | | | Comparison | | |
|---|---|---|---|---|---|---|---|---|---|
| Variables | n | Mean (SD) | Range (Min-Max) | n | Mean (SD) | Range (Min-Max) | U | p | r |
| Annual household income (MMK) | 137 | 1'661'727.3 (1'625'272.7) | 109'636.4 – 6'930'000.0 | 155 | 5'166'486.5 (5'581'891.9) | 570'000.0 – 31'080'000.0 | 5937.0 | <0.001 | 0.380 |
| Annual non-rice income (MMK) | 38 | 684'272.7 (774'272.7) | 70'000.0 – 3'600'000.0 | 58 | 2'882'837.8 (2'301'486.5) | 120'000.0 – 10'000'000.0 | 406.0 | <0.001 | 0.532 |
| Annual credit (MMK) | 105 | 686'818.2 (803'000.0) | 50'000.0 – 5'000'000.0 | 154 | 2'164'864.9 (3'311'756.8) | 60'000.0 – 15'000'000.0 | 4157.0 | <0.001 | 0.414 |
| Cultivation area (ha) | 159 | 4.5 (3.9) | 0.8 – 24.3 | 159 | 4.9 (4.3) | 0.8 – 28.3 | 11'726.0 | 0.263 | 0.063 |
| Rice yield (t/ha) | 159 | 3.0 (1.1) | 0.5 – 8.6 | 159 | 3.6 (0.9) | 1.5 – 6.6 | 7325.0 | <0.001 | 0.365 |
| Δ Yield (t/ha) | n/a | n/a | n/a | 159 | 0.6 (1.1) | -4.5 – 3.5 | n/a | n/a | n/a |
| Rice income (MMK/ha) | 136 | 324'818.2 (191'818.2) | 45'181.8 – 1'457'909.1 | 158 | 750'675.7 (274'054.1) | 273'108.1 – 1'462'837.8 | 4774.0 | <0.001 | 0.479 |
| Input cost (MMK/ha) | 158 | 72'454.5 (62'636.4) | 11'363.6 – 418'909.1 | 158 | 209'459.5 (105'270.3) | 17'027.0 – 608'108.1 | 4112.0 | <0.001 | 0.580 |
| Labor cost (MMK/ha) | 158 | 74'454.5 (86'090.9) | 1272.7 – 543'636.4 | 145 | 185'675.7 (161'216.2) | 1851.3 – 711'891.9 | 7940.0 | <0.001 | 0.265 |
| Labor (d/ha) | 159 | 31.7 (27.5) | 1.2 – 221.4 | 154 | 43.4 (39.5) | 0.5 – 196.0 | 10'682.0 | 0.051 | 0.110 |

Note: SD = Standard deviation; U = Mann Whitney U test

### 10.3.3 Mediation Analysis for Rice Yield

Hierarchical linear regression analysis in combination with mediated structural equation modeling was conducted. It was investigated if the farmer group acted as a mediating variable on farmers' rice yields from 2012 to 2017. Therefore, the influence of the CORIGAP interventions on the adopters' group compared to the non-adopters group was analyzed. Rice yield was selected as the dependent variable for the hierarchical linear regression analysis. In the first step of the hierarchical linear regression analysis, sociodemographic and socioeconomic variables as well as farm characteristics were used as control variables. These were selected on the basis of general characteristics relevant to characterize a farmer. The chosen sociodemographic control variables were age, education, and household size. The selected socioeconomic control variable was non-rice income (0 = no, 1 = yes). The designated control variables for farm characteristics were cultivation area (ha), cropping pattern (0 = rice-rice, 1 = rice-pulse), crop establishment method (0 = transplanting, 1 = direct seeding), agricultural credit (0 = no, 1 = yes), and member of a farmer organization (0 = no, 1 = yes). In the next step, farm inputs were included as independent variables. These encompassed labor cost (MMK/ha), power cost (MMK/ha), and agrochemical cost, including fertilizer and pesticide expenses (MMK/ha). Power cost included energy expenditures for seedbed and land preparation, crop establishment as well as harvest and postharvest activities. For the final step, the farmer group (0 = non-adopter, 1 = adopter) was introduced as a mediating independent variable to test the model (Table 10.9).

The results of the first linear regression analysis controlling for sociodemographic, socioeconomic, and farm characteristics showed that years of education, cropping pattern, and agricultural credit were significant predictors of yield. The first model explained 17.9 % of the variance. In the second linear regression analysis, years of education and cropping pattern remained significant control predictors. The newly added independent variables power cost and agrochemical cost revealed a significant influence on rice yield. $R^2$ increased significantly by 14.6 %. The final model with the addition of the mediating variable farmer group did not increase $R^2$. The same control variables as in model 2 remained significant as well as the same independent variables. However, the mediation variable farmer group did not become a significant predictor of rice yield. The final model explained 32.5 % of the variance. It demonstrates an increased proportion of the variance of the dependent variable through power cost and agrochemical cost but not through the farmer group. In general, the standardized residuals were normally distributed, and all models were statistically significant.

In the subsequent single mediation SEM model, the relationship between farm inputs, namely labor cost, power cost, agrochemical cost, and rice yield, was mediated through the single mediator variable farmer group (Figure 10.1). The significance of the model and the standardized direct as well as standardized indirect effects were tested using bootstrapping procedures. The bootstrapping was performed for 2000 bootstrapped samples and a 90% bias-corrected confidence interval was selected. The results showed that the standardized direct effects from the independent farm input variables power cost ($\beta = 0.308$, $p = 0.001$) and agrochemical cost ($\beta = 0.147$, $p = 0.015$) to rice yield were statistically significant. However, the standardized direct effects from the three farm input variables to the farmer group were not significant (labor cost: $\beta = 0.086$, $p = 0.200$; power cost: $\beta = 0.055$, $p = 0.460$; agrochemical cost: $\beta = -0.093$,$p = 0.218$). Furthermore, the standardized direct effect from farmer group to rice yield was not statistically significant either ($\beta = -0.039$, $p = 0.523$). Hence, the model did not result in mediation through the farmer group because all three indirect effects on rice yield through the mediator were not statistically significant (labor cost: $\beta = -0.003$, $p = 0.330$; power cost: $\beta = -0.002$, $p = 0.360$; agrochemical cost: $\beta = 0.004$, $p = 0.340$).

Table 10.9 Mediated multiple hierarchical regression analysis for the dependent variable rice yield (t/ha)

| Variables | **Model 1** | **Model 2** | **Model 3** |
|---|---|---|---|
| **Control variables** | Standardized beta values | | |
| Age (years) | 0.048 | 0.046 | 0.046 |
| Education (years) | 0.178 ** | 0.207 *** | 0.207 *** |
| Household size (headcount) | -0.091 | -0.068 | -0.068 |
| Non-rice income | -0.089 | -0.048 | -0.048 |
| Cultivation area (ha) | 0.076 | 0.081 | 0.081 |
| Cropping pattern | 0.333 *** | 0.291 *** | 0.291 *** |
| Crop establishment method | 0.045 | 0.014 | 0.014 |
| Agricultural credit | -0.153 ** | -0.037 | -0.037 |
| Farmer organization member | -0.003 | 0.035 | 0.034 |
| **Independent variables** | | | |
| Labor cost (MMK/ha) | | 0.085 | 0.085 |
| Power cost (MMK/ha) | | 0.246 *** | 0.247 *** |
| Agrochemical cost (MMK/ha) | | 0.192 ** | 0.192 ** |
| **Mediation variable** | | | |
| Farmer group | | | -0.002 |
| **Coefficient of determination** | | | |
| $R^2$ | 0.179 *** | 0.325 *** | 0.325 *** |
| $\Delta R^2$ | | 0.146 *** | 0.000 |

Notes: N = 264; * p = ≤0.05, ** p = <0.01, *** p = <0.001; Model 1: F(9,254) = 6.174, p = <0.001, Model 2: F(12,263 = 10.087, p = <0.001, Model 3: F(13,250) = 9.274, p = <0.001

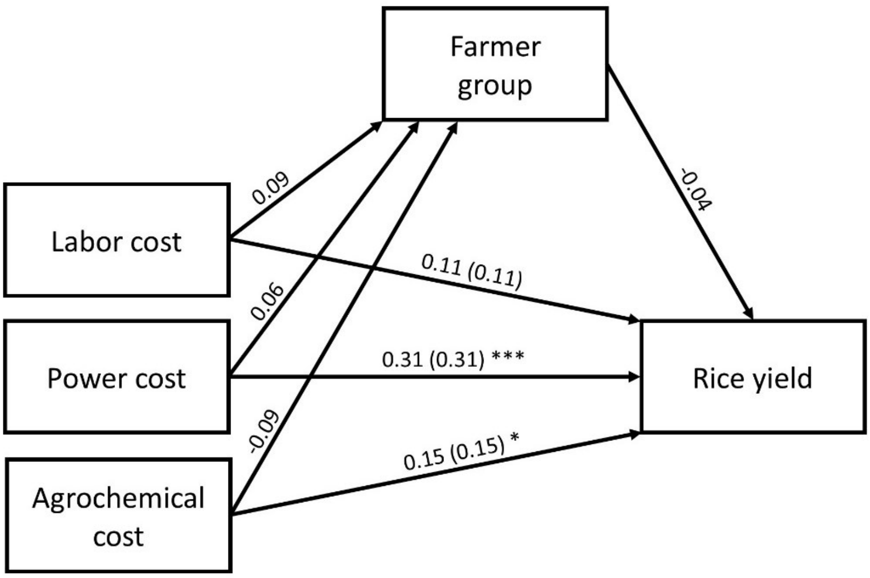



Figure 10.1 Single mediation SEM model of farmer group mediating labor cost, power cost, agrochemical cost, and rice yield
Note: Including standardized direct effects and corresponding p values (* p = ≤0.05, ** p = <0.01, *** p = <0.001)

**Mediation analysis for rice yield by cropping pattern.** A hierarchical linear regression analysis with a subsequent mediated SEM model was performed for the rice-rice and rice-pulse farmers separately. This additional analysis was conducted because the variable cropping pattern was shown to be a significant predictor of rice yield in the mediated multiple hierarchical regression analysis for all farmers. The objective was to distinguish the possible effect of the cropping pattern on farmers' rice. For the hierarchical regression analyses and mediated SEM models of the two cropping patterns, the selected control and independent variables as well as the mediating variable farmer group remained the same. The control variable cropping pattern was removed.

The results of the first hierarchical regression analysis for the rice-rice farmers showed that years of education, household size, and non-rice income were significant for predicting rice yield. The model explained 16.2 % of the variance (Table 10.10). In model 2, years of education remained as the only significant control variable after the addition of the independent farm input variables. Of these, agrochemical cost was the only significant predictor of rice yield. The model's $R^2$ increased considerably by 15.4 % to 31.6 %. Nevertheless, after the addition of the mediating variable farmer group in model 3, $R^2$ barely increased. This indicated that the mediating variable did not have a significant effect on rice-rice farmers' yields. The same variables, years of education and agrochemical cost, remained considerable predictors of rice yield and the final model explained 32.0 % of the variance. All three models were statistically significant and the standardized residuals were normally distributed. The corresponding single mediation SEM model for the rice-rice farmers showed that only the direct standardized effect from agrochemical cost to rice yield was statistically significant ($\beta = 0.326$, $p = 0.001$) (Figure 10.2). The direct standardized effects from agrochemical cost to farmer group ($\beta = -0.135$, $p = 208$) and from farmer group to rice yield ($\beta = 0.007$, $p = 0.970$) were not statistically meaningful. Additionally, the indirect standardized effects of the farm input variables on rice yield through the mediator farmer group were not statically significant (labor cost: $\beta = 0.001$, $p = 0.819$; power cost: $\beta = 0.001$, $p = 0.849$; agrochemical cost: $\beta = -0.001$, $p = 0.828$). Hence, mediation through the farmer group for rice yield did not occur in the group of the rice-rice farmers.

The first hierarchical regression analysis for the rice-pulse farmers resulted in two control variables being significant for rice yield, namely crop establishment method and agricultural credit (Table 10.11). The initial model explained 14.8 % of the variance. In model 2, the explainable variance increased by 13.1 % to 27.9 % by adding the three farm input variables. The variables years of education and power cost became the only two significant predictors of rice yield. In contrast to the independent farm input variables, the addition of the mediator variable farmer group did not substantially increase $R^2$ in the third model. Thus, it was not a considerable predictor of rice yield. The final model explained 28.7 % of the variance. In general, the three models were statistically significant, and the standardized residuals were normally distributed. The corresponding single mediation SEM model for the rice-pulse farmers' rice yield showed that only the standardized effect from power cost to rice yield was statistically significant ($\beta = 0.301$, $p = 0.004$) (Figure 10.3). The direct standardized effects from labor cost ($\beta = 0.112$, $p = 0.253$) and agrochemical cost ($\beta = 0.149$, $p = 0.145$) to rice yield were not statistically substantial. Additionally, the direct effect from farmer group to rice yield was not statistically significant either ($\beta = -0.101$, $p = 0.168$). Therefore, the indirect effects on rice yield through the mediator variable farmer group did not produce statistically meaningful results (labor cost: $\beta = -0.005$ $p = 0.347$; power cost: $\beta = 0.000$, $p = 0.954$; agrochemical cost: $\beta = 0.009$, $p = 0.225$). Hence, mediation through farmer group for rice yield did not occur for the rice-pulse farmers.

Table 10.10 Mediated multiple hierarchical regression analysis for the dependent variable rice yield (t/ha) of rice-rice farmers

| Variables | Model 1 | Model 2 | Model 3 |
|---|---|---|---|
| **Control variables** | Standardized beta values | | |
| Age (years) | 0.187 | 0.122 | 0.122 |
| Education (years) | 0.220 * | 0.264 ** | 0.273 ** |
| Household size (headcount) | -0.189 * | -0.145 | -0.154 |
| Non-rice income | -0.212 * | -0.141 | -0.138 |
| Cultivation area (ha) | 0.155 | 0.108 | 0.122 |
| Crop establishment method | -0.146 | -0.113 | -0.113 |
| Agricultural credit | -0.156 | -0.006 | -0.025 |
| Farmer organization member | -0.064 | -0.047 | -0.059 |
| **Independent variables** | | | |
| Labor cost (MMK/ha) | | 0.057 | 0.060 |
| Power cost (MMK/ha) | | 0.159 | 0.144 |
| Agrochemical cost (MMK/ha) | | 0.299 ** | 0.302 ** |
| **Mediation variable** | | | |
| Farmer group | | | 0.074 |
| **Coefficient of determination** | | | |
| $R^2$ | 0.162 ** | 0.316 *** | 0.320 *** |
| $\Delta R^2$ | | 0.154 *** | 0.004 |

Notes: N = 120; * p = ≤0.05, ** p = <0.01, *** p = <0.001; Model 1: F(8,111) = 2.680, p = 0.010, Model 2: F(11,108) = 4.538, p = <0.001, Model 3: F(12,107) = 4.205, p = <0.001

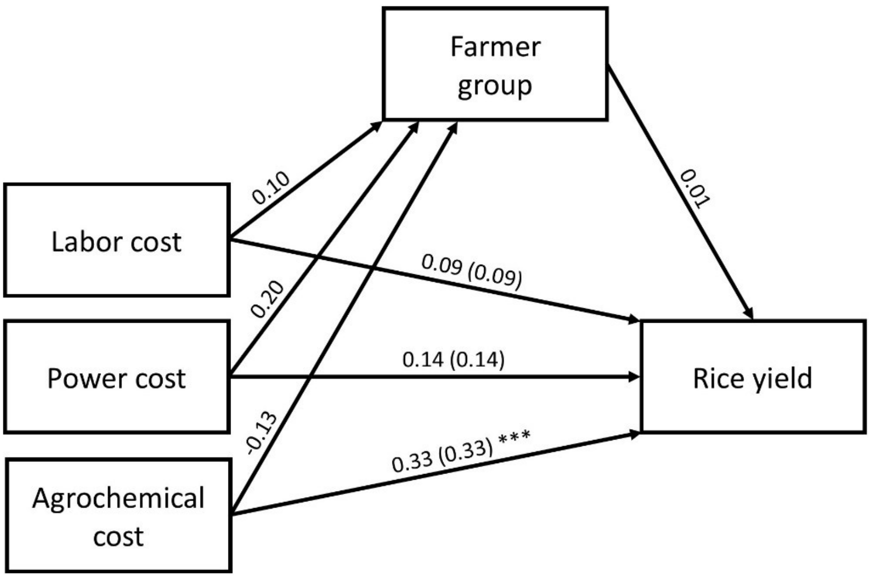



Figure 10.2 Single mediation SEM model of farmer group mediating rice-rice farmers' farm inputs and rice yield
Note: Including standardized direct effects and corresponding p values (* p = ≤0.05, ** p = <0.01, *** p = <0.001)

Table 10.11 Mediated multiple hierarchical regression analysis for the dependent variable rice yield (t/ha) of rice-pulse farmers

| Variables | **Model 1** | **Model 2** | **Model 3** |
|---|---|---|---|
| **Control variables** | Standardized beta values | | |
| Age (years) | -0.050 | -0.007 | -0.007 |
| Education (years) | 0.169 | 0.200 * | 0.199 * |
| Household size (headcount) | -0.087 | -0.065 | -0.056 |
| Non-rice income | -0.010 | 0.024 | 0.011 |
| Cultivation area (ha) | -0.014 | 0.037 | 0.036 |
| Crop establishment method | 0.199 * | 0.108 | 0.115 |
| Agricultural credit | -0.214 * | -0.128 | -0.124 |
| Farmer organization member | 0.020 | 0.074 | 0.057 |
| **Independent variables** | | | |
| Labor cost (MMK/ha) | | 0.095 | 0.101 |
| Power cost (MMK/ha) | | 0.309 ** | 0.306 ** |
| Agrochemical cost (MMK/ha) | | 0.092 | 0.078 |
| **Mediation variable** | | | |
| Farmer group | | | -0.096 |
| **Coefficient of determination** | | | |
| $R^2$ | 0.148 ** | 0.279 *** | 0.287 *** |
| $\Delta R^2$ | | 0.131 *** | 0.008 |

Notes: N = 142; * p = ≤0.05, ** p = <0.01, *** p = <0.001; Model 1: F(8,133) = 2.893, p = 0.005, Model 2: F(11,130) = 4.569, p = <0.001, Model 3: F(12,129) = 4.331, p = <0.001

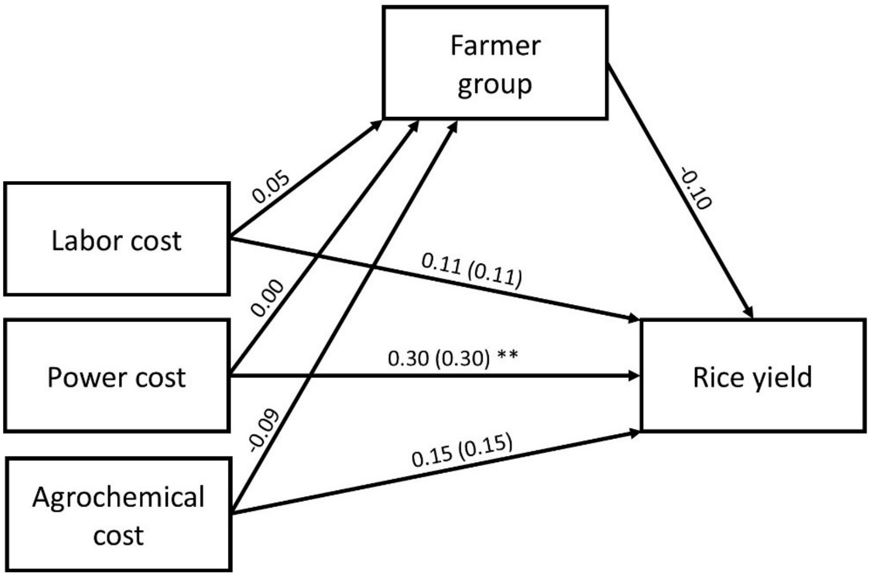



Figure 10.3 Single mediation SEM model of farmer group mediating rice-pulse farmers' farm inputs and rice yield
Note: Including standardized direct effects and corresponding p values (* p = ≤0.05, ** p = <0.01, *** p = <0.001)

## 10.4 Discussion

The present study examined farmers' agronomic, socioeconomic, and sociodemographic changes before and after the introduction of sustainable farming practices through the CORIGAP project. The differences between adopters and non-adopters from 2012 to 2017 were small and not significant. However, notable differences were found between the two cropping patterns, rice-rice and rice-pulse. In general, the farmers who participated in this study experienced significant changes between 2012 and 2017. This development was shown for all groups, namely for the adopters and non-adopters as well as for the rice-rice and rice-pulse farmers. Thus, over the course of five years, the majority of the farmers increased their production quantities and financial capital.

Farmers' sociodemographic indicators were similar between adopters and non-adopters. They did not change significantly from 2012 to 2017, although half of the farmers switched the farmer group. The only exception was that considerably more non-adopters received upper secondary education compared to the adopters group in both years. Overall, these results demonstrate that the sampling of the farmers was well performed. It enabled the interpretation of agronomic differences based on changes in farming practices and technology adoption. Regarding the two cropping patterns, no significant differences were detected in 2012, but by 2017 changes had occurred. This can partially be explained by the fact that some farmers had shifted from rice-rice to rice-pulse. Rice-pulse farmers achieved higher levels of education compared to rice-rice farmers and were more likely to be a member of a farmer organization. They were also more likely to be a non-adopter, but the effect was small. Furthermore, in 2017, a distinct shift with a strong statistical effect took place regarding the crop establishment method. In both farmer groups, many farmers switched from transplanting to direct seeding. This could be explained by the introduction of new technologies for crop establishment promoting agricultural modernization, either through the CORIGAP project or other national and international initiatives. For example, it has been shown that the use of drum seeders compared to manual transplanting saves time and money. In particular, labor expenses and hours as well as seed cost can be reduced and labor productivity improved (Rojas 2018: 1). Regarding farmers' seed choice, most did not change their seed source over the course of the project. Hence, the changes in yield can rather be attributed to altered input use and the adoption of other technologies and practices. In this context, the government's attempt to promote the efficient use of certified HYVs in rice farming did not show to have a considerable effect (Myanmar Ministry of Agriculture and Irrigation 2015: 47). However, significantly higher farmer credits indicate that the government's efforts to facilitate the reception of agricultural credits were successful. The government considerably improved access to financial means for farmers in the past decade. In the rice sector development strategy, a key intervention is the establishment of better credit services in rural areas (Myanmar Ministry of Agriculture and Irrigation 2015: 57,69). Overall, more farmers obtained a credit in 2017. The mean credit amount increased significantly. Annual agricultural credits almost doubled from 2012 to 2017. Especially non-adopters were able to increase their levels more than threefold from an average of USD 655.2 (SD = 576.0) in 2012 to USD 2121.9 (SD = 3249.1) in 2017. Rice-rice farmers received significantly higher agricultural credits than rice-pulse farmers. This could be explained by the fact that they cultivate rice during two seasons. Thus, they can obtain more support from the government because the modernization of the rice sector is considered crucial for Myanmar's overall development strategy (Myanmar Ministry of Agriculture and Irrigation 2015: 1–3). The findings of this study suggest that the national policy efforts to improve access to credits have been successful. The positive rice productivity trend can partially be associated with better access to financial resources for improving rice cultivation.

In general, the financial situation of all farmers evolved greatly. Their annual income more than doubled between 2012 and 2017, albeit with a wide range between the farmers. In addition, although Burmese Kyat significantly depreciated to US Dollars during this period, they were able to increase their financial capital regardless of the currency fluctuations (XE.com 2020). Income from rice increased by over 55 %. Non-rice income and the number of farmers earning an income for non-rice activities also grew. Differences between the farmer groups and cropping patterns were not significant. These findings are in line with Myanmar's agricultural and economic development over the past decade and are also reflected in other studies (World Bank 2019b: 11–12). Rural poverty has been steadily declining, but over 30 % of the rural population remains poor. However, in Bago Region, the poor rural population constitutes 17.4 %. This is considerably lower than the national average (Central Statistical Organization, United Nations Development Programme (UNDP), World Bank 2020: 8, 2019: 10). In this respect, the study participants demonstrated rather high rural incomes. Farms in the delta regions mostly have higher revenues than other parts of the country and landholdings are larger than in other regions. The mean farm size in Myanmar is around 2.5 ha. The farmers in this study had significantly larger farms with 4.9 ha on average in 2017 (Harper et al. 2017: 10,37-38). In addition, their income distribution changed towards more non-rice income sources. The significance of non-rice income increased. In 2012, 41.1 % of farmers' income was from non-rice farming sources. By 2017, it grew to 55.6 %. This is higher than the national rural average of 47.6 % (UNDP 2019: 115–116). The trend of increasing non-farming income sources has been observed all over Myanmar. Non-poor households are more likely to engage in non-agricultural activities, which the findings of this study confirm. According to UNDP, non-poor households are 68.8 % more likely than poor households to manage a non-farm business. They are also 33.9 % more likely to pursue a non-agricultural activity. Correspondingly, household welfare is negatively correlated with participation in agriculture and positively correlated with participation in non-agriculture (UNDP 2019: 110–111).

In 2012, the interviewed farmers had an average yield of 3.0 t/ha (SD = 1.1). This was significantly below the reported national average of that same year of 3.7 t/ha (FAO Statistics Division 2020). Nevertheless, by 2017, farmers' reported mean rice yields increased by 0.6 t/ha (SD = 1.1); hence, closely reaching the 2017 national average of 3.8 t/ha (FAO Statistics Division 2020). No significant differences were found between adopters and non-adopters. This development demonstrates that rice farmers in Myanmar have benefited from the economic and agricultural reforms that began in the 2010s (Aye Aye et al. 2017: 13). However, these findings are also highly influenced by climatic conditions. In 2017, favorable weather conditions in Bago Region and high rice prices were present. This resulted in particularly preferable yields and high profitability for farmers (USDA - Foreign Agricultural Service 2017: 3, 2018a: 3). Nevertheless, in the previous years, the climate phenomenon El Niño heavily impacted agricultural production in Southeast Asia between 2015 and 2016 (Thirumalai et al. 2017: 2). In Myanmar, flooding and unseasonal rains led to rice production decreases of 3 % and affected the water supply for the dry season rice crop. Rice prices, however, remained stable (USDA - Foreign Agricultural Service 2015: 3, 2016: 3). Aside from that, the fast recovery of Myanmar's rice production levels can also be attributed to the expansion of the irrigated dry season paddy area and improved irrigation infrastructure (USDA - Foreign Agricultural Service 2015: 3–4). The results of this study confirm this trend as the rice-rice farmers have shown significant growth in cultivation area and rice yield in the dry season from 2012 to 2017.

Multiple reasons could have led to a rather equal productivity development of the two farmer groups. The government of Myanmar instated several agricultural development policies. The new rice sector development strategy was launched in 2015 (Myanmar Ministry of Agriculture and Irrigation 2015: 6–10). Most project farmers had probably been in contact with extension agents in addition to CORIGAP. Hence, farmers were able to improve their farming practices either directly through the CORIGAP trainings or national extension programs. It can be assumed that rice farmers in Myanmar were able to advance their farm business as a result of broader overall extension efforts. The government's strategy was developed with the support of IRRI and the experiences gained from IRRC. Therefore, the national rice sector strategy applies a similar approach to CORIGAP (Myanmar Ministry of Agriculture and Irrigation 2015: 36,51,55-59). In this respect, agronomic advancements in the rice sector have been successful due to multiple-actor engagements on the national and regional levels. Another reason for the little differences between adopters and non-adopters could be a spillover effect. A significant number of farmers had to be reclassified in 2017. It can be estimated that many participants were made aware of the CORIGAP interventions no matter the farmer group, either through farmer-to-farmer communication or other communication channels. In addition, farmer groups were determined based on the village level and not on farmers' personal willingness to adopt. Hence, after five years, farmers could have come in contact with other farmers and received information on best management practices independently from the

CORIGAP project. Studies have shown that a spillover effect can take place in networks and when farmers are in close geographical proximity to each other (Aramburu et al. 2019: 6–7; Gao et al. 2020: 181–182). Thus, some farmers subsequently decided to adopt CORIGAP practices even if they had not initially been in the adopter group and vice versa. This explanation demonstrates the importance of Rogers' innovation-decision process (Chapter 4.1.1). If a farmer were sufficiently informed and perceived an innovation to be compatible with their farming, they would decide to adopt irrespective of the farmer group. In addition, the recommended technologies and practices of CORIGAP and the national rice sector strategy were promoted around the same time. Therefore, it can be presumed that farmers received information from multiple sources. This increased their willingness to adopt. The mediation analyses demonstrated that the effect of the CORIGAP practices and technologies did not mediate farmers' rice yield. Considering the aforementioned arguments, this does not reduce the efficacy of the CORIGAP project. It rather demonstrates the well-timed interventions that have been introduced in line with the national rice sector development strategy. It can be assumed that the CORIGAP project has supported and enhanced farmers' access to information about sustainable farming practices alongside other initiatives. Furthermore, the results of this study highlight that adopters reached similar rice output using sustainable farming practices and technologies compared to non-adopters.

In contrast to the farmer group, rice production differences between the two cropping patterns were present. Rice-pulse farmers had higher yields in both survey years compared to rice-rice farmers. Nevertheless, rice-rice farmers were able to increase their yields (+0.7 t/ha) considerably more than rice-pulse farmers (+0.2 t/ha). Rice-rice farmers also reached substantially higher yields in both rice seasons in 2017 compared to 2012. However, their yields still remained significantly below the national average of that year. The results of this study suggest that there is a tendency of farmers to switch to a rice-pulse cropping pattern. This can be linked to the multiple benefits a mixed cropping system can bring to farmers. A rice-pulse cropping system has been shown to be beneficial for farmers' economic security, improve nutrition due to more varied diet options, and enhance environmental conditions (Adarsh, Jacob, Giffy 2019: 185). Farmers who apply a mixed cropping pattern diversify their income sources and are less dependent on rice for their livelihoods. Thus, rice-pulse cropping contributes to farmers' economic sustainability. This is of particular importance for resource-poor farmers. Pulse farming generally requires fewer inputs and less labor than rice (FAO 2016: 41; Adarsh, Jacob, Giffy 2019: 185,189-190). Myanmar is the world's third-largest producer of pulses after India and Canada as well as the fourth-largest exporter in the world. Bago Region is the second-highest pulse producer in the country (World Bank 2019b: 12–13). Hence, pulses are an important income source. Furthermore, a mixed cropping system has been shown to ensure higher yields of subsequent crops compared to conventional monoculture cereal-fallow rotation systems (Deep et al. 2018: 28; Adarsh, Jacob, Giffy 2019: 189–190). Pulses support fixing atmospheric nitrogen in the soil and increase carbon sequestration as well as soil biodiversity. They also require less water than other crops. Thus, they are particularly well suited for regions where irrigation infrastructure and water supply are limited and inconsistent. These aspects are important to consider in the context of climate change mitigation because pulses need fewer inputs, improve soil health, and reduce GHG emissions (FAO 2016: 39–40; Adarsh, Jacob, Giffy 2019: 188–190). In this study, rice-pulse farmers had lower input costs than rice-rice farmers. Also, the use of agrochemicals was not a significant predictor of rice yield. This could be because of the improved environmental conditions due to pulse cultivation. However, the mediation analysis showed that rice-pulse farmers' yield was dependent on power expenses. A possible explanation could be explained by labor shortages. Phyo et al. discuss that labor shortages and mechanization levels are closely related (2019: 10). They state that mechanization cannot yet address the problem of labor shortages as a whole, particularly for rice-pulse farmers.

Lastly, this study found that education was a significant predictor of yield over all farmers and cropping patterns. Farmers' education levels are important to consider when planning agricultural development strategies in Myanmar. Because education levels are low, the modernization process is more complicated and a constraint for rural development (Myanmar Ministry of Agriculture and Irrigation 2015: 38). Almost two-thirds of the interviewed farmers had received no more than primary school education and were, on average, older than 50 years. These levels are rather low compared to the younger population aged 15-24 (United Nations Educational, Scientific and Cultural Organization (UNESCO) 2016; ASEAN Federation of Engineering Organisations 2018: 2). Other studies on rice farmers in the Ayeyarwady Delta have come to comparable sociodemographic results. They have shown that technical efficiency increases with higher education levels (YuYu, Hye-Jung 2015: 179–180; World Bank 2019b: 28). Therefore, it is critical to consider this factor when planning a diffusion strategy and implementing a development project in Myanmar. A more educated farmer can adopt a new technology or practice more easily and faster due to higher knowledge, receive better access to necessary information, and be less risk-averse (Liu, Bruins, Heberling 2018: 15,18; Ugochukwu, Phillips 2018: 364-365,367-368). This can enhance the diffusion process and subsequently accelerate agricultural development in Myanmar.

**Limitations.** The present study was conducted in selected townships in Bago Region, Myanmar, with a small sample size of 160 survey participants. The information entirely relies on recall and self-reported measures. In this regard, the results are susceptible to biases such as recall bias and social desirability bias. In addition, the datasets included missing and incoherent data points. This limits the informative value of certain variables. The non-normal distribution of the data necessitated the use of less statistically strict analysis tests. Overall, the findings of this study might not represent the general situation of all farmers in Bago Region and Myanmar. The participants demonstrated a rather high financial status. They had large landholdings and non-rice income. Furthermore, this study is a snapshot of two separate years compared with each other. It does not include farmers' development as a time series. Hence, this study rather highlights farmers’ evolution at different stages. Finally, due to the 2020 global pandemic, the planned perception survey was postponed. Therefore, no information on farmers' adoption decision behavior, perception of the recommended practices, and livelihood changes could be collected.

## Published work

The present chapters 11, 12, and 13 are based on the following published peer-reviewed publications.

Connor M., Tuan L. A., DeGuia A. H., **Wehmeyer H.** (2020): Sustainable rice production in the Mekong River Delta: Factors influencing farmers' adoption of the integrated technology package "One Must Do, Five Reductions" (1M5R). In: Outlook on Agriculture 50 (1), p. 90-104. https://doi.org/10.1177/0030727020960165

Weblink: https://journals.sagepub.com/doi/10.1177/0030727020960165

Tuan L. A., **Wehmeyer H.**, Connor M. (2021): "One Must Do, Five Reductions": Qualitative analysis of the diffusion and adoption constraints in Vietnam. In: Development in Practice, 32 (6), p. 768-780. https://doi.org/10.1080/09614524.2021.1937556.

Weblink: https://www.tandfonline.com/doi/abs/10.1080/09614524.2021.1937556

Flor R.J., Tuan L.A., Hung N.V., Phung N.T.M, Connor M., Stuart A.M., **Wehmeyer H.**, Sander B.O., Cao B.T., Tchale H., Singleton G.R. (2021): Unpacking the processes that catalyzed the adoption of best management practices for lowland irrigated rice in the Mekong Delta. In: Agronomy, 11(9), 1707. https://doi.org/10.3390/agronomy11091707.

Weblink: https://www.mdpi.com/2073-4395/11/9/1707

Supplementary material: Household baseline and endline survey questionnaire and Vietnam perception survey questionnaire in Appendix

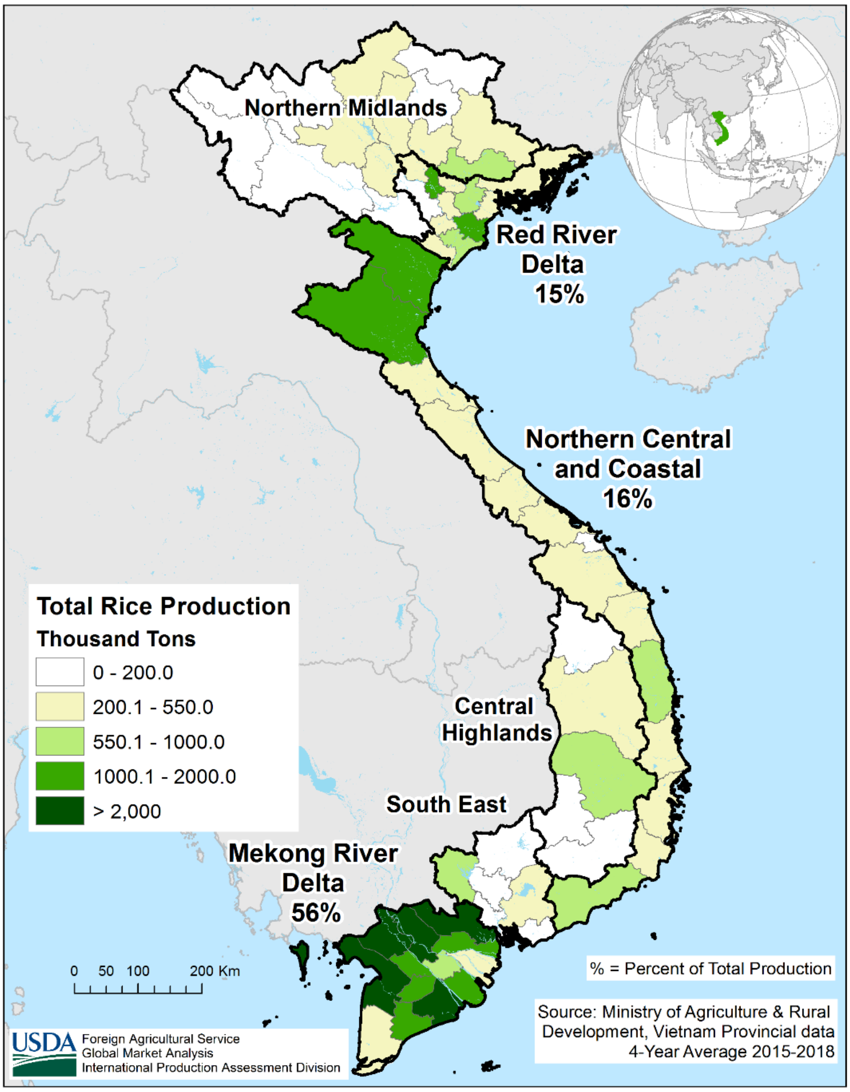
# 11 Vietnam – Rice Agriculture Development for Economic Growth

This chapter presents Vietnam's rapid agricultural development path and the role of the rice sector. The economic reforms that led to this evolution and the ensuing environmental, social, and economic impacts are discussed. A specific focus is put on the Mekong River Delta. Its significance for Vietnam's dominant position as a rice producer and exporter is explained. Lastly, two policy programs promoting sustainable rice production in the Mekong River Delta are introduced.

## 11.1 Rice Production and Agricultural Development in Vietnam

Vietnam's agriculture sector has experienced significant changes over the past decades. In particular, the transformation of rice farming has made Vietnam one of the world's largest rice producers and exporters (GRiSP 2013: 127). Rice production continuously increased from 16 Mt in 1985 to 43 Mt in 2019 (GRiSP 2013: 127; FAO Statistics Division 2020). Today, it is the world's fifth-largest rice-producing country and the largest in Southeast Asia before Thailand. In addition, Vietnam has become one of the world's leading rice exporters, being third after India and Thailand (GRiSP 2013: 127; FAO Statistics Division 2020, 2021a; USDA Foreign Agricultural Service 2021: 24). Its prominence in the global rice trade can be attributed to the expansion of the harvested and irrigated cultivation area and the considerable growth in yields over the last three decades. The rice area expanded from 6.0 Mha in 1990 to a record of 7.9 Mha in 2013. It has since been declining, reaching 7.4 Mha in 2019 (GRiSP 2013: 127; FAO Statistics Division 2020; Ricepedia 2021). Regarding the expansion in irrigation area, the proportion of rice area under irrigation has considerably increased. In 2005, the total equipped agricultural area for irrigation was 4.6 Mha. It increased to 8.7 Mha in 2017. The rice irrigated area has remained significantly larger than for other crops. It constitutes more than 78 % (6.8 Mha in 2017) of the total irrigated area (FAO 2011: 7–8; FAO AQUASTAT 2021). Overall, hydraulic controls, the regulation of floods, and prevention systems against saltwater intrusion, particularly in the Mekong River Delta, have stimulated the expansion of the irrigated area. This has enhanced rice yields considerably. Hence, the modernization of the irrigated area has been a determining factor for Vietnam's leading position to date (GRiSP 2013: 127; Tivet, Boulakia 2017: 4). The transformation began with the introduction of Green Revolution technologies that led to substantial changes in production practices. HYVs, modern irrigation infrastructure, and agrochemicals were introduced. Today, Vietnamese rice farmers mostly use HYVs in combination with high amounts of inputs. They generally operate modern mechanization equipment that improves labor productivity and reduces postharvest losses. Many farmers have adequate irrigation infrastructure, they receive sufficient financial support, and have good market access (Hai 2012: 2; GRiSP 2013: 127; Tivet, Boulakia 2017: 4; Lam 2019: 284–285). Overall, the transformation of rice farming enabled double or triple cropping in a single year to a greater extent. This crop intensification allowed for increased production quantities. Thus, rice yields consistently improved from 2.7 t/ha to 5.8 t/ha in 2019 (Tivet, Boulakia 2017: 4; FAO Statistics Division 2020).

The two main rice-growing regions are the Red River Delta in the north and the Mekong River Delta in the south of Vietnam (Map 11.1). The Mekong River Delta covers an area of 40'000 $km^2$, of which 26'000 $km^2$ are used for agri- and aquaculture (Nguyen 2007: 10; Connor et al. 2020a: 90; General Statistics Office of Vietnam 2021). It produces considerably more rice than other regions. More than half of Vietnam's total rice is produced in the Mekong River Delta (USDA Foreign Agricultural Service 2018b; Ricepedia 2021). Farmers can grow rice up to three times per year. The natural conditions make the delta region particularly suitable for intensive rice cultivation (FAO 2002; GRiSP 2013: 127–128; Ricepedia 2021).




Map 11.1 Main rice cultivation areas in Vietnam by production quantity
Source: USDA Foreign Agricultural Service (2018b)

**Economic reforms.** After the reunification of Vietnam in 1975, the centrally planned economy led to stagnating economic growth while the population was increasing. This resulted in a negative GDP per capita growth causing Vietnam to become one of the poorest countries in the world. Due to the catastrophic economic conditions and overall decreasing rice output, Vietnam had to import rice from 1975 to 1987 (Lam 2019: 283). Fundamental reforms were introduced in the 1980s and 1990s. The 'Doi Moi' political and economic reforms of 1986 and onward facilitated the transition from a centralized economy to a socialist-oriented market economy with trade liberalization. Regarding the agriculture sector, agricultural cooperatives were abolished, communal lands were de-collectivized and allocated to individual farm households, the promotion of free-market incentives and foreign investments became a priority, price controls on agricultural goods were removed, and exchange rate policies were revised (GRiSP 2013: 127; Hoang, Pham, Ulubaşoğlu 2016: 133; Tivet, Boulakia 2017: 4,6; Lam 2019: 286). One key aspect to reviving agricultural growth was the abolition of the agricultural cooperative model. Individual land-use rights were first set to 15 years. In 1993, farmers were permitted to have their designated land for up to 50 years (Tuyen 2010: 2; Sebesvari et al. 2012: 334–335; Lam 2019: 286). Additionally, the government allowed farmers to transfer their land use rights to another user within the duration of the lease (Laiprakobsup 2019: 3; Lam 2019: 286). These policy reforms led to more planning security and responsibility for the land. Farmers were incentivized to invest more into their farms to improve their cultivation practices and increase their production quantities. This had a positive impact on farmers' livelihoods and the Vietnamese rice sector as a whole. Furthermore, free trade and access to the global markets greatly enhanced the role of agriculture as an engine of growth for the economy. These policies allowed for higher growth rates of agricultural production than needed for domestic consumption. This led to increasing export volumes (Sebesvari et al. 2012: 335). Thereupon, agricultural growth accelerated significantly and poverty levels started dropping considerably. The agricultural policies boosted exports and created job opportunities in various fields within the agriculture sector but also in other sectors. This boosted the development of the Vietnamese economy in all areas (Lam 2019: 284–286). With regard to the rice sector, most of the growth in rice production over the past decades has been exported, approximately one third of the total rice production. The main importing countries are China (2.1 Mt) and the Philippines (1.1 Mt). Vietnamese rice is usually lower priced and of poorer quality to remain competitive. However, this strategy has caused the net value-added content from exported rice to be considerably lower compared to other agricultural exports of Vietnam (World Bank 2012: 6; GRiSP 2013: 127; Demont, Rutsaert 2017: 1–2).

Overall, the economic reforms have resulted in average incomes increasing by more than 3.5 times. Improved agricultural efficiency and a shift from low productivity agriculture created higher productivity non-farm jobs. Hence, the poverty rate has fallen drastically from 60 % in 1993 to 14 % in 2010, resulting in Vietnam being classified as a middle-income country since 2009 (OECD 2013: 20; Eckardt, Demombynes, Behr 2016: 36; Demont, Rutsaert 2017: 1; Lam 2019: 298–299). While the contribution of the agricultural sector to the country's GDP has been steadily declining for decades, the sector still accounts for a large share of employment. In 2020, over 36 % of the population was employed in agriculture compared to 28 % in the industrial sector and 35 % in the services sector (World Bank 2020d). In this regard, the agriculture sector remains particularly important for those exclusively dependent on agriculture. Any decline in output due to factors such as climate change or price erosion of agricultural products is likely to have significant welfare implications (Rigg, Salamanca 2018: 48).

## 11.2 Impacts of Agricultural Transformation and Economic Growth

Vietnam's rapid agricultural development since the mid-1980s has significantly transformed the country. However, these changes have had considerable ecological, social, and economic impacts that could lead to long-term issues in the 21st century, particularly in the context of climate change (Table 11.1) (Smyle, Cooke 2010: 1; Yu et al. 2010: 1). Vietnam is considered as one of the countries to be hit more severely by climate change and experience serious implications for economic development, especially in the agricultural sector. According to a comparative analysis by the World Bank Development Research Group, Vietnam would be the most seriously impacted country in East and Southeast Asia by sea level rise. It would have the largest percentage of the population, almost 40 %, affected (Dasgupta et al. 2007: 28–31). Around two-thirds of the population of Vietnam who lives in lowland areas are exposed to these risks. Most of the impact is expected in high population density areas, such as the Mekong River Delta (Nguyen 2007: 5–6; Yu et al. 2010: 1; Trung 2013: 54–55). Saltwater intrusion, the irregular intensity of rainfall, and frequent flood occurrence can affect the available period of cultivation, hence shorten crops' growth period. The harmful effects of salinity on soils are expected to reduce yield growth, as several other Asian countries have already experienced (Kotera et al. 2014: 352–353; Deb, Tran, Udmale 2016: 642). Furthermore, high levels of salinity in irrigation water coupled with reduced surface water flow could lead to a significant reduction of the total rice cultivation area. The Mekong River Delta will be hit especially hard (Khang et al. 2008: 167; Yu et al. 2010: 8; Deb, Tran, Udmale 2016: 642). Without the implementation of climate change adaptation strategies, the losses in the agriculture sector could represent a decline in overall GDP of 0.7-2.4 % by 2050 (Smyle, Cooke 2010: 28–29). In the future, intensive cropping patterns, i.e., cultivating rice two to three times per year, will be significantly reduced and the performance of HYVs will decline (Khang et al. 2010: 19; Rutten et al. 2014: 40; Deb, Tran, Udmale 2016: 642).

The rice export sector will be hit strongly and will no longer be able to rely on cost-competitiveness. Vietnam's current economic growth model is based on boosting agricultural exports for rural development and creating job opportunities in other sectors. This model has started reaching its limits and cannot maintain past performances (Eckardt, Demombynes, Behr 2016: 34; Lam 2019: 286). As of today, agriculture as an engine for rural development and economic growth has subsided because of rising input costs. Although agricultural export volumes and gross export revenues have steadily increased, the underlying production costs have risen likewise. As a result, the net value added from exported agricultural goods, in particular rice, has been declining; 40-50 % of the costs of exportable rice are associated with fertilizer and agrochemicals. Hence, high input use increases production costs resulting in lower financial returns for farmers. Overall, the competitiveness of Vietnamese agricultural products is decreasing (World Bank 2012: 6,17; Demont, Rutsaert 2017: 1; Nguyen 2017: 41).

Table 11.1 Environmental, social, and economic impacts of agricultural transformation and economic development

| Problem | Environmental impacts | Social impacts | Economic impacts |
|---|---|---|---|
| Climate change | • Rising sea level leading to permanent inundation and loss of agricultural land<br>• Extended saltwater intrusion<br>• More frequent extreme weather events | • Large section of the population exposed to environmental impacts and at risk of loss of livelihood and living environment<br>• Increased migration | • Reduced agricultural productivity in delta regions due to cultivation land deterioration (particularly in Mekong Delta)<br>• Decline in overall GDP and specifically rice exports |
| High usage of agrochemicals (fertilizers, pesticides, etc.) | • Biodiversity loss<br>• Waterbody pollution<br>• Soil pollution<br>• Low-quality rice due to high levels of pollution | • Reduced food security<br>• Smallholder farming at risk due to insufficient resources<br>• Gap between small and large farmers increases | • Reduced profitability due to lower prices for rice products<br>• Negative image of Vietnamese rice affects export business<br>• Declining competitiveness |
| GHG emissions | • Climate change intensification<br>• Global temperature rise<br>• Permanent ecosystem changes<br>• Soil depletion | • Threat to human health due to increased air pollution<br>• Risk of food insecurity rises due to accelerated climate change | • Reduced productivity levels in the context of climate change<br>• High irrigation costs for traditional water regimes in rice cultivation |
| Rural-urban discrepancies | • Increased pressure on natural resources<br>• Degradation and depletion of water, soil, and air<br>• Detrimental effects of land-use change | • Continued wealth gap<br>• Migration and demographic change will accelerate<br>• Shift of the role of the agricultural sector for social welfare | • Low rural incomes<br>• Low labor productivity due to high employment rate in the agriculture sector<br>• Continued infrastructural deficits in rural areas |

Environmental problems caused by farming activities have also become pressing issues. Agriculture has a large environmental footprint in Vietnam. Excessive fertilizer use combined with increasing pesticide use has led to biodiversity losses, soil degradation, and water pollution (Rutten et al. 2014: 38–39; Eckardt, Demombynes, Behr 2016: 64–65; Nguyen 2017: 18–19). Vietnam consumes significantly more fertilizer than other Southeast Asian countries, especially rice farmers in the Mekong River Delta (Figure 11.1). This has resulted in overfertilization, pest resistance, and the disappearance of natural predators (Vietnam Ministry of Natural Resources and Environment 2015: 46; Eckardt, Demombynes, Behr 2016: 64; Nguyen 2017: 18-19,22). Furthermore, untreated wastewater has been affecting the natural ecosystem and aquatic communities. The surface and groundwater contamination is intensified by water shortages in the dry season and high soil salinity (Kellog Brown & Root Pty Ltd 2009: iv–v; Demont, Rutsaert 2017: 2; Nguyen 2017: 31–32). Another issue is increased GHG emissions, namely carbon dioxide ($CO_2$), nitrous oxide ($N_2O$), and methane ($CH_4$). Rice cultivation plays a considerable role being responsible for 10 % of agricultural GHG emissions worldwide or approximately 1-2 % of total anthropogenic GHG emissions (Tivet, Boulakia 2017: 9; Maraseni et al. 2018: 2288; Connor et al. 2020b: 1–2). In Vietnam, almost 60 % of GHG emissions from agriculture are due to intensive rice systems and related practices (Vietnam Ministry of Natural Resources and Environment 2010: 45–46; Maraseni et al. 2018: 2289; Connor et al. 2020b: 2). Rice straw burning increases $CO_2$ emissions and is a significant source of air pollution (Junpen et al. 2018: 2; Allen et al. 2020: 174). In irrigated rice systems, $N_2O$ emissions are small when water is managed well. However, if high amounts of nitrogen fertilizer are applied, high $N_2O$ emissions occur during fallow periods and after flooding (GRiSP 2013: 25). Furthermore, when the rice straw is left in the field and not fully composted, $N_2O$ and $CH_4$ emissions are high (Yagi, Minami 1990: 599; Wassmann et al. 2000: 23; Connor et al. 2020b: 2). $CH_4$ emissions from rice fields are determined mainly by the water regime and flooding of the soil. In the case of inadequate water management, high levels of $CH_4$ are emitted. In addition, the use of organic manure also increases methane emissions (GRiSP 2013: 25). Overall, these practices lead to loss of nitrogen, phosphorus, and potassium in the soil, deplete soil organic matter, reduce beneficial soil bacteria, and pose a threat to human health and the environment (Mandal et al. 2004: 224; Connor et al. 2020b: 1–2).

Regarding social impacts, the transfer of land use rights from the state to the farmers was a pivotal decision that incentivized farmers to continue working in agriculture and boosted Vietnam's economic development. This had a large effect on overall poverty alleviation. As of 2018, less than 7 % of Vietnamese are considered poor (Eckardt, Demombynes, Behr 2016: 16; Lam 2019: 286; World Bank 2021). This progress has benefited the society at large and Vietnam demonstrates broadly shared prosperity (Smyle, Cooke 2010: 20; Eckardt, Demombynes, Behr 2016: 16–17; Lam 2019: 286). However, social structures in Vietnam have been changing slowly. The income gap between rural and urban populations has not been eliminated (Eckardt, Demombynes, Behr 2016: 18; Lam 2019: 286,300). The shift from rural to urban areas in Vietnam is at a rate of about 1 % per year. Hence, most Vietnamese, 65 % of the population, still reside in rural areas (Rutten et al. 2014: 29; General Statistics Office of Vietnam 2019: 31; Lam 2019: 288). This share of the population accounts for 43 % of the labor force but contributes only 17 % to the national GDP (Lam 2019: 288). In contrast, the growth of the services sector has mostly advanced GDP growth in the past decade (Alejandro et al. 2012: 6; Chuc, Duong 2019: 257–258). The government has been reforming the economy to promote employment opportunities, specifically in the services sector. It aims to improve overall income levels and social mobility, particularly rural to urban migration (Lam 2019: 289). Nonetheless, Vietnam is starting to face other social problems. It is becoming one of the fastest aging societies in the world. This demographic shift will have broad societal and economic implications, including drastic changes regarding the labor market, public services, and economic growth. Overall, the role of the agriculture sector as an important element for sustaining rural livelihoods and defining Vietnam's social structures will be considerably challenged in the upcoming decades (Eckardt, Demombynes, Behr 2016: 36).

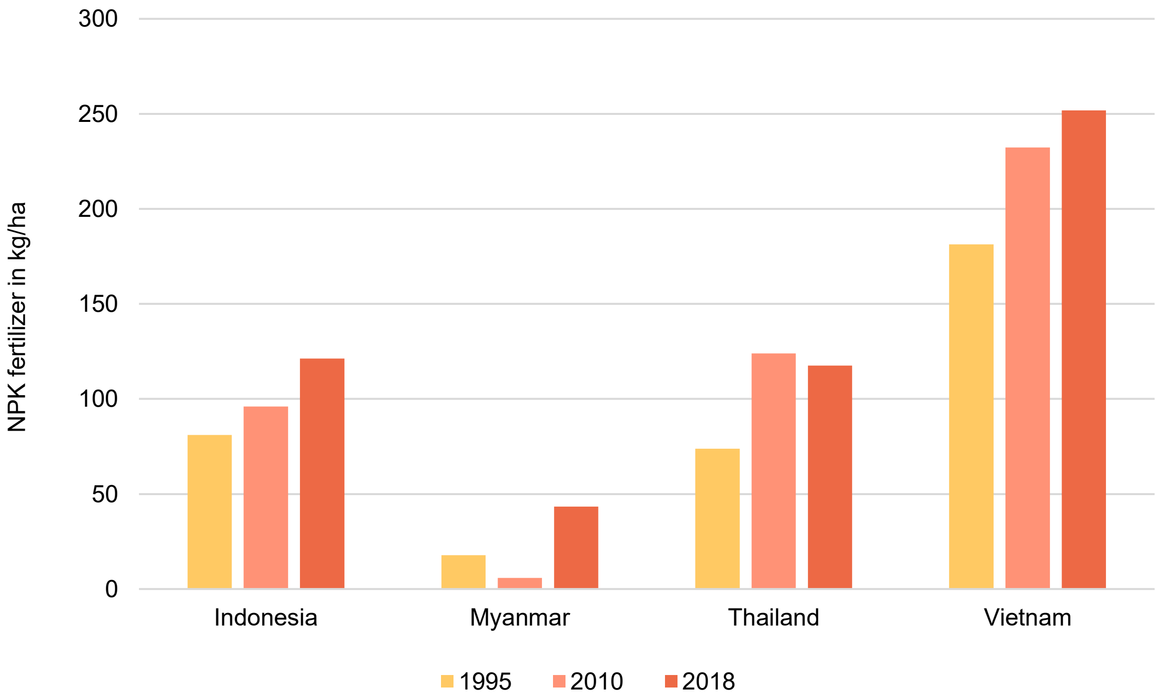



Figure 11.1 NPK fertilizer use in agriculture in kg/ha in selected Southeast Asian countries
Source: FAO Statistics Division (2021b); Concept: H. Wehmeyer (2021)

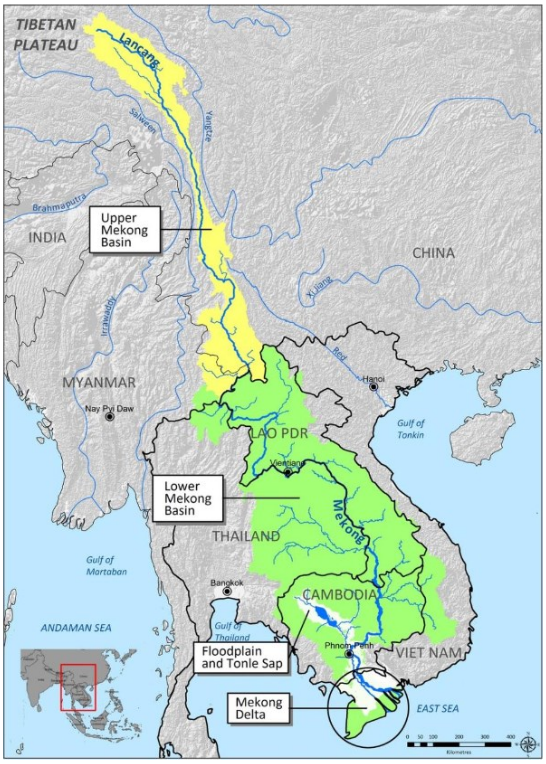
### 11.2.1 Rice Production Constraints in the Mekong River Delta

The Mekong River Delta is part of the Mekong River Basin, which is one of the most important ecosystems in Southeast Asia (Box 11.1). Over the past decades, issues related to agriculture, energy, and economic activity have come up in several countries of the Mekong River Basin. The long-term sustainability of water resources is challenged by competing interests (The Economist Intelligence Unit (EIU) 2017: 4).

**Box 11.1 The Mekong River Basin**

The Mekong River covers a distance of 5000 km from its source in the Tibetan Plateau in China to the Mekong Delta in Vietnam forming the transboundary Mekong River Basin consisting of six countries: China, Myanmar, Laos, Thailand, Cambodia, and Vietnam (Map 11.2). The river basin is divided in the Upper Mekong Basin in China and the Lower Mekong Basin starting at the border between China, Laos, and Myanmar extending until the South China Sea where the river discharges (FAO AQUASTAT 2011: 1; MRC 2021a). Agriculture is the most dominant water-related sector in the Mekong River Basin and approximately 70 % of the basin's population rely on it for their livelihoods. Regarding hydropower development, the basin has become one of the most active regions in the world. Due to the large hydropower potential, several new dams are planned by 2030, especially in the Lower Mekong Basin (FAO AQUASTAT 2011: 6–9).

To ensure equitable use of the Mekong River, the Mekong River Commission (MRC), endorsed by the UN, was established in 1957. Its four members states, Cambodia, Laos, Thailand, and Vietnam have agreed to share responsibilities for financing, management, and maintenance of water resources. They promote an effective development of the Lower Mekong Basin. The MRC includes China and Myanmar as dialogue partners to promote and coordinate the sustainable use of the water and related resources. The MRC is funded by its member countries and development partners including multilateral and bilateral funding organizations, such as the World Bank, EU, and the Swiss government (MRC 2021b; c; d).



Map 11.2 Map of the Mekong River Basin
Source: MRC (2019: iii)

The Mekong River Delta in Vietnam has started to face several difficulties. Rice production is expected to become more difficult due to multiple constraints. The aforementioned impacts and environmental constraints will hit the Mekong River Delta considerably. It is expected that the total rice cultivation area in the Mekong River Delta will decline significantly. Hydrological modeling in the Mekong River Basin predicts extended flooding periods and significant increases in drought length and frequency in the southern and eastern portions of the basin (Rigg, Salamanca 2018: 48). By 2050, sea level rise is expected to be approximately 30 cm above current levels (Yu et al. 2010: 8; World Bank 2012: 33). A rise in sea level of one meter expected by 2100 could flood 15'000-20'000 km2 of the Mekong River Delta, reducing Vietnam's total rice production by 5 Mt and affecting more than half of the total paddy rice area of Vietnam (Nguyen 2007: 7; Hai 2012: 1; Rutten et al. 2014: 40). The overall rice production quantities will decline due to advancing sea level rise, saline water intrusion, and prolonged water shortages (FAO 2002; World Bank 2012: 33; GRiSP 2013: 85,128; Trung 2013: 54; EIU 2017: 9–10). In addition, soil degradation and subsequent depletion of soil fertility as well as increased pests and diseases result in a further decline of total rice output (Hai 2012: 1; GRiSP 2013: 128). Rice yield reduction by 2050 is estimated between 4-8 % and the decline in agricultural productivity could range from 2-15% by 2080 (Zhai, Zhuang 2009: 5; Yu et al. 2010: 19; Trung 2013: 56; Deb, Tran, Udmale 2016: 642). By

2100, 70 % of the Mekong River Delta's agricultural land could become too saline for rice cultivation. This could force five million people to leave due to unviable environmental and economic conditions (Yu et al. 2010: 1; EIU 2017: 9). Overall, losses in agricultural productivity are forecasted. Hence, if the Vietnamese government fails to address these issues, the decrease in rice output could jeopardize the country's export position and compromise the livelihoods and food security of millions. Furthermore, it has been signaled that Vietnam could become a net importer of rice in the case the problem of salinization is not adequately addressed (Zhai, Zhuang 2009: 5; Yu et al. 2010: 1; Chen, McCarl, Chang 2012: 559; Rutten et al. 2014: 43–44; OECD, FAO 2017: 89).

Economic constraints in the Mekong River Delta include a high inflation rate, rising input costs, inadequate credit facilities for farmers, low rice prices, and thus low returns from rice production (FAO 2002; GRiSP 2013: 128; Demont, Rutsaert 2017: 2). Vietnam's rice export strategy has been based on low-quality rice produced in high quantities and sold at a low price. The majority, about 70 %, of the rice produced in the Mekong River Delta is destined for export. In this regard, the inferior quality and negative image of Vietnamese rice affect rice growers directly. They suffer from lower rice prices due to the weak reputation of their product (World Bank 2012: 37; Demont, Rutsaert 2017: 2). Consequently, many rice farmers in the Mekong River Delta have become net buyers of rice because their rice production expenditures exceed paddy sale revenue. In particular, small landholdings (<1.25 ha) have experienced increasing economic difficulties. More and more households are becoming reliant on non-rice income and off-farm employment (World Bank 2012: 6,45-47; Demont, Rutsaert 2017: 2). On the contrary, farmers of large landholdings (>2 ha) have been able to improve their livelihoods due to specializing exclusively in rice production. Their utilization of technologies, specifically labor-saving technologies, is higher, postharvest losses are lower, and their access to the markets is better. In general, the more integrated farmers are in the market, the higher their average rice yield is (Yu et al. 2010: 12; World Bank 2012: 45–46). Most of these farmers are geographically concentrated in certain provinces of the Mekong River Delta, namely in An Giang, Kien Giang, Long An, and Dong Thap. Since the 1990s, these provinces have emerged as dominant rice producers accounting for most of the growth in Vietnam over the past 30 years. The so-called 'Long Xuyen Quadrangle' has become the core rice belt of the Mekong River Delta. It consists of 30 districts that have been reaching considerably higher productivity rates than other regions. The area comprises only 20 % of all growers in the Mekong River Delta but accounts for more than half of the region's production. Most of the rice is destined for export and net returns for farmers range from 23-33 %. The average rice yields of these farmers reach 6 t/ha compared to the average of 4 t/ha in the delta. In addition, their mean cultivation area of more than 2.5 ha is significantly larger than the general 1.3 ha in the Mekong River Delta and the national average of 0.4 ha. Hence, only a small proportion of rice farmers in the Mekong River Delta has been able to increase profits and achieve a sufficient income on the basis of specialized rice production (Hai 2012: 5; World Bank 2012: 6,42-46).

## 11.3 Policies for Sustainable Rice Production in the Mekong River Delta

A policy strategy based on sustainable agricultural growth is considered important for safeguarding domestic food security and increasing Vietnam's resilience to shocks on the world market. This emphasizes the need for the Vietnamese government to boost investment in agricultural R&D, sustainable input use, and extension services to improve yields (Rutten et al. 2014: 43). Consequently, the Vietnamese government launched two policy programs in the Mekong River Delta. These incentivize farmers to adopt farming practices for sustainable rice production (Connor et al. 2020a: 91).

The first major program to promote sustainable practices in rice farming in the Mekong River Delta was launched in 2003 and termed 'Three Reductions, Three Gains' (3R3G). Rice farmers were encouraged to reduce their seed rate, fertilizer use, and application of insecticides (Figure 11.2). The three gains for the farmers were an improved net-farm profit, a reduced exposure to agrochemicals, and enhanced environmental conditions (Inclusive Cities Observatory 2010: 3; World Bank 2012: 50; Nguyen 2017: 25; Connor et al. 2020a: 91). 3R3G was developed because farmers in the Mekong River Delta were using high levels of agrochemicals that created unfavorable field conditions and were harming the environment. The program is a package of input management recommendations for farmers that they can use for their input use decision making. It is based on the principles of IPM and capitalizes on the synergistic effects of reducing inputs without sacrificing yield. Concretely, if seed rates are lower, farmers require less fertilizer. This makes crops less attractive to pests because the canopy is less dense and the need for insecticides is reduced. Hence, the overall advantages of the 3R3G technology package are the reduction of high seed rates and agrochemical use without yield loss. This results in lowered input costs leading to higher profits, an improvement of the rice agroecosystem, and better rural livelihoods (Huan et al. 2005: 457; Huelgas, Templeton, Castanar 2008: 3–4; Inclusive Cities Observatory 2010: 3; Connor et al. 2020a: 91). 3R3G was first introduced in the provinces of Can Tho, Tien Giang, and Vinh Long in 2003. The program was rolled out through standard extension activities combined with a mass media campaign based on a multi-stakeholder participatory planning process. For the dissemination of 3R3G, a leaflet, a poster for billboards along main roads, a radio drama and soap opera for national radio and television, respectively, as well as a TV advertisement were developed in addition to the organization of farmer field days (Huan et al. 2005: 463; Huelgas, Templeton, Castanar 2008: 3; Inclusive Cities Observatory 2010: 3).

| 3R3G | 1M5R |
|---|---|
| • Reduce seed rate below 100 kg/ha<br>• Reduce fertilizer below 130 kg/ha of nitrogen<br>• Reduce pesticide applications below 4 per season | • Must use certified seed<br>• Reduce seed rate below 100 kg/ha<br>• Reduce fertilizer rate below 130 kg/ha<br>• Reudce pesticide applications below 4 per season<br>• Reduce water use by applying AWD<br>• Reduce postharvest loss by using combine harvester |

Figure 11.2 Components of 3R3G and 1M5R national policy programs
Source: Adapted from Huan et al. (2008: 340) and Josephson et al. (2020: 20)

On the basis of 3R3G, a second program was initiated by IRRI in collaboration with the An Giang Department of Agriculture and Rural Development. This program was named 'One Must Do, Five Reductions' (1M5R) and was first released in An Giang Province in 2008. 1M5R includes two further reductions, namely the reduction of water use and postharvest losses, and the use of certified seeds as a requirement (Inclusive Cities Observatory 2010: 4; Cassou, Jaffee, Ru 2017: 113). Hence, the 1M5R integrated technology package promotes the use of sustainable best management practices in rice agriculture by endorsing the use of certified seeds in combination with five reductions. These encompass the seed rate, fertilizer use, pesticide use, water use, and postharvest losses (Rejesus, Martin, Gypmantasiri 2014: 42; Stuart et al. 2018: 104; Connor et al. 2020a: 91). The specific recommendations for the farmers who adopt 1M5R are to apply a seed quantity ranging from 80-120 kg/ha depending on the seeding method (direct seeding or transplanting), adapt nitrogen fertilizer quantity and application times to the planted rice variety and soil type, limit the usage of pesticides as much as possible by following IPM, adopt water-saving techniques such as AWD, use a combine harvester, and employ a paddy dryer to reduce postharvest losses (Chi et al. 2013: 238; Willett, Barroga 2016: 10; Nguyen 2017: 72). One of the benefits of reducing water use through the 1M5R recommended technology AWD is the decrease of methane emissions. Rice cultivation in the Mekong River Delta is currently one of the highest sources of GHG emissions in Vietnam (World Bank 2012: 50; Vo et al. 2018: 47–48). So far, 1M5R with AWD has shown promising results in reducing GHG emissions (Nguyen 2017: 35; Leon et al. 2021: 7–8). The amount of methane emitted in 1M5R with AWD experimental fields was significantly lower than for traditional farming. Furthermore, AWD, together with organic fertilizer use, can help reduce $CH_4$ and $N_2O$ emissions by 53 % in comparison to traditional farming (Nguyen 2017: 35; Tran et al. 2018: 14–15).

The adoption diffusion strategy of 1M5R in the Mekong River Delta followed E.M. Roger's innovation-decision process emphasizing the stages of knowledge provision and persuasion (Chapter 4.1.1) (Rogers 2003: 170; Connor et al. 2020a: 91; Tuan, Wehmeyer, Connor 2021). First, workshops with multiple stakeholders ranging from provincial officials to staff of the Vietnam Department of Agriculture and Rural Development (DARD) were organized. The workshop participants were trained on how to inform farmers on the principles of 1M5R. They were also taught how to provide knowledge about 1M5R to improve the diffusion of the technology package. Furthermore, possible limitations regarding the implementation and adoption of 1M5R technologies and practices were discussed (Connor et al. 2020a: 91; Tuan, Wehmeyer, Connor 2021). Second, focus group discussions with farmers were conducted regularly to evaluate the constraints they face in adopting 1M5R technologies and implementing the recommendations. Third, demonstration sites of recommended 1M5R technologies were established to directly provide information and knowledge to farmers (Connor et al. 2020a: 91). As of today, the diffusion of the 1M5R integrated technology package has been scaled up and promoted throughout the entire Mekong River Delta. Therefore, a leading panel was established to support the dissemination of 1M5R in other provinces (Nguyen 2017: 49–50).

# 12 Vietnam – Sustainable Rice Production with 'One Must Do, Five Reductions'

In this chapter, the agronomic development of rice farmers in Can Tho Province in the context of the CORIGAP project under the 1M5R national policy program is examined. The study focuses on farmers' introduction and adoption of 1M5R recommended technologies and their effects on rice yield and farmer profitability. First, the rationale and the objectives of the study are stated. Second, the data collection approach and study area are described. Third, the results of farmers' agronomic development are presented and discussed, specifically focusing on differences between CORIGAP project and control farmers.

## 12.1 Rationale of the Study

Farmers in Vietnam have generally adopted a 'more is better' attitude regarding agricultural inputs. This has become a major cause of the increasing environmental losses in rice production. Additionally, this approach is lowering farmers' profitability (Huelgas, Templeton, Castanar 2008: 3; Nguyen 2017: 50; Tu 2017: 285). Especially rice farmers in the Mekong River Delta have incessantly been using high amounts of inputs and adopted environmentally unfriendly practices as a result of agricultural intensification over the past decades (World Bank 2012: 50; Nguyen 2017: 67; Tu 2017: 285). Therefore, the 3R3G and now 1M5R national policy programs have been developed to promote sustainable rice production. They aim to modernize rice-based production systems without further increasing environmental damages and improving farmers' profitability (Huelgas, Templeton, Castanar 2008: 2–3; Nguyen 2017: 25). In this context, the activities of the CORIGAP project in Vietnam focus on continuing the promotion of the 1M5R integrated technology package. It was initially promoted during the IRRC Phase IV in the provinces of Long An and Can Tho. The CORIGAP activities concentrate on increasing the number of farmers adopting 1M5R practices and recommended technologies (IRRI 2018e). Under the CORIGAP project, the recommended amount of seeds using a drum seeder is 80 kg/ha. Furthermore, clear limits for pesticide use, i.e., no more than two applications per target pest group, are advised. Fertilizer application rates should not exceed 130 kg of nitrogen per hectare (Willett, Barroga 2016: 10; Stuart et al. 2018: 108; Josephson et al. 2020: 3). In addition to informing and training farmers on the 1M5R recommendations, CORIGAP efforts focus on introducing farmers to technologies that can support their objective of reaching the 1M5R requirements. AWD, for instance, significantly reduces water use and improves farmers' environmental footprint by reducing methane emissions (Willett, Barroga 2016: 14; IRRI 2018e). The learning alliances support the out scaling of the introduction to resource-saving technologies and the promotion of multiple technologies for mechanizing rice farming (Willett, Barroga 2016: 14). For example, farmers have been introduced to laser land leveling, a technology that levels the field to improve water use efficiency and increases grain yield as well as quality (IRRI 2018e; IRRI Rice Knowledge Bank 2021f). Furthermore, farmer groups have been supported in purchasing combine harvesters to improve their harvest and postharvest practices, particularly rice straw management, and drum seeders to reduce their seed rate (IRRI 2014: 15, IRRI 2015: 28–29, IRRI 2018e).

Studies have shown that the impact of 1M5R under IRRC IV and the first phase of CORIGAP was beneficial for farmers. They were able to improve their sustainability performance and natural resource management, reducing pesticide, fertilizer, and seed use. In addition, economic welfare increased (Rejesus, Martin, Gypmantasiri 2014: 44–46; Stuart et al. 2018: 103). The implementation of 1M5R related technologies has been demonstrated successful in reducing GHG emissions, particularly through the introduction of AWD (Tivet, Boulakia 2017: 15–16; Khai et al. 2018: 4–5). Furthermore, evidence of increased profitability due to the adoption of 1M5R recommended technologies has been shown. The main reason, therefore, is the reduction of input cost (Rejesus, Martin, Gypmantasiri 2014: 43–44; Stuart et al. 2018: 108–109). The current publications and reports on 1M5R under the CORIGAP project have investigated the earlier phases of the CORIGAP project or only single aspects such as yield gap analyses (Rejesus, Martin, Gypmantasiri 2014; Stuart et al. 2016, 2018). As of now, there is no information on how farmers' agricultural profitability and productivity have changed due to 1M5R under the second phase of the CORIGAP project. Therefore, the present study aims to examine the long-term changes farmers have experienced over a period of five years, specifically analyzing socioeconomic and agronomic changes. By separating CORIGAP project farmers from control farmers, this study examines the differences between two farmer groups. Project farmers received additional 1M5R trainings on AWD and land laser leveling, workshop invitations, and were included in stakeholder seminars such as learning alliances and other events. On the other hand, control farmers received information on 1M5R practices through channels such as national and provincial extension services, local information sharing, other development projects, and other channels. However, they were not included in additional CORIGAP activities. Thus, the present study analyzes socioeconomic differences and agronomic changes between farmer groups. It investigates the influence of farmers' adoption behavior of 1M5R recommended technologies with or without the presence of the CORIGAP project.

## 12.2 Materials and Methods

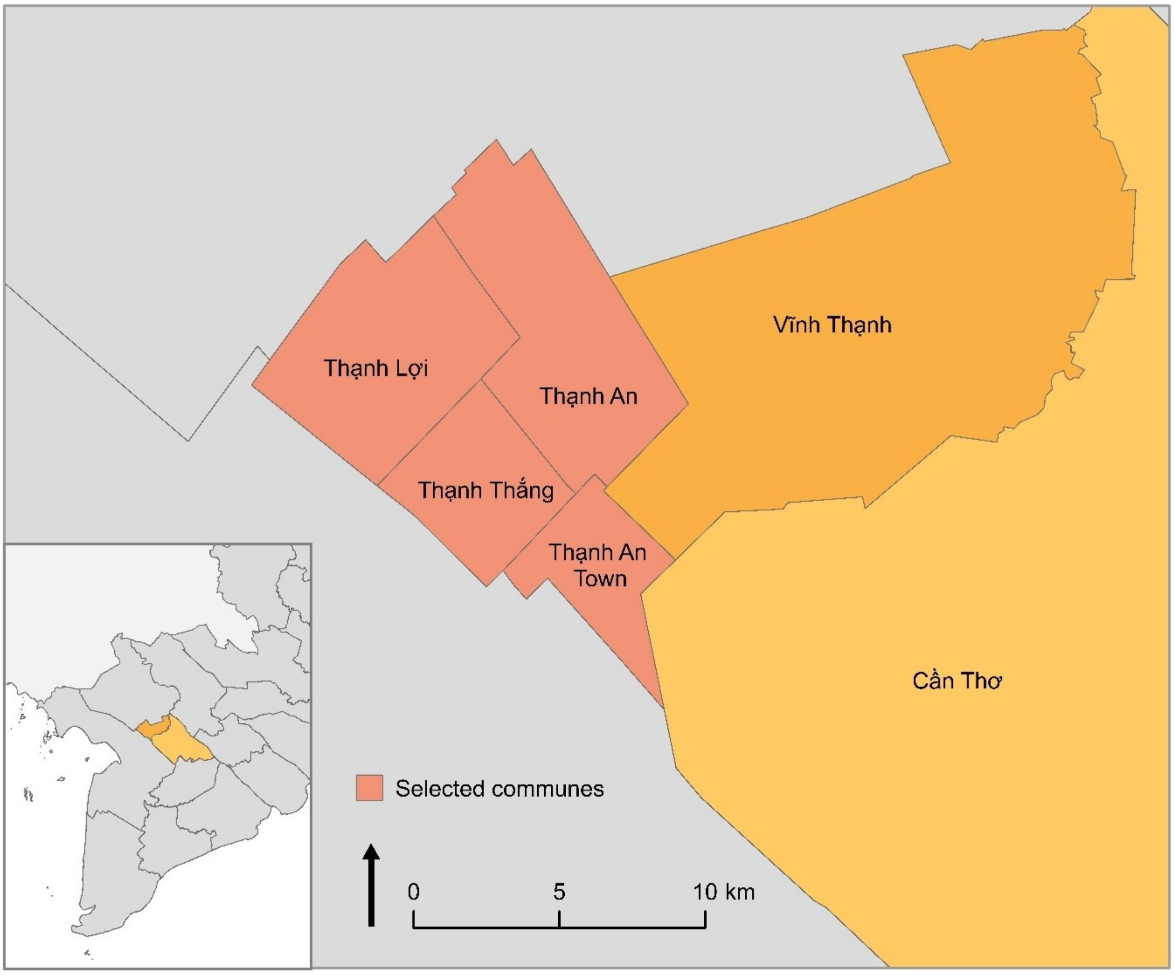
### 12.2.1 Survey Questionnaire and Data Collection Approach

A household survey questionnaire was used for the collection of baseline and endline agronomic data in 2015 and 2019. The household survey questionnaire consisted of five sections: 1) socioeconomic and farm characteristics, 2) cropping pattern and land preparation, 3) information on production output, 4) fertilizer, pesticide, and irrigation application, and 5) harvest and postharvest activities. A detailed description of the questionnaire is presented in Chapter 6.2.1. Farmers answered questions related to their farming practices applied during the cropping seasons of 2014-2015 for the baseline survey. For the endline survey, they described their activities executed during the cropping seasons of 2018-2019. The interviewed farmers could produce up to three rice crops a year. The first season is the winter-spring season (early season) that lasts from planting in November-December to harvesting in March-April. It is the main crop season in the Mekong River Delta and reaches the highest yields. The second season is the summer-autumn season (midseason), with planting in April-May and harvesting in July-August. Lastly, the third season is the autumn-winter season (late wet season), when rice is planted in July-September and harvested in October-December (Phan et al. 2018: 3; USDA - Foreign Agricultural Service 2019: 18). At the completion of the winter-spring season 2015, farmers were interviewed for the household baseline survey. During the first part of the interview, farmers answered questions related to their agronomic practices used in the winter-spring season from October-December 2014 to February-April 2015. In the second half of the interview, they answered the same set of questions for the summer-autumn season from March-May 2014 to June-August 2014. This process was repeated for the endline survey asking farmers about their farming practices in the winter-spring rice season from October-December 2018 to February-April 2019 and the summer-autumn season from March-April 2019 to June-August 2019. Additionally, the endline questionnaire included a section on 1M5R technology introduction and adoption to collect information on farmers' experiences with CORIGAP recommended technologies in the context of 1M5R between 2015 and 2019.

The survey questionnaire was created in English and translated into Vietnamese. This was followed by back-translation to English to ensure content validity and review for possible imparities. Data were collected by means of face-to-face interviews using a CAPI system. A detailed description of the CAPI systems is presented in Chapter 6.2. For the household baseline survey questionnaire in 2015, the CAPI tool Surveybe (Version: Freedom 3.1.4918) was employed. In 2019, the collection of the household endline data took place after all the interventions related to the CORIGAP project had occurred. The data collection was performed using the CAPI tool CommCare (Version: Dimagi 2.44.3). For both surveys, Samsung Galaxy Tablets A 7.0 (2016) LTE SM-T285 were used. Farmers' answers were typed into the Surveybe and CommCare application by the local extension workers during the interview. The information was then automatically synchronized with the Surveybe or CommCare dashboard without requiring post-data entry.

### 12.2.2 Sampling and Survey Implementation

Purposive geographic selection on a district level was used for the household survey sampling. The Can Tho DARD selected the district of Vinh Than in Can Tho Province based on logistical reasons, a high level of coordination between the communes and DARD officers, good extension networks, and strong linkages with relevant institutions. In addition, the farmers in the district of Vinh Thanh had received information on 3R3G and 1M5R practices. Local extension officers provided a master list of rice farmers in four communes from which a stratified random sample was developed. The communes Thanh Loi, Thanh An Town, Thanh An, and Thanh Thang were all located within a 25 km radius (Map 12.1).




Map 12.1 Survey location of household baseline and endline survey in five communes of Vinh Thanh District, Can Tho Province
Cartography: H. Wehmeyer; Cartographic base: GADM (2020)

Project communes were defined as sites exposed to best management practices and technologies through the CORIGAP project. The communes of Thanh Loi and Thanh An Town included the CORIGAP project farmers. They participated in activities such as additional training on AWD and laser land leveling or supplementary workshops on improving postharvest practices. Farmers in the communes of Thanh An and Thanh Thang did not participate in such activities, and hence were categorized as control farmers. The selection criteria for the control communes were based on the same farm and demographic characteristics as the project communes. Furthermore, a large enough distance from the project communes was established to limit diffusion effects.

Before conducting the survey, enumerators from the CanTho DARD were informed about the contents of the questionnaire and trained on using the survey application. Pre-testing of the application was conducted before the definitive farmer interviews. The household baseline survey was conducted from 10-18 June 2014 in the district of Vinh Thanh, Can Tho Province. An interview would be completed in approximately 75-90 minutes per farmer. In total, 180 farmers were interviewed. The project farmers were comprised of 50 farmers each in Thanh Loi and Thanh An Town and the control farmers in Thanh An and Thanh Tang were 40 each. The household endline survey was conducted from 22 September to 6 October 2019 in the same four communes with the same farmers. However, this was not possible in a few instances because farmers had moved, were not available, or had passed away. In those cases, the closest family member would be interviewed if they were still farming. An interview would take approximately 60-75 minutes to accomplish. Each farmer received compensation for their travel costs going to and from the central survey location.

### 12.2.3 Data Analysis

The data were automatically digitalized through the CAPI tools. The raw datasets were imported into Microsoft Excel from the Surveybe and CommCare dashboard. They were merged by farmer ID and imported into the IBM SPSS. For the data analysis, Microsoft Excel (version 2101, Redmond, WA, USA), IBM SPSS (version 27, Armonk, NY, USA), and IBM SPSS AMOS (version 27, Amos Development Corporation, Wexford, PA, USA) were used. Agronomic and socioeconomic data were checked for normal distribution. The selected agronomic variables for this study were not normally distributed. A detailed description of the variables' normality distribution is presented in Table 12.1. The first part of the data analysis consists of descriptive statistics to produce sample descriptions of the sociodemographic, socioeconomic, and agronomic data. Chi-square ($\chi^2$) test statistics were used to compare frequencies of categorical variables. Effect sizes were determined using Pearson's r. A value of 0.05 and below indicates no effect, 0.1-0.3 a small effect, 0.3-0.5 an intermediate effect, and 0.5 and higher a strong effect (Cohen 1988: 79–81). The socioeconomic and agronomic variables were evaluated by season and annually. Therefore, the winter-spring and summer-autumn season were aggregated. Farmers' total annual income consisted of their rice cultivation and non-rice farming income. Rice income was computed by multiplying the sold rice harvest with the mentioned selling price. Rice income, input cost, and labor cost are presented per hectare. The survey years and seasons were analyzed as independent samples. Since the selected variables for the socioeconomic and agronomic analysis were not normally distributed, the Mann Whitney U statistical test was used to determine the mean differences between the farmer groups, seasons, and two survey years.

The second part of the data analysis consisted of a mediated hierarchical linear regression analysis. This was used to analyze the determinants of rice yield and profitability using the farmer group as a mediating variable. Hence, yield and profitability development between the project and control group could be examined. By performing this method, the present study aimed to investigate whether the CORIGAP project interventions had a mediating effect on rice yield and profitability compared to those without the project interventions. In addition to the hierarchical regression analysis, a mediated structural equation modeling (SEM) model was tested in IBM SPSS AMOS. The maximum likelihood method of estimation was applied to calculate the SEM coefficients (Byrne 2013: 141). Bootstrapping was selected for testing the statistical significance due to the fact that the selected data are non-normally distributed (Byrne 2013: 336-337,340). Statistical significance was set to $p = \leq 0.05$.

## 12.3 Results

The results of this study are structured as follows. First, sociodemographic results and farm characteristics of the sample are described and the differences between the two farmers groups are illustrated. Second, the introduction and adoption rate of the CORIGAP technologies are presented. Third, the socioeconomic and agronomic results by farmer group, season, and year are shown, followed by the mediation analysis for farmers' rice yield and profitability performed over all farmers.

Table 12.1 Normality test for selected socioeconomic and agronomic data

| | 2015 | | | | |
|---|---|---|---|---|---|
| Variables | **n** | **Skewness (SE)** | **Kurtosis (SE)** | **K-S test** | **Shapiro-Wilk test** |
| Annual household income (‘000 VND) | 135 | 0.566 (0.209) | -0.471 (0.414) | KS (135) = 0.088, p = 0.012 | SW (135) = 0.956, p = <0.001 |
| Annual non-rice income (‘000 VND) | 107 | 1.714 (0.234) | 2.888 (0.463) | KS (107) = 0.215, p = <0.001 | SW (107) = 0.818, p = <0.001 |
| Cultivation area (ha) | 135 | 0.783 (0.209) | 1.596 (0.414) | KS (135) = 0.126, p = <0.001 | SW (135) = 0.934, p = <0.001 |
| Seed rate (kg/ha) | 135 | 3.595 (0.209) | 17.593 (0.414) | KS (135) = 0.284, p = <0.001 | SW (135) = 0.623, p = <0.001 |
| NPK fertilizer (kg/ha) | 134 | 0.991 (0.209) | 2.726 (0.416) | KS (134) = 0.075, p = 0.063 | SW (134) = 0.945, p = <0.001 |
| Rice yield (t/ha) | 135 | -1.592 (0.209) | 5.888 (0.414) | KS (135) = 0.135, p = <0.001 | SW (135) = 0.878, p = <0.001 |
| Δ Yield (t/ha) | n/a | n/a | n/a | n/a | n/a |
| Rice income (‘000 VND/ha) | 135 | -1.299 (0.209) | 4.592 (0.414) | KS (135) = 0.132, p = <0.001 | SW (135) = 0.904, p = <0.001 |
| Input cost (‘000 VND/ha) | 135 | 4.537 (0.209) | 28.730 (0.414) | KS (135) = 0.213, p = <0.001 | SW (135) = 0.586, p = <0.001 |
| Labor cost (‘000 VND/ha) | 59 | 0.099 (0.311) | -1.415 (0.613) | KS (59) = 0.144, p = 0.004 | SW (59) = 0.899, p = <0.001 |
| | **2019** | | | | |
| Variables | **n** | **Skewness (SE)** | **Kurtosis (SE)** | **K-S test** | **Shapiro-Wilk test** |
| Annual household income (‘000 VND) | 132 | 2.424 (0.211) | 12.387 (0.419) | KS (132) = 0.105, p = 0.001 | SW (135) = 0.956, p = <0.001 |
| Annual non-rice income (‘000 VND) | 65 | 2.440 (0.297) | 8.317 (0.586) | KS (65) = 0.204, p = <0.001 | SW (65) = 0.763, p = <0.001 |
| Cultivation area (ha) | 135 | 0.892 (0.209) | 0.525 (0.414) | KS (135) = 0.126, p = <0.001 | SW (135) = 0.901, p = <0.001 |
| Seed rate (kg/ha) | 132 | -0.005 (0.211) | 0.155 (0.419) | KS (132) = 0.136, p = <0.001 | SW (132) = 0.967, p = <0.001 |
| NPK fertilizer (kg/ha) | 112 | 0.018 (0.192) | 0.387 (0.381) | KS (112) = 0.084, p = 0.053 | SW (112) = 0.978, p = 0.067 |
| Rice yield (t/ha) | 129 | -0.571 (0.213) | 1.451 (0.423) | KS (129) = 0.060, p = 0.200 | SW (129) = 0.979, p = 0.044 |
| Δ Yield (t/ha) | 129 | 0.279 (0.213) | 2.397 (0.423) | KS (129) = 0.092, p = 0.010 | SW (129) = 0.958, p = 0.001 |
| Rice income (‘000 VND/ha) | 131 | -1.615 (0.212) | 3.999 (0.420) | KS (131) = 0.125, p = <0.001 | SW (131) = 0.882, p = <0.001 |
| Input cost (‘000 VND/ha) | 132 | 0.391 (0.211) | 1.213 (0.419) | KS (132) = 0.051, p = 0.200 | SW (132) = 0.975, p = 0.017 |
| Labor cost (‘000 VND/ha) | 132 | 0.601 (0.211) | 0.125 (0.419) | KS (132) = 0.086, p = 0.017 | SW (132) = 0.969, p = 0.005 |

Note: SE = Standard error, K-S test = Kolmogorov-Smirnov test with Lilliefors correction test

### 12.3.1 Sociodemographic Results and Farm Characteristics

In total, 135 farmers remained for the final data analysis. A detailed description of farmers' sociodemographic and farm characteristics by year and farmer group can be found in Table 12.2.

Table 12.2 Sociodemographic results and farm characteristics by year and farmer group

| | 2015 | | | | 2019 | | | |
|---|---|---|---|---|---|---|---|---|
| | Project | | Control | | Project | | Control | |
| Variables | n | Mean (SD) | n | Mean (SD) | n | Mean (SD) | n | Mean (SD) |
| Age (years) | 67 | 49.2 (9.0) | 68 | 48.4 (9.1) | 66 | 52.7 (9.4) | 69 | 51.2 (8.5) |
| Years farming | 67 | 25.0 (9.9) | 68 | 24.5 (9.0) | 66 | 27.8 (10.3) | 69 | 28.4 (8.3) |
| Education (years) | 67 | 9.6 (2.3) | 68 | 8.9 (2.3) | 66 | 9.5 (2.5) | 69 | 9.1 (2.2) |
| Household size (headcount) | 67 | 4.8 (1.7) | 68 | 4.4 (1.6) | 66 | 4.2 (1.4) | 69 | 4.2 (1.5) |
| Gender | n | % | n | % | n | % | n | % |
| Male | 59 | 88.1 | 64 | 94.1 | 59 | 89.4 | 62 | 89.9 |
| Female | 8 | 11.9 | 4 | 5.9 | 7 | 10.6 | 7 | 10.1 |
| Civil status | n | % | n | % | n | % | n | % |
| Married | 61 | 91.0 | 63 | 92.6 | 61 | 92.4 | 66 | 95.7 |
| Widowed | 2 | 3.0 | 2 | 2.9 | 2 | 3.0 | 3 | 4.3 |
| Single | 4 | 6.0 | 3 | 4.4 | 3 | 4.6 | 0 | 0.0 |
| 1M5R practice | 18 | 26.9 | 28 | 41.2 | 56 | 84.8 | 56 | 81.2 |
| Member of an organization | 34 | 50.7 | 0 | 0.0 | 11 | 15.9 | 14 | 21.2 |
| Crop establishment method | n | % | n | % | n | % | n | % |
| Transplanting | 5 | 7.5 | 5 | 7.4 | 1 | 1.6 | 0 | 0.0 |
| Direct seeding | 62 | 92.5 | 63 | 92.6 | 62 | 98.4 | 68 | 100.0 |
| Seed type | n | % | n | % | n | % | n | % |
| Registered | 0 | 0.0 | 1 | 1.5 | 1 | 1.6 | 2 | 2.9 |
| Certified | 63 | 98.4 | 63 | 92.6 | 59 | 93.7 | 65 | 94.2 |
| Own seeds | 1 | 1.6 | 2 | 2.9 | 2 | 3.2 | 2 | 2.9 |
| Farmer exchange | 0 | 0.0 | 2 | 2.9 | 1 | 1.6 | 0 | 0.0 |
| Seed source | n | % | n | % | n | % | n | % |
| Own harvest | 2 | 3.4 | 4 | 6.6 | 3 | 5.8 | 2 | 3.1 |
| Farmer exchange | 1 | 1.7 | 2 | 3.3 | 0 | 0.0 | 1 | 1.5 |
| Seed grower | 2 | 3.4 | 4 | 6.6 | 4 | 7.7 | 5 | 7.7 |
| Input dealer | 5 | 8.6 | 5 | 8.2 | 36 | 69.2 | 41 | 63.1 |
| Government | 12 | 20.7 | 8 | 13.1 | 2 | 3.8 | 2 | 3.1 |
| Private company | 36 | 62.1 | 38 | 62.3 | 7 | 13.5 | 14 | 21.5 |

Note: SD = Standard deviation

Most of the surveyed farmers were male (89.6 %, n = 121) in both years. The mean age of the respondents was 48.8 (SD = 9.0) and 52.2 (SD = 8.9) in 2015 and 2019, respectively. The female respondents (10.4 %, n = 14) were, on average, 2.3 years younger than the male respondents. In general, farmers' households had 4.6 (SD = 1.7) members in 2015 and 4.2 (SD = 1.5) in 2019. The majority of the respondents was married. The average duration of the respondents' school education was 9.2 (SD = 2.3) years. The male respondents (9.4 years, SD = 2.3) received 1.7 years of additional school education compared to the female respondents (7.7 years, SD = 1.9). More than half (53.7 %, n = 73) of the participants attained lower secondary school up to grade nine, and over one-third reached upper secondary school up to grade twelve (34.9 %, n = 47). Hence, most farmers (88.7 %, n = 120) received the compulsory nine years of school education (UNESCO Bangkok 2007: 1; General Statistics Office of Vietnam 2019: 751).

Farmer groups were distributed equally with 67 (49.6 %) project farmers and 68 (50.4 %) control farmers in 2015 as well as 66 (48.9 %) and 69 (51.1 %), respectively, in 2019. Only one farmer changed the farmer group from being a project farmer to a control farmer. Possibly this farmer did not participate in specific CORIGAP activities. No significant differences for age, farming years, education level, household headcount, gender, and civil status were found between the groups in 2015 and 2019. In 2015, 18 (26.9 %) project farmers indicated applying 1M5R best management practices compared to 28 (41.2%) control farmers. This difference was eliminated in 2019 when 56 farmers in each group, 84.8 % and 81.2 %, respectively, indicated practicing 1M5R. The increase was significant for both groups. The effect size for the project farmers was strong and moderate for the control farmers (project: $\chi^2(1) = 19.514$, $p = <0.001$, $r = 0.513$; control: $\chi^2(1) = 9.333$, $p = 0.002$, $r = 0.333$).

Regarding the number of farmers being a member of an organization in 2015, no control farmers were part of an organization compared to 34 (50.7 %) project farmers. By 2019, 14 (20.2 %) of the control farmers became a member of a farmer organization. The number of members in the project farmer group decreased to 11 (15.9 %). The effect size for the control farmers was strong and the effect for the project farmers was small (project: $\chi^2(1) = 10.293$, $p = 0.001$, $r = 0.278$; control: $\chi^2(1) = 96.533$, $p = <0.001$, $r = 0.839$). No significant differences in both groups in 2015 and 2019 were detected concerning the crop establishment method. The majority of the farmers used direct seeding (e.g., broadcasting or drum seeder) as their preferred method. Farmers' most used seed type was certified seeds in both years and for both farmer groups. Lastly, farmers' preferred seed source changed from private company in 2015 to input dealer in 2019. This change was significant with high effect sizes for both groups (project: $\chi^2(1) = 23.439$, $p = <0.001$, $r = 0.756$; control: $\chi^2(1) = 28.174$, $p = <0.001$, $r = 0.783$).

## 12.3.2 Introduction and Adoption of 1M5R Technologies

In both farmer groups, all farmers received an introduction to one or more 1M5R recommended technologies and adopted at least one in 2019 (Table 12.3). All farmers found the technologies useful and wanted to continue the use except for one control farmer, who does not wish to continue with the adoption of a combine harvester. In general, farmers indicated that the benefits of adopting 1M5R technologies were less labor (95.6 %, n = 129), lower input cost (79.3 %, n = 107), better yield (65.9 %, n = 89), and better crop stand (57.8 %, n = 78). The adoption rate was particularly high for combine harvester, drum seeder, AWD, and improved varieties. Most farmers who were introduced to them decided to adopt the technologies. In addition, these were the technologies that most farmers received an introduction to. The adoption rate for the IRRI super bag and solar bubble dryer was 100 % due to the fact that the one farmer who had been introduced to the technology also adopted it. However, the introduction of half of the farmers to laser land leveling and a mechanical transplanter did not translate into broad adoption. Only 19.1 % and 9.0 %, respectively, decided to adopt the technologies. Thus, just one out of five farmers decided to adopt laser land leveling after the introduction, and one out of eleven to adopt a mechanical transplanter.

Overall, no significant differences were found in the number of farmers introduced to the 1M5R technologies between the farmer groups. Regarding technology adoption, significantly more project farmers adopted ecologically-based rodent management ($\chi^2(1) = 8.000$, $p = 0.005$, $r = 0.\ 0.666$) and laser land leveling ($\chi^2(1) = 6.231$, $p = 0.013$, $r = 0.692$) compared to the control farmers. Lastly, farmers in both groups indicated that their most-used sources of information on farming and best management practices were other farmers (83.0 %, n = 112), family (77.0 %, n = 104), television (59.3 %, n = 80), government agencies (51.9 %, n = 70), newspaper (43.7 %, n = 59), input supplier (20.0 %, n = 27), radio (20.0 %, n = 27), trainings (20.0 %, n = 27), books (13.3 %, n = 18), social media (10.4 %, n = 14), and magazine/journal (5.9 %, n = 8).

Table 12.3 1M5R technology introduction and adoption rate

| | Introduction | | | Adoption | | |
|---|---|---|---|---|---|---|
| 1M5R technology | Introduction rate % (n) [1] | Project farmers % (n) [2] | Control farmers % (n) [3] | Adoption rate % (n) | Project farmers % (n) | Control farmers % (n) |
| AWD | 94.1 (127) | 91.3 (63) | 97.0 (64) | 85.8 (109) | 93.7 (59) | 78.1 (50) |
| Combine harvester | 99.3 (134) | 98.5 (65) | 100.0 (69) | 100.0 (134) | 100.0 (65) | 100.0 (69) |
| Drum seeder | 97.0 (131) | 98.5 (65) | 95.7 (66) | 85.5 (112) | 95.4 (62) | 75.8 (50) |
| Ecologically-based rodent management | 35.6 (48) | 37.9 (25) | 33.3 (23) | 37.5 (18) | 60.0 (15) | 13.0 (3) |
| Flatbed dryer | 3.0 (4) | 6.1 (4) | 0 (0.0) | 0.0 (0) | 0.0 (0) | 0.0 (0) |
| Improved varieties | 77.8 (105) | 81.8 (54) | 73.9 (51) | 90.5 (95) | 88.8 (48) | 92.2 (47) |
| IRRI super bag | 0.7 (1) | 1.5 (1) | 0 (0.0) | 100.0 (1) | 100.0 (1) | 0.0 (0) |
| Laser land leveler | 50.4 (68) | 57.6 (38) | 43.5 (30) | 19.1 (13) | 28.9 (11) | 6.7 (2) |
| Mechanical transplanter | 49.6 (67) | 59.1 (39) | 40.6 (28) | 9.0 (6) | 12.8 (5) | 3.6 (1) |
| Solar bubble dryer | 0.7 (1) | 1.5 (1) | 0.0 (0) | 100.0 (1) | 100.0 (1) | 0.0 (0) |

Note: [1] N = 135, [2] n = 66, [3] n = 69

### 12.3.3 Socioeconomic and Agronomic Results

Significant differences in annual household income, seed rate, NPK fertilizer application quantity, and rice yield were found between the two survey years over all farmers (Table 12.4). Farmers' annual household income significantly decreased in 2019, but the effect size was small. In this context, the number of farmers indicating having a non-rice income declined substantially by one-third from 107 in 2015 to 65 farmers in 2019 ($\chi^2(1) = 10.256$, $p = 0.001$, $r = 0.244$). Nonetheless, the decrease in non-rice income was not statistically significant. Farmers' non-rice income sources included working in the private (14.6 %, n = 13) and public (13.4 %, n = 12) sector as a salary earner as well as being a casual wage earner (9.4 %, n = 7), selling farm products (10.6 %, n = 8), and external farm labor (9.4 %, n = 7). Regarding the input variables, the seed rate and NPK fertilizer application quantities were considerably reduced in 2019, but the effect sizes were small. Lastly, farmers' average rice yield increased significantly from the first to the second survey and reached 6.6 t/ha (SD = 0.9) in 2019.

Table 12.4 Socioeconomic and agronomic results by year

| | 2015 | | | 2019 | | | Comparison | | |
|---|---|---|---|---|---|---|---|---|---|
| Variables | n | Mean (SD) | Range (Min-Max) | n | Mean (SD) | Range (Min-Max) | U | p | r |
| Annual household income ('000 VND) | 135 | 172'852.1 (78'684.7) | 37'494.5 – 361'098.8 | 132 | 149'140.0 (83'949.6) | 10'087.2 – 687'906.4 | 7193.0 | 0.006 | -0.166 |
| Annual non-rice income ('000 VND) | 107 | 46'557.8 (41'633.3) | 1000.0 - 200'000.0 | 65 | 36'236.1 (33'575.3) | 2000.0 – 200'000.0 | 2944.0 | 0.091 | -0.128 |
| Cultivation area (ha) | 135 | 2.0 (0.9) | 0.5 – 6.0 | 135 | 2.1 (0.9) | 0.8 – 5.0 | 8528.0 | 0.360 | 0.055 |
| Seed rate (kg/ha) | 134 | 180.2 (78.7) | 90.0 – 500.0 | 132 | 171.2 (28.1) | 100.0 – 231.3 | 7461.0 | 0.027 | -0.135 |
| NPK fertilizer (kg/ha) | 134 | 433.1 (96.4) | 183.3 – 833.3 | 112 | 379.0 (110.3) | 127.6 – 725.0 | 5415.0 | <0.001 | -0.239 |
| Rice yield (t/ha) | 135 | 6.3 (1.2) | 0.7 – 8.9 | 129 | 6.6 (0.9) | 2.7 – 9.0 | 7204.0 | 0.015 | 0.149 |
| Δ Yield (t/ha) | n/a | n/a | n/a | 129 | 0.3 (1.5) | -5.4 – 5.3 | n/a | n/a | n/a |
| Rice income ('000 VND/ha) | 135 | 31'544.6 (6427.5) | 3432.6 – 45'229.4 | 131 | 31'868.7 (6853.9) | 1681.2 – 44'021.3 | 8053.0 | 0.208 | 0.077 |
| Input cost ('000 VND/ha) | 135 | 13'004.0 (8484.1) | 5752.5 – 78'772.3 | 132 | 10'850.4 (3803.5) | 2627.5 – 25'630.2 | 8168.0 | 0.240 | -0.071 |
| Labor cost ('000 VND/ha) | 59 | 2770.8 (2195.8) | 16.0 – 7330.8 | 132 | 3352.6 (1644.1) | 355.8 – 8674.5 | 3314.0 | 0.100 | 0.118 |

Note: SD = Standard deviation; U = Mann Whitney U test

Significant differences between project and control farmers were observed for the selected socioeconomic and agronomic variables in both survey years (Table 12.5). In 2015, project farmers demonstrated a considerably lower seed rate, NPK fertilizer application quantity, input and labor costs than control farmers. The effect sizes were small except for NPK fertilizer, which displayed a strong effect. Project farmers used 18 % less NPK fertilizer compared to control farmers. In 2019, project farmers continued to apply significantly fewer inputs than control farmers. They used considerably less NPK fertilizer and had lower input costs, but the effect sizes were small. However, project farmers' rice yield and rice income were also significantly lower than control farmers' with a small and moderate effect size, respectively. Project farmers reached a mean annual yield of 6.3 t/ha (SD = 1.0) compared to 6.9 t/ha (SD = 0.9) in the control farmers group.

Seasonal differences were present in both survey years (Table 12.6). In 2015, rice yield, rice income, and input costs were significantly lower in the summer-autumn season than in the winter-spring. The effect for yield and income was strong. In 2019, rice yield and income were significantly higher in the winter-spring season with strong effect sizes. The seed rate was considerably higher in the summer-autumn season. The lowest seed rate and NPK fertilizer application quantity were achieved in the winter-spring season of 2018/2019. The mean quantities were 167.8 kg/ha (SD = 30.2) and 378.8 kg/ha (SD = 104.2), respectively. In both survey years, farmers were able to achieve a rice yield of more than 7 t/ha in the winter-spring season. Their mean cultivation area remained consistent at 2 ha in both seasons and survey years. In general, farmers were able to decrease their seed rate, NPK fertilizer quantities, and input cost in both seasons from 2015 to 2019. The differences in each season from 2015 to 2019 were significant for all selected variables except for cultivation area and input cost. For the winter-spring season, effect sizes were small for all variables but labor cost, which demonstrated a moderate effect. The summer-autumn season showed a moderate effect size for rice yield, rice income, and labor cost as well as a small effect for seed rate and NPK fertilizer.

Table 12.5 Socioeconomic and agronomic results by farmer group per year

| | 2015 | | | | | | |
|---|---|---|---|---|---|---|---|
| | Project | | Control | | Comparison | | |
| Variables | n | Mean (SD) | n | Mean (SD) | U | p | r |
| Annual household income ('000 VND) | 67 | 179'535.3 (83'613.6) | 68 | 166'487.7 (73'551.4) | 2092.0 | 0.413 | -0.070 |
| Annual non-rice income ('000 VND) | 55 | 50'056.2 (47'192.8) | 52 | 42'857.7 (34'889.5) | 1322.0 | 0.500 | -0.065 |
| Cultivation area (ha) | 67 | 2.0 (1.0) | 68 | 1.9 (0.8) | 2070.5 | 0.359 | -0.078 |
| Seed rate (kg/ha) | 67 | 174.4 (85.8) | 67 | 186.0 (71.2) | 1562.5 | 0.002 | 0.262 |
| NPK fertilizer (kg/ha) | 67 | 390.2 (72.5) | 67 | 476.1 (98.5) | 1040.5 | <0.001 | 0.463 |
| Rice yield (t/ha) | 67 | 6.2 (1.1) | 68 | 6.3 (1.3) | 1871.0 | 0.073 | 0.154 |
| Δ Yield (t/ha) | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| Rice income ('000 VND/ha) | 67 | 31'342.3 (5835.2) | 68 | 31'743.9 (7000.1) | 2053.0 | 0.322 | 0.085 |
| Input cost ('000 VND/ha) | 67 | 11'311.9 (5489.0) | 68 | 14'671.2 (10'418.3) | 1699.0 | 0.007 | 0.286 |
| Labor cost ('000 VND/ha) | 38 | 2331.5 (2169.9) | 21 | 3565.7 (2059.5) | 260.0 | 0.028 | 0.230 |
| | 2019 | | | | | | |
| | Project | | Control | | Comparison | | |
| Variables | n | Mean (SD) | n | Mean (SD) | U | p | r |
| Annual household income ('000 VND) | 63 | 150'478.5 (94'860.4) | 69 | 147'918.0 (73'274.7) | 2142.5 | 0.888 | -0.012 |
| Annual non-rice income ('000 VND) | 35 | 39'302.8 (39'970.2) | 30 | 32'658.3 (24'293.5) | 521.5 | 0.963 | -0.006 |
| Cultivation area (ha) | 66 | 2.2 (0.9) | 69 | 2.0 (0.9) | 1918.0 | 0.111 | -0.137 |
| Seed rate (kg/ha) | 63 | 166.5 (30.8) | 69 | 175.5 (25.0) | 1827.0 | 0.111 | 0.138 |
| NPK fertilizer (kg/ha) | 46 | 345.9 (107.9) | 66 | 402.2 (106.8) | 1071.0 | 0.008 | 0.249 |
| Rice yield (t/ha) | 62 | 6.3 (1.0) | 67 | 6.9 (0.9) | 1415.0 | 0.002 | 0.274 |
| Δ Yield (t/ha) | 62 | 0.1 (1.5) | 67 | 0.5 (1.5) | 1772.0 | 0.151 | 0.126 |
| Rice income ('000 VND/ha) | 63 | 29'786.6 (7526.7) | 68 | 33'797.6 (5556.2) | 1347.5 | <0.001 | 0.319 |
| Input cost ('000 VND/ha) | 63 | 10'056.8 (4376.1) | 69 | 11'574.9 (3048.4) | 1547.0 | 0.004 | 0.248 |
| Labor cost ('000 VND/ha) | 63 | 3205.4 (1623.7) | 69 | 3487.0 (1662.8) | 2032.5 | 0.521 | 0.056 |

Note: SD = Standard deviation; U = Mann Whitney U test

Table 12.6 Agronomic results by season per year and by year per season

| | Winter-Spring season | | | | | | | 2015 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2015 | | 2019 | | Comparison | | | Winter-Spring season | | Summer-Autumn season | | Comparison | | |
| Variables | n | Mean (SD) | n | Mean (SD) | U | p | r | n | Mean (SD) | n | Mean (SD) | U | p | r |
| Cultivation area (ha) | 135 | 1.9 (0.9) | 132 | 2.2 (1.3) | 8368.5 | 0.388 | 0.052 | 135 | 1.9 (0.9) | 133 | 2.0 (0.9) | 8920.5 | 0.928 | 0.005 |
| Seed rate (kg/ha) | 132 | 175.9 (81.6) | 132 | 167.8 (30.2) | 7198.5 | 0.014 | -0.150 | 132 | 175.9 (81.6) | 133 | 184.6 (85.7) | 7888.5 | 0.152 | 0.088 |
| NPK fertilizer (kg/ha) | 135 | 442.2 (128.1) | 111 | 378.8 (104.2) | 5422.5 | <0.001 | -0.237 | 135 | 442.2 (128.1) | 135 | 434.6 (125.7) | 8700.5 | 0.521 | -0.039 |
| Rice yield (t/ha) | 135 | 7.7 (1.4) | 129 | 7.3 (1.1) | 6103.0 | <0.001 | -0.258 | 135 | 7.7 (1.4) | 135 | 4.8 (1.5) | 1069.0 | <0.001 | -0.763 |
| Rice income ('000 VND/ha) | 135 | 39'069.9 (7659.2) | 130 | 35'395.1 (7661.3) | 5808.0 | <0.001 | -0.292 | 135 | 39'069.9 (7659.2) | 135 | 24'500.0 (8178.4) | 1212.0 | <0.001 | -0.749 |
| Input cost ('000 VND/ha) | 135 | 13'491.2 (8953.8) | 132 | 11'205.8 (4283.8) | 8092.0 | 0.195 | -0.079 | 135 | 13'491.2 (8953.8) | 133 | 12'400.5 (8870.1) | 7604.5 | 0.030 | -0.132 |
| Labor cost ('000 VND/ha) | 58 | 1674.6 (1342.3) | 131 | 3414.0 (1751.2) | 1659.5 | <0.001 | 0.448 | 58 | 1674.6 (1342.3) | 48 | 1428.8 (1008.5) | 1226.0 | 0.292 | -0.102 |
| | Summer-Autumn season | | | | | | | 2019 | | | | | | |
| | 2015 | | 2019 | | Comparison | | | Winter-Spring season | | Summer-Autumn season | | Comparison | | |
| Variables | n | Mean (SD) | n | Mean (SD) | U | p | r | n | Mean (SD) | n | Mean (SD) | U | p | r |
| Cultivation area (ha) | 133 | 2.0 (0.9) | 128 | 2.1 (0.9) | 8145.0 | 0.545 | 0.037 | 132 | 2.2 (1.3) | 128 | 2.1 (0.9) | 8347.5 | 0.867 | -0.010 |
| Seed rate (kg/ha) | 133 | 184.6 (85.7) | 127 | 174.6 (29.4) | 7090.0 | 0.025 | -0.139 | 132 | 167.8 (30.2) | 127 | 174.6 (29.4) | 7120.5 | 0.032 | 0.133 |
| NPK fertilizer (kg/ha) | 135 | 434.6 (125.7) | 109 | 401.8 (232.6) | 5902.0 | 0.008 | -0.170 | 111 | 378.8 (104.2) | 109 | 401.8 (232.6) | 5959.5 | 0.847 | 0.013 |
| Rice yield (t/ha) | 135 | 4.8 (1.5) | 122 | 5.8 (1.1) | 4401.0 | <0.001 | 0.401 | 129 | 7.3 (1.1) | 122 | 5.8 (1.1) | 2365.0 | <0.001 | -0.604 |
| Rice income ('000 VND/ha) | 135 | 24'500.0 (8178.4) | 126 | 28'609.9 (6871.6) | 5035.0 | <0.001 | -0.352 | 130 | 35'395.1 (7661.3) | 126 | 28'609.9 (6871.6) | 3062.5 | <0.001 | -0.541 |
| Input cost ('000 VND/ha) | 133 | 12'400.5 (8870.1) | 128 | 10'600.4 (4356.3) | 8253.0 | 0.671 | -0.026 | 132 | 11'205.8 (4283.8) | 128 | 10'600.4 (4356.3) | 7634.0 | 0.179 | -0.083 |
| Labor cost ('000 VND/ha) | 48 | 1428.8 (1008.5) | 128 | 3334.5 (1774.4) | 1120.5 | <0.001 | -0.488 | 131 | 3414.0 (1751.2) | 128 | 3334.5 (1774.4) | 8054.5 | 0.585 | -0.033 |

Note: SD = Standard deviation; U = Mann Whitney U test

### 12.3.4 Mediation Analysis for Rice Yield and Profitability

Hierarchical linear regression analysis with mediated structural equation modeling was conducted to investigate if the farmer group acted as a mediating variable on the rice yield and profitability from 2015 to 2019. The aim was to analyze the effect of the CORIGAP interventions on the project farmers. This group received specific trainings and information on how to improve their rice farming to make it more sustainable and profitable. Rice yield and profitability were therefore selected as dependent variables for the hierarchical linear regression analysis. First, sociodemographic, socioeconomic, and farm characteristics were used as control variables. These were selected on the basis of general attributes relevant to characterize a farmer. The chosen sociodemographic control variables were age, education, and household size. The selected socioeconomic control variable was non-rice income (0 = no, 1 = yes). Finally, the control variables for farm characteristics were cultivation area, 1M5R practice (0 = no, 1 = yes), and member of a farmer organization (0 = no, 1 = yes). Second, farm inputs related to 1M5R recommendations were added as independent variables. These included seed rate, NPK fertilizer use, pesticide cost, irrigation cost, power cost, and labor cost. Power cost included energy expenditures for seedbed and land preparation, crop establishment, irrigation as well as harvest and postharvest activities. For the final step, the farmer group (0 = control, 1 = project) was introduced as a mediating independent variable to test the model (Table 12.7).

Table 12.7 Mediated multiple hierarchical regression analysis for the dependent variable rice yield (t/ha) of rice farmers

| Variables | Model 1 | Model 2 | Model 3 |
|---|---|---|---|
| **Control variables** | Standardized beta values | | |
| Age (years) | -0.242 ** | -0.227 * | -0.190 * |
| Education (years) | 0.027 | 0.027 | -0.079 |
| Household size (headcount) | -0.173 * | -0.149 | -0.140 |
| Non-rice income | -0.231 * | -0.250 ** | -0.221 * |
| Cultivation area (ha) | 0.007 | 0.072 | 0.068 |
| 1M5R practice | 0.027 | -0.030 | -0.069 |
| Farmer organization member | -0.027 | -0.033 | -0.013 |
| **Independent variables** | | | |
| Seed rate (kg/ha) | | -0.199 * | -0.209 * |
| NPK fertilizer (kg/ha) | | 0.190 * | 0.139 |
| Pesticide cost ('000 VND/ha) | | 0.035 | 0.005 |
| Irrigation cost ('000 VND/ha) | | -0.003 | 0.032 |
| Power cost ('000 VND/ha) | | 0.150 | 0.123 |
| Labor cost ('000 VND/ha) | | 0.122 | 0.125 |
| **Mediation variable** | | | |
| Farmer group | | | -0.279 ** |
| **Coefficient of determination** | | | |
| $R^2$ | 0.146 ** | 0.225 ** | 0.288 *** |
| $\Delta R^2$ | | 0.079 | 0.062 ** |

Notes: N = 123; * p = ≤0.05, ** p = <0.01, *** p = <0.001; Model 1: F(7,115) = 2.819, p = 0.010, Model 2: F(13,109) = 2.441, p = 0.006, Model 3: F(14,108) = 3.116, p = <0.001

The results of the first linear regression showed that age and non-rice income were significant predictors of yield. The first model explained 14.6 % of the variance. In the second linear regression analysis, the same variables remained significant control predictors of yield. The newly added independent variables seed rate and NPK fertilizer showed a significant influence on rice yield. $R^2$ increased by 7.9 % and the model explained 22.5 % of the variance. The addition of the mediating variable farmer group in the third model increased $R^2$ significantly by 6.2 %, and hence the final model explained 28.8 % of the variance. The farmer group became a very considerable predictor of yield in addition to seed rate, non-rice income, and age. Therefore, the final model explained an increased proportion of the variance of the dependent variable through the farmer group. In general, the standardized residuals were normally distributed, and all models were statistically significant. In the subsequent single mediation SEM model, the relationship between 1M5R recommendations, namely seed rate, NPK fertilizer, pesticide cost, irrigation cost, power cost, and labor cost, and rice yield was mediated through the single mediator variable farmer group (Figure 12.1). The significance of the model and the standardized direct as well as standardized indirect effects were tested using bootstrapping procedures. The bootstrapping was performed for 2000 bootstrapped samples and a 90% bias-corrected confidence interval was selected. The results showed that the standardized direct effect from the independent variable irrigation cost to the farmer group was statistically significant (β = 0.168, p = 0.048). Furthermore, the standardized direct effect from the farmer group to rice yield was also statistically significant (β = -0.313, p = 0.001). The model for irrigation cost resulted in full mediation through the farmer group. Hence, the entire amount of variance that irrigation cost described in rice yield is explained through the farmer group.

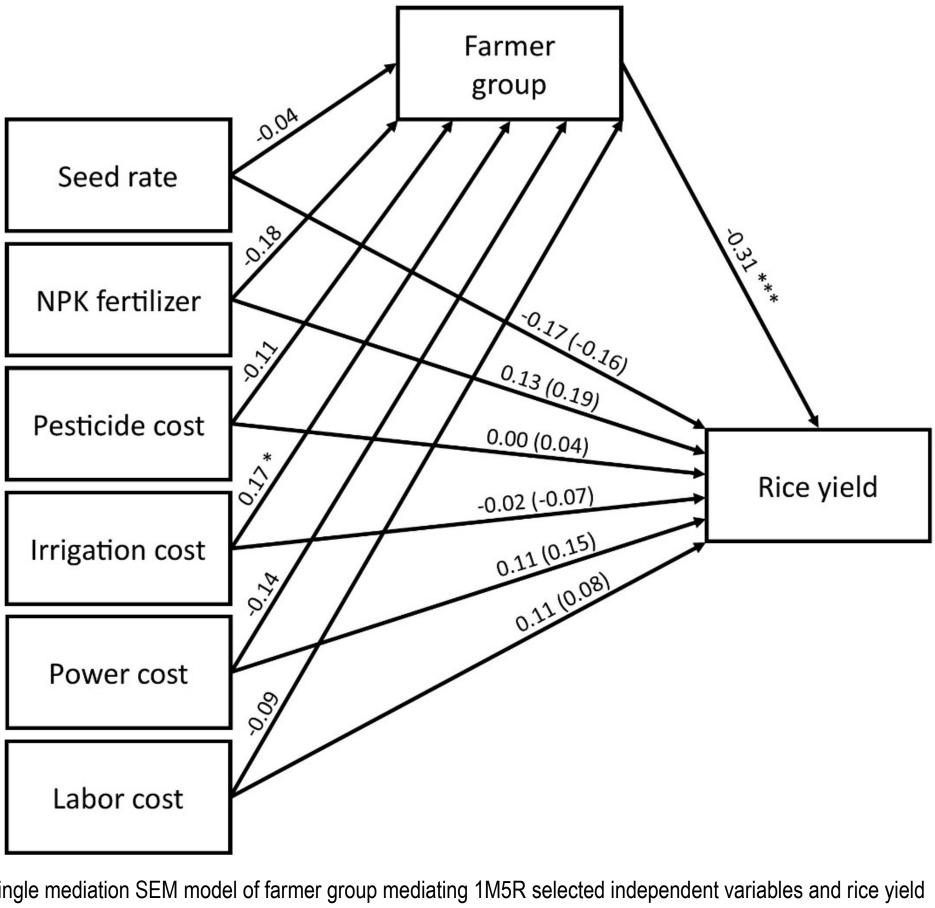



Figure 12.1 Single mediation SEM model of farmer group mediating 1M5R selected independent variables and rice yield
Note: Including standardized direct effects and corresponding p values (* p = ≤0.05, ** p = <0.01, *** p = <0.001)

The first linear regression analysis for profitability resulted in non-rice income being the only significant predictor (Table 12.8). The model explained 4.0 % of the variance and was not statistically significant. In the second model, age, non-rice income, seed rate, NPK fertilizer, as well as pesticide and irrigation cost became significant predictors of profitability. $R^2$ increased significantly to 37.5 %. In the third model, non-rice income, seed rate, NPK fertilizer, pesticide, and irrigation cost remained important variables after the addition of the mediating variable farmer group. The farmer group was statistically significant for predicting profitability. The variance of the final model grew significantly and reached a total variance of 41.3 %. Hence, the farmer group became a very considerable predictor of farmers' profitability in addition to non-rice income, seed rate, NPK fertilizer, pesticide and irrigation cost. Overall, the standardized residuals were normally distributed.

Table 12.8 Mediated multiple hierarchical regression analysis for the dependent variable profitability (%) of rice farmers

| Variables | **Model 1** | **Model 2** | **Model 3** |
|---|---|---|---|
| **Control variables** | Standardized beta values | | |
| Age (years) | -0.166 | -0.151 * | -0.126 |
| Education (years) | -0.041 | -0.067 | -0.021 |
| Household size (headcount) | -0.052 | -0.060 | -0.056 |
| Non-rice income | -0.198 * | -0.200 * | -0.173 * |
| Cultivation area (ha) | 0.144 | 0.139 | 0.132 |
| 1M5R practice | 0.087 | -0.016 | -0.044 |
| Farmer organization member | 0.016 | -0.014 | 0.013 |
| **Independent variables** | | | |
| Seed rate (kg/ha) | | -0.173 * | -0.177 * |
| NPK fertilizer (kg/ha) | | -0.168 * | -0.206 ** |
| Pesticide cost ('000 VND/ha) | | -0.444 *** | -0.472 *** |
| Irrigation cost ('000 VND/ha) | | -0.207 ** | -0.179 * |
| Power cost ('000 VND/ha) | | -0.146 | -0.162 |
| Labor cost ('000 VND/ha) | | 0.158 | 0.167 |
| **Mediation variable** | | | |
| Farmer group | | | -0.224 ** |
| **Coefficient of determination** | | | |
| $R^2$ | 0.040 * | 0.375 * | 0.413 *** |
| $\Delta R^2$ | | 0.335 *** | 0.038 ** |

Notes: N = 121; * p = ≤0.05, ** p = <0.01, *** p = <0.001; Model 1: F(7,113) = 1.719, p = 0.111, Model 2: F(13,107) = 6.530, p = <0.001, Model 3: F(14,106) = 7.039, p = <0.001

The corresponding single mediation SEM model was performed exactly like the previous model except for switching the dependent variable to profitability (Figure 12.2). The results showed that the standardized direct effects from the independent variables NPK fertilizer (β = -0.326, p = 0.02), power cost (β = -0.191, p = 0.006), and labor cost (β = -0.289, p = 0.001) to farmer group were statistically significant. All standardized direct effects from the independent variables, except power cost (β = -0.065, p = 0.211), to profitability were significant (seed rate: β = -0.203, p = 0.001; NPK fertilizer: β = -0.154, p = 0.006; pesticide cost: β = -0.397, p = 0.001; irrigation cost: β = -0.119, p = 0.003; labor cost: β = 0.212, p = 0.003). Nevertheless, the standardized direct effect from farmer group to profitability was not statistically significant (β = 0.017, p = 0.754). Hence, the model did not result in mediation through the farmer group because all indirect effects through the mediator were not significant (seed rate: β = -0.001, p = 0.617; NPK fertilizer: β = -0.006, p = 0.748; pesticide cost: β = 0.001, p = 0.477; irrigation cost: β = -0.006, p = 0.644; power cost: β = -0.003, p = 0.665; labor cost: β = -0.005, p = 0.703).

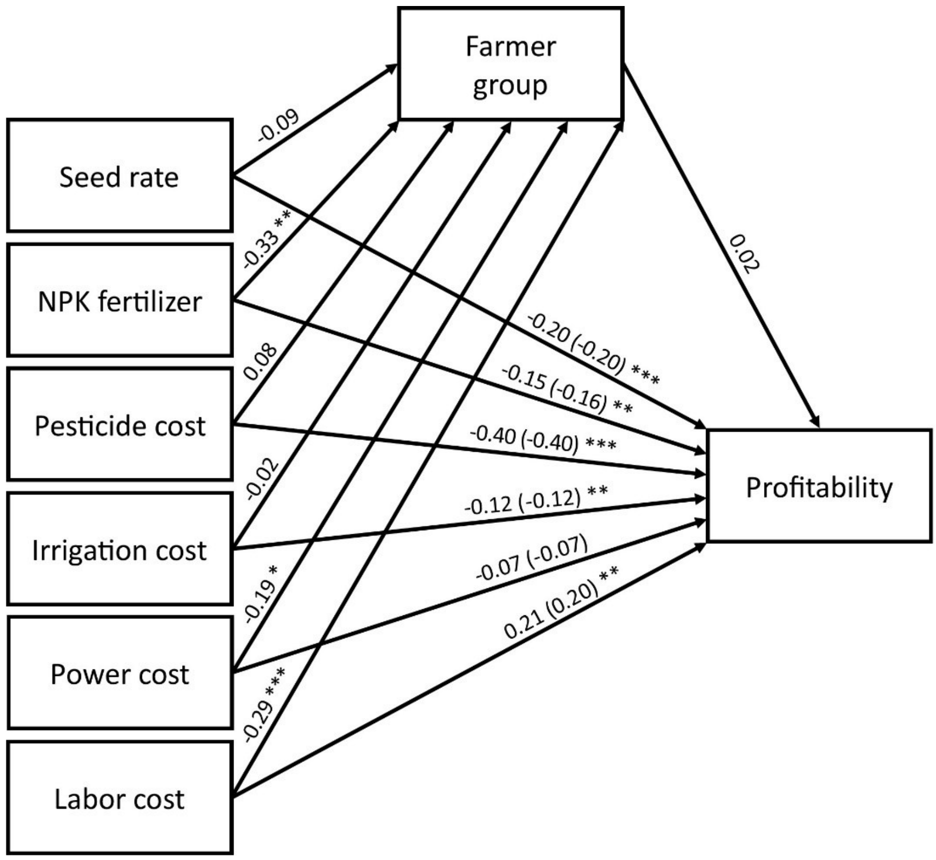



Figure 12.2 Single mediation SEM model of farmer group mediating 1M5R selected independent variables and profitability
Note: Including standardized direct effects and corresponding p values (* p = ≤0.05, ** p = <0.01, *** p = <0.001)

## 12.4 Discussion

The present study examined farmers' 1M5R technology introduction and adoption rate under the CORIGAP project and analyzed the related agronomic and socioeconomic changes. The differences between the project and control farmers were investigated and the influence of the farmer group on rice yield and rice income was tested using mediation analysis. The number of farmers per group was distributed equally and remained mostly the same during the project period. No significant sociodemographic differences were found between the groups in 2015 and 2019. These results demonstrate that the sampling of the farmers was performed well in order to interpret agronomic differences based on farmer group. Before the CORIGAP interventions, fewer farmers in the project group (<30 %) indicated applying 1M5R best management practices compared to the control group (<50 %). Nevertheless, by 2019 more than 80 % of farmers in both groups followed 1M5R guidelines. Thus, it appears that the 1M5R extension activities in Can Tho Province between 2015 and 2019 were successful no matter the farmer group. This could be explained by the fact that other agricultural development projects such as the World Bank 'Vietnam - Sustainable Agriculture Transformation' (VnSAT) project and initiatives such as 'Small Farm, Large Field' and 'VietGap' (Vietnam – Good Agricultural Practice) have also incentivized farmers to apply the 1M5R recommended practices (Willett, Barroga 2016: 26; Stuart et al. 2018: 103–104). Furthermore, spillover effects may have occurred due to the rather close distance of the townships. Hence, possible communication between members of the two farmer groups was established present. Such effects have been shown, particularly in the case of proximity, in multiple technology diffusion studies in the agricultural smallholder context (Nakano et al. 2018; Aramburu et al. 2019; Varshney, Joshi, Dubey 2019; Gao et al. 2020). This finding is positive. It shows that diverse outreach and extension schemes can support the diffusion of sustainable farming practices to benefit a large number of farmers while appealing to farmers' diverse extension needs.

Farm characteristics between the two farmer groups were similar. The majority of the farmers used direct seeding as their preferred method and their most used seed type was certified seeds. This result demonstrates that farmers followed the ‘One Must Do’. This is in line with the results found in Connor et al. (2020c: 7) and Chapter 13.3.2. Accordingly, most farmers indicated having been introduced to and having subsequently adopted a drum seeder and improved rice varieties. However, significant differences between the two farmer groups were found for the seed rate. Project farmers used considerably lower amounts of seeds than control farmers. This finding was present in both survey years. Nonetheless, the seed rate difference between the two groups was comparable with project farmers reducing their seeds on average by 8.2 kg/ha and control farmers by 9.6 kg/ha between the two survey years. Hence, both farmer groups were following the 1M5R recommendation. Still, assuming that most farmers were using a drum seeder, the mean seed rate of >170 kg/ha remains exceedingly high. It is not close to the recommended 80 kg/ha of seeds for drum seeder application. This problem has already been found in other 1M5R studies, e.g., Stuart et al. (2018a) and Connor et al. (2020c) as well as in Chapter 13.3. Different barriers play a role in seed rate reduction. For example, Connor et al. found that it was difficult for farmers to use fewer seeds because the weather conditions impeded their use, it did not fit their cropping pattern, and farmers said that they would encounter yield losses (2020a: 8). This result was also found in Tuan, Wehmeyer, and Connor, where farmers were using high seed rates as a strategy to overcome production risks, particularly when there is a pest outbreak or uncertain climate variations (2021). Further examination of the difficulties related to seed rate reduction is needed since farmers are using recommended technologies but are not able to decrease their seed quantities effectively.

Regarding NPK fertilizer use reduction, farmers demonstrated a significant decrease from 2015 to 2019. Project farmers used considerably lower NPK fertilizer quantities than control farmers. This finding was present in both survey years. Although both groups successfully implemented the 1M5R recommendation, control farmers (>-70 kg/ha) were able to decrease their average NPK fertilizer use more strongly than project farmers (>-40 kg/ha). But this difference was not statistically significant ($p = 0.430$). In general, NPK fertilizer application remains very high, with a mean application rate of 380 kg/ha in the selected townships. It is considerably higher than the national average of 300 kg/ha. It is almost threefold the global average of approximately 130 kg/ha (Toan, Minh, Thong 2019: 4; World Bank 2019a). Rice farming accounts for 65 % of the total fertilizer use in Vietnam. Of the 11 Mt of total fertilizer applied, 90 % is inorganic fertilizers (Nguyen 2017: 18–19; Toan, Minh, Thong 2019: 3). In addition, improper use of fertilizer in rice production is common. Farmers generally overuse nitrogen fertilizer in the form of urea, while phosphorus and potassium are often ignored (Nguyen 2017: 19). Besides, they have generally continued applying the same fertilization regimes used for traditional rice varieties. They have not updated fertilizer rates to the improved HYVs, which have largely replaced traditional varieties. This issue has also been found in other countries, e.g., China (Jia et al. 2013: 365; Guo et al. 2015: 100; Nguyen 2017: 19). As a result, the nutritional demands of plants and soil are not matched. Farmers try counteracting this issue with additional fertilizer use against the recommended dosage (Nguyen 2017: 19). This causes low fertilizer use efficiency of around 60 % for nitrogen, 40 % for phosphorus, and 50 % for potassium. Consequently, the NPK is absorbed into the soil and water, resulting in environmental pollution (Savci 2012: 287; Nguyen 2017: 19). Furthermore, from an economic perspective, farmers are wasting their money. Large amounts of the applied fertilizer are not effective and washed away. Hence, a considerable economic benefit can be gained from reducing fertilizer quantities and, as such, input cost. The reduction of chemical fertilizer application quantities in rice cultivation can lead to multiple beneficial effects. It can have a strong positive impact on the environment as well as on farmers' input cost and livelihood overall (Wehmeyer, de Guia, Connor 2020).

To improve NPK fertilizer efficiency, studies suggest that increasing the proportion of organic fertilizer could reduce the negative environmental effects of chemical fertilizer overuse. It could also improve the performance of synthetic fertilizers. For example, Iqbal et al. 2020 demonstrated that the combination of 30 % nitrogen from livestock manure and 70 % nitrogen from chemical fertilizer is a promising option for the improvement of soil quality. This is due to the reduction of high nitrogen losses to the environment (2020: 19–20). Furthermore, nutrient use efficiency and the number of productive tillers increased. As a result, rice yields grew significantly. They attributed the improvements in productivity growth and yield mainly to the enhanced soil fertility. Hence, as other studies have also pointed out, the reduction or adaption of fertilizer regimes enhances environmental factors. In particular, improved soil quality has an important positive effect on rice production quantities and quality (Mangalassery, Kalaivanan, Philip 2019; Liu et al. 2019b). Moreover, it has been shown that combining rice straw incorporation with other inputs such as livestock manure or compost can further improve soil quality and nutrient supply (Chivenge et al. 2020: 133). In the case of rice farmers in the Mekong River Delta, it could be valuable to advise farmers on the increased use of organic fertilizer and its benefits (Nguyen 2017: 19). Finally, laying the focus on adapted fertilizer regimes for HYVs in 1M5R extension trainings and workshops could also be effective in reducing farmers' high NPK fertilizer use. Overall, climate change will slow down Vietnamese agriculture. Therefore, policy agendas have to target further how technological progress can sustain crop yields and reduced yield gaps. This is why continuous investment in the agriculture sector remains crucial for Vietnam to mitigate the negative impacts of climate change (Rutten et al. 2014: 40–41).

Most surveyed farmers were introduced to improved varieties and also adopted them with an adoption rate of more than 90 %. HYVs have become crucial for assuring yield potential and good grain quality for sustainable rice production (GRiSP 2013: 128). Overall, rice yields increased from 2015 to 2019 in both farmer groups, but most of the growth came from control farmers. Project farmers did not show a considerable yield difference. There are multiple possible reasons for this finding. Their yields did not grow as strongly in the winter-spring (-0.5 t/ha) and summer-autumn season (-0.6 t/ha) compared to the control farmers. Control farmers also experienced a decrease in their winter-spring harvest (-0.4 t/ha). But they were able to significantly increase their productivity in the summer-autumn season (+1.3 t/ha) between the two survey years. This ultimately led to the yield discrepancy between the two groups. It was clearly shown in the mediation analysis because the farmer group was a significant mediator for rice yield. One of the main reasons for the rice yields in the winter-spring season of 2018/2019 being considerably lower than in 2014/2015 in both groups is that weather conditions heavily affected rice cultivation. The winter-spring season 2018/2019 was particularly dry compared to other years due to a prolonged El Niño. This resulted in overall lower yields (USDA - Foreign Agricultural Service 2020c: 15, d: 13). El Niño's impacts are generally most severe during the winter-spring season from November to March (Sutton et al. 2019: 5). This was present in the 2018/2019 rice yield results of this study. During El Niño, the rainy season ends approximately a month early. This increases the temperature and evaporation rate, and hence reduces water levels and river water flows. These factors aggravate drought conditions and salinity concentrations, which are 2-4 % higher than average and lead to the loss of agricultural land (Sutton et al. 2019: 5; Yen et al. 2019: 2). An earlier El Niño starting in late 2014 barely influenced this study's baseline information. Its most severe stage peaked from February to May 2016 (Sutton et al. 2019: 10). The climatic context of this study demonstrates the importance of supporting farmers in adopting climate adaptation strategies to secure their livelihoods. In particular, salt and drought-tolerant rice varieties as well as water-saving technologies, such as AWD, during El Niño years are becoming crucial to deal with more extreme weather conditions. In general, Vietnamese rice production quantities have been rather stagnant over the past years (FAO Statistics Division 2020; USDA - Foreign Agricultural Service 2020e: 1–2).

In the mediation analysis for rice yield, the farmer group was a significant mediator in combination with age, non-rice income, seed rate, and irrigation cost in the SEM input model. It can be assumed that the reason for the yield differences is due to changes in input management in accordance with the farmer group. Project farmers used fewer inputs and had lower input expenses. Nonetheless, they were able to sustain comparatively high yields while reducing their input quantities and costs. Furthermore, they were able to produce rice with mean yields over 6 t/ha more sustainably. In the long term, this is important to remain competitive and maintain healthier environmental conditions in consideration of climate change. Overall, the project farmers have been able to remain highly productive compared to the national average rice yield of 5.8 t/ha in 2019. Additionally, they are also more advanced than other important rice-producing and exporting countries, such as Indonesia (5.1 t/ha in 2019) or Thailand (2.9 t/ha in 2019) (FAO Statistics Division 2020).

Farmers in both groups have adopted one or more 1M5R technologies. It can be expected that they will continue reducing their inputs. In general, more CORIGAP farmers adopted the recommended technologies compared to the control farmers. This is a positive finding. It clarifies that a well-structured and well-adapted extension strategy can have long-lasting effects. The outcome of the mediation analysis for profitability did not result in the farmer group being a mediator. However, the SEM input model clearly showed that almost all selected input variables had a direct effect on profitability, specifically through input cost decrease. Farmers in both groups were able to improve their profitability from the baseline to the endline survey. Overall, farmers' mean profitability was 58.8 % in 2015 and 64.5 % in 2019. This is in the range of other studies, for example, Dang (2017: 191). Control farmers improved their profitability by 9.1 % (2015: 55.2 %; 2019: 64.3 ) compared to the project farmers who were able to maintain their profit (+2.4 %) over the years (2015: 62.4 %; 2019: 64.8 %).

The results of the regression models and subsequent SEM models give a strong indication that farmers are applying the 1M5R recommendations. They are benefiting from them economically and environmentally in the long term. It can be generally assumed that both groups experienced positive changes to their rice farming by adopting the recommended best management practices. CORIGAP farmers were able to remain economically stable and produce rice more sustainably without profit losses by implementing the 1M5R guidelines. Although control farmers still used higher amounts of inputs, they were able to improve their input-output from 2015 to 2019. This study demonstrates that 1M5R has been successfully disseminated. Further beneficial changes to rice farming can be expected. This is a positive sign for improving the diffusion rate of 1M5R practices in the Mekong River Delta. Nevertheless, it has been shown that farmers have difficulties reaching the recommended input quantities. They remain very clearly above the maximum requirements, in particular for the seed rate and NPK fertilizer application quantities. Therefore, more research on why farmers are not able to reach these and extension to improve their reduction activities further is needed.

**Limitations.** The present study was conducted in one district of Can Tho Province, Vietnam, with a small sample size of 135 farmers. The sample size was limited due to purposive geographic sampling, although farmer sampling was conducted randomly. The information entirely relies on recall and self-reported measures. Thus, the results are susceptible to biases such as recall bias and social desirability bias. Additionally, only two out of three rice seasons were included in this study because of limited data availability of the summer-autumn season 2014. Furthermore, the results showed a non-normal distribution. This is associated with statistical tests that are less powerful because they require fewer assumptions. Overall, the findings of this study might not represent the general situation of all farmers in Can Tho Province and the Mekong River Delta. The participants demonstrated a rather high financial status and had large landholdings, in particular, compared to rice farmers in other regions of Vietnam. Furthermore, this is a snapshot of two separate years compared with each other. It does not include farmers' development as a time series. This study, therefore, does not represent farmers' development over time but rather highlights farmers' evolution at different stages.

# 13 Vietnam – Farmers' Perceptions of 'One Must Do, Five Reductions' Technologies

In this chapter, farmers' perceptions of 1M5R technologies as well as perceived changes in livelihood and agronomic performance are presented. First, the rationale and research objectives are described. Second, the methodological approach using data collected by means of a CAPI survey questionnaire is explained. Third, the results are presented and discussed, focusing on farmers' technology adoption behavior and perceived benefits of technology adoption. Additionally, farmers' perceived agronomic changes and twelve dimensions of livelihood change since using the technologies are analyzed.

## 13.1 Rationale of the Study

As of today, the 3R3G and 1M5R national policy programs have been introduced to rice farmers in the Mekong River Delta for almost two decades (Huelgas, Templeton, Castanar 2008: 3; Rejesus, Martin, Gypmantasiri 2014: 42; Connor et al. 2020a: 91). The two programs have reached more than 230'000 farmers in eight provinces in South Vietnam. They have benefited the region economically, socially, and environmentally as a whole (IRRI 2020c: 8). In particular, the broad diffusion strategy has increased the outreach possibilities and kept farmers informed through multiple channels (Huelgas, Templeton, Castanar 2008: 3; Tuan, Wehmeyer, Connor 2021). As a result, the diffusion of 1M5R is well established. Connor et al. found that farmers have been following 1M5R practices for several years (2020a: 95–96). Farmers particularly reduced harvest and postharvest losses through improved mechanization but also by changing their rice straw practice. Moreover, farmers' application and perceptions of the 1M5R practices were examined. They generally applied multiple 1M5R recommendations. Using certified seeds and reducing the seed rate as well as postharvest losses were mentioned the most. Nevertheless, farmers were not able to reduce their seed rate to the recommended 1M5R quantities (Connor et al. 2020a: 96–98). In fact, multiple studies and reports found that farmers find it difficult to achieve the recommended amount of seeds applied to their fields. Famers continue to use more than 120 kg/ha of seeds on their rice fields (Willett, Barroga 2016: 10; Nguyen 2017: 67). Therefore, notwithstanding the successful dissemination of 1M5R, difficulties remain particularly in reaching the recommended input levels. Although most farmers are willing to follow the recommendation, many are still not yet able to do so properly. Barriers include possible lower yield, incompatibility with farmers' cropping patterns, or the adoption being too expensive (Connor et al. 2020a: 97). Additionally, Tuan, Wehmeyer, and Connor found that external factors, such as access to adequate irrigation infrastructure or access to certified seeds, remain an issue for farmers. Additionally, the availability of the technologies differs between the provinces and communes (2021). In this regard, Demont and Rutsaert discuss the importance of linkages in the value chain and farmers' role in value chain development (2017: 7). They conducted a strengths, weaknesses, opportunities, and threats (SWOT) analysis with stakeholders from the rice sector in the Mekong River Delta. Their findings indicate that on the strength of the robust government support and a well-organized extension system, rice farmers widely adopted sustainable rice cultivation practices and technologies. A crucial element for further development is to focus on agricultural investments. This is important to reduce the threat of climate change and to assure Vietnam's position in the world market. They also argue that specifically inadequate postharvest infrastructure is responsible for much of the quality and quantity losses in rice. This problem is exacerbated by insufficient investment in agricultural machinery (Demont, Rutsaert 2017: 7).

The body of research focusing on 3R3G and 1M5R has described the crucial elements for the success of the two programs but also indicates that there remain barriers for farmers (Huelgas, Templeton, Castanar 2008; Hai 2012; Nguyen 2017; Connor et al. 2020a; Tuan, Wehmeyer, Connor 2021; Chapter 12.4). Many farmers have been applying the practices for many years. Nonetheless, they struggle with improving their practices further, particularly due to difficulties in mechanization. Most studies have been focusing on agronomic and socioeconomic changes under the two programs or analyzed farmers' adoption of the requirements. However, it has not yet been examined what farmers' perceptions of the specifically recommended technologies are. Hence, this study aims to examine farmers' adoption behavior regarding the different 1M5R technologies, namely AWD, combine harvester, drum seeder, and HYVs. Furthermore, the present study analyzes how farmers' input cost allocation, including perceived savings on inputs, has changed since applying the 1M5R recommendations. Finally, farmers' perceived livelihood changes are also investigated. Farmers in the provinces of An Giang and Can Tho were interviewed to distinguish if there is a difference in adoption time, perception of the technologies, and perceived livelihood changes since having adopted one or more technologies. 1M5R was first introduced in An Giang Province, but farmers in both provinces had previously already been educated on 3R3G, which had overlapping recommendations (Chapter 11.3).

## 13.2 Materials and Methods

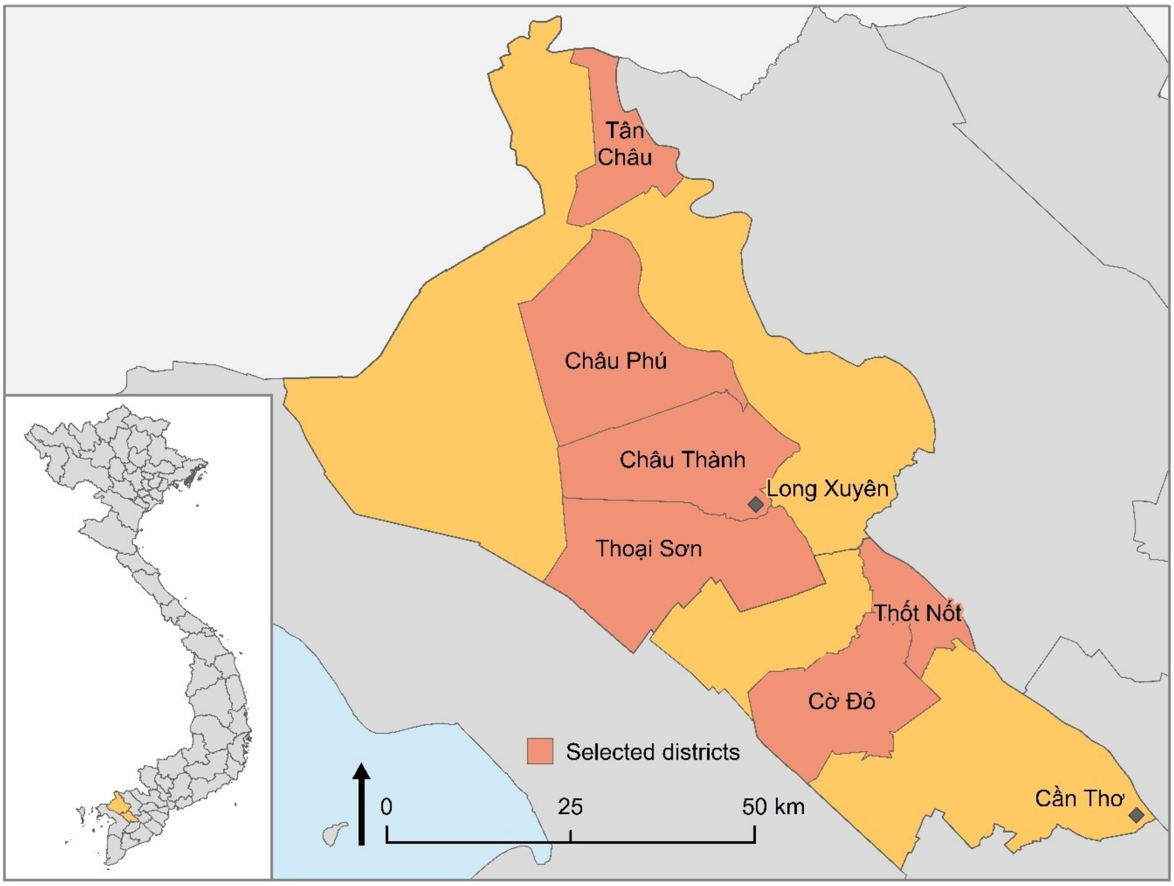
### 13.2.1 Survey Questionnaire and Data Collection Approach

The 'Farmers' Perceptions of Sustainable Development' survey questionnaire was developed to focus on farmers' adoption behavior and change perceptions since the introduction of the 3R3G and 1M5R programs. The questionnaire was divided into an information and consent form followed by four thematic categories: 1) sociodemographic information, 2) details on farming practices and adoption, 3) cropping seasons, and 4) perceived changes due to the adoption of best management practices. A detailed description of the survey questionnaire is presented in Chapter 6.2.1. It began with demographic questions such as age, gender, marital status, and household composition. Questions about children's education and possible farm succession were included. In the second section, farmers were asked about their adoption of the 3R3G and 1M5R best management practices and technologies. For each best management practice and technology, they answered 24 Likert-type scale statements on the benefits of adoption (1 = not applicable at all, 6 = very applicable) (Table 13.3). In the case of non-adoption or rejection, they rated 20 Likert-type scale statements on the disadvantages. In the third part, farmers reported their agronomic performance for the 2018-2019 rice seasons. The seasons were the 2018 summer-autumn season from April-May to July-August, the 2018 autumn-winter season from July-September to October-December, and the 2018-2019 winter-spring season from November-December to March-April. The same questions on cultivation area (ha), production quantities (kg), and input costs (VND), e.g., expenditures for seeds, fertilizer, and pest management, were asked for each season. In the last section, farmers described the changes they have perceived since adopting 1M5R best management practices and technologies. They answered 21 Likert-type scale statements (1 = completely disagree, 6 = fully agree) (Table 13.7) related to changes in their farming practices. Furthermore, farmers who experienced an income increase described how they allocated their increase based on a 20 item list (Yes, No, N/A), including elements such as food, clothing, savings, or renting agricultural machinery. Farmers were also asked to report on their satisfaction level (8 items), subjective knowledge (8 items), and expectations (4 items) regarding the recommended practices. Lastly, 12 dimensions of change were included in the questionnaire using 6-point Likert-type scales (1 = completely disagree, 6 = fully agree) for the statements (Blundo-Canto et al. 2018: 164–166; Wehmeyer, de Guia, Connor 2020: 5; Connor et al. 2021a: 10). These were 1) agricultural production (13 items) (Table 13.8), 2) physical capital (6 items) (Table 13.9), 3) human capital (4 items) (Table 13.10), 4) social capital (4 items) (Table 13.11), 5) food security (6 items) (Table 13.12), 6) financial capital (3 items) (Table 13.13), 7) cultural capital (4 items) (Table 13.14), 8) poverty (6 items) (Table 13.15), 9) land tenure (4 items) (Table 13.16), 10) health (5 items) (Table 13.17), 11) employment (3 items) (Table 13.18),and 12) natural capital (20 items) (Table 13.19).

The perception questionnaire was created in English and translated into Vietnamese. The Vietnamese questionnaire was independently back-translated to English. Data were collected by means of face-to-face interviewing using the mobile data collection application CommCare (Version: Dimagi 2.44.3). Just as for the household endline survey, the perception questionnaire was built offline on the CommCare dashboard and consisted of both languages. Samsung Galaxy Tablets A 7.0 (2016) LTE SM-T285 with the installed CommCare application were used during the farmer interviews. Before the survey implementation, the questionnaire was reviewed and approved by the IRRI Research Ethics Committee (2019-0006-A-2016-61).

### 13.2.2 Sampling and Implementation

Officers from the Can Tho DARD purposively identified the geographic units that served as the sampling strata. These included six districts in the provinces of Can Tho (Thốt Nốt, Cờ Đỏ) and An Giang (Tân Châu, Châu Phú, Châu Thành, Thoại Sơn) (Map 13.1). These districts were selected because 3R3G and 1M5R practices and technologies had been introduced. A random sample list was drawn from a master list of all farmers from various cooperatives and farmer groups. The farmers were invited by the local extension staff to participate in the study at a central survey location. Each farmer received compensation for their travel costs going to and from the central survey location.




Map 13.1 Survey locations of the 'Farmers' Perceptions of Sustainable Development' survey in An Giang and Can Tho Province
Concept: H. Wehmeyer; Cartography: M. Brunner; Cartographic base: GADM (2020)

The perception survey was conducted from 2-12 July 2019 in An Giang and Can Tho Province. In total, 465 rice farmers were interviewed. During four survey days in An Giang Province, 236 farmers from the districts of Châu Phú (n = 62), Tân Châu (n = 62), Châu Thành (n = 55), and Thoại Sơn (n = 57) participated in the survey. In two districts of Can Tho Province, Cờ Đỏ (n = 119) and Thốt Nốt ( n= 110), a total of 229 farmers were interviewed within four days. The questionnaire was completed in approximately 45 minutes. Farmers would either read the questions themselves and enumerators would insert the answers, or enumerators would read the questions aloud to the farmers if literacy levels or eyesight did not allow for reading alone. Furthermore, the enumerators took notes of farmers' agronomic information to enter the data into the application correctly.

### 13.2.3 Data Analysis

Raw data were exported from the CommCare dashboard and imported into Microsoft Excel (version 2102). The raw data exports were merged by farmer ID and imported to the statistical package IBM SPSS 27 for data analysis. Agronomic and socioeconomic data were checked for normal distribution. All data were normally distributed. Descriptive statistics were conducted to provide sample descriptions of the demographic, socioeconomic, and financial as well as agricultural data of the entire sample and two provinces. Agronomic variables were computed per hectare. Chi-square ($\chi^2$) test statistics were used to investigate associations between categorical variables. Parametric tests (t-tests) were used to determine mean differences between the provinces. Effect sizes were determined using Cohen's d and Pearson's r. Reliability analysis (Cronbach's α) was applied to investigate the internal consistency of items forming a scale of the perceived technology benefits, changes in farming practice, and dimension of change. Exploratory and confirmatory factor analyses were chosen to analyze the farmers' perceived benefits of 1M5R technologies and the related changes in farming practice to identify the underlying relationships between items. The chosen extraction method was principal components based on eigenvalues >1. Varimax rotation was the selected rotation method. This method was chosen because the perceived changes can be multifactorial. It can be assumed that the items are not fully independent of each other. Statistical significance was set to p = ≤0.05 and multicollinearity was set to ≥0.8 (Franke 2010).

## 13.3 Results

The results of this study are structured as follows. First, sociodemographic results and farm characteristics of the sample are described, including the differences between the two provinces. Second, the adoption rate and farmers' perceived benefits of the CORIGAP technologies are presented. Third, the agronomic results and input cost allocation as well as perceived input savings are shown. Lastly, farmers' perceptions of change in rice farming practices and dimensions of change are illustrated.

### 13.3.1 Sociodemographic Results and Farm Characteristics

The number of farmers in An Giang (50.8 %, n = 236) and Can Tho Province (49.2 %, n = 229) was evenly distributed. A detailed description of the sociodemographic and farm characteristics is presented in Table 13.1. No significant differences were found between farmers in An Giang and Can Tho Province for age and years of farming. However, Can Tho farmers had significantly larger households compared to farmers in An Giang Province, but the effect was small (t(463) = -3.506, p = <0.001, d = 0.325). Furthermore, regarding education levels, there were considerable differences between farmers in the two provinces. Farmers in An Giang Province demonstrated significantly higher education levels than farmers in Can Tho Province. Approximately 50 % of Can Tho farmers reached primary school education levels. Thus, considerably more farmers in Can Tho Province only reached primary school levels in comparison with the neighboring province ($\chi^2(1) = 7.321$, p = 0.007, r = 0.198). On the other hand, considerably more farmers in An Giang Province indicated having reached upper secondary school ($\chi^2(1) = 4.651$, p = 0.031, r = 0.233) or received a bachelor's degree ($\chi^2(1) = 5.333$, p = 0.021, r = 0.666). Also, with regard to being a member of a farmer organization, there was a significant discrepancy between the two provinces. Considerably more farmers in An Giang Province were a member in contrast to Can Tho farmers and the effect size was moderate ($\chi^2(1) = 30.250$, p = <0.001, r = 0.458).

Differences were present concerning the agricultural programs farmers followed. In both provinces, the majority of farmers applied 1M5R guidelines. Nevertheless, the number was significantly higher in An Giang compared to Can Tho Province ($\chi^2(1) = 6.612$, p = 0.010, r = 0.165). Regarding 3R3G, there were considerably more farmers in Can Tho Province following the program recommendations in comparison to the neighboring province ($\chi^2(1) = 5.170$, p = 0.023, r = 0.191). Nevertheless, the effect sizes remained small for both programs. Lastly, farmers indicated that their most-used sources of information on farming and agricultural best management practices were the DARD (60.2 %, n = 280), neighboring farmers (32.3 %, n = 150), television (31.2 %, n = 145), technical change agent (29.2 %, n = 136), farmer cooperative (28.0 %, n = 130), the Ministry of Agriculture and Rural Development (MARD) (17.6 %, n = 82), radio (16.6 %, n = 77), family members (11.4 %, n = 53), village farmer group (9.2 %, n = 43), agrochemical representative (9.2 %, n = 43), and trader/rice buyer (1.7 %, n = 8).

Table 13.1 Sociodemographic results and farm characteristics by province

| | An Giang | | Can Tho | |
|---|---|---|---|---|
| Variables | n | Mean (SD) | n | Mean (SD) |
| Age (years) | 236 | 50.5 (11.4) | 229 | 51.4 (13.4) |
| Years farming | 236 | 25.9 (11.8) | 229 | 28.1 (14.6) |
| Household size (headcount) | 236 | 4.8 (1.3) | 229 | 5.4 (1.8) |
| Gender | n | % | n | % |
| Male | 222 | 94.1 | 218 | 95.2 |
| Female | 14 | 5.9 | 11 | 4.8 |
| Civil Status | n | % | n | % |
| Married | 230 | 97.5 | 224 | 97.8 |
| Single | 6 | 2.5 | 5 | 2.2 |
| Education | n | % | n | % |
| No school | 2 | 0.8 | 2 | 0.9 |
| Primary school | 75 | 31.8 | 112 | 48.9 |
| Secondary school | 96 | 40.7 | 80 | 34.9 |
| Upper secondary school | 53 | 22.5 | 33 | 14.4 |
| Bachelor's degree | 10 | 4.2 | 2 | 0.9 |
| Member of an organization | 105 | 44.5 | 39 | 17.0 |
| Program | n | % | n | % |
| 1M5R | 141 | 59.7 | 101 | 44.1 |
| 3R3G | 57 | 24.2 | 84 | 36.7 |
| Not sure | 38 | 16.1 | 44 | 19.2 |
| Non-rice income | 133 | 56.4 | 137 | 59.8 |
| Agricultural financial support | 107 | 45.3 | 100 | 43.7 |

Note: SD = Standard deviation

### 13.3.2 Adoption of 1M5R Technologies and Perceived Benefits

In Table 13.2, a detailed description of technology adoption behavior is presented. It includes the number of farmers who adopted a technology, time from introduction to adoption, length of adoption, and continued use in the forthcoming season. Table 13.3 presents the mean benefit ratings per technology adopted and by province. Table 13.4 displays the mean ratings of the perceived benefits of the technologies. It contains the statistically significant rating differences between the provinces and the results of the confirmatory factor analysis over three factors.

Table 13.2 Details on 1M5R technology adoption behavior

| | An Giang [1] | Can Tho [2] | All [3] |
|---|---|---|---|
| **AWD** | | | |
| Farmers adopted % (n) | 33.9 (80) | 35.4 (81) | 34.6 (161) |
| Years from introduction to adoption (SD) | 0.2 (0.5) | 0.1 (0.3) | 0.2 (0.4) |
| Years adopted (SD) | 6.8 (5.6) | 6.2 (5.5) | 6.5 (5.6) |
| Still practicing 2019 % (n) | 100.0 (80) | 100.0 (81) | 100.0 (161) |
| Planning continued use % (n) | 100.0 (80) | 100.0 (81) | 100.0 (161) |
| **Combine harvester** | | | |
| Farmers adopted % (n) | 99.2 (234) | 100.0 (229) | 99.6 (463) |
| Years from introduction to adoption (SD) | 0.4 (1.2) | 0.4 (1.3) | 0.4 (1.2) |
| Years adopted (SD) | 9.3 (3.7) | 8.1 (3.0) | 8.7 (3.4) |
| Still practicing 2019 % (n) | 100.0 (234) | 100.0 (229) | 100.0 (463) |
| Planning continued use % (n) | 100.0 (234) | 100.0 (229) | 100.0 (463) |
| **Drum seeder** | | | |
| Farmers adopted % (n) | 17.8 (42) | 8.3 (19) | 13.1 (61) |
| Years from introduction to adoption (SD) | 0.4 (1.2) | 0.4 (1.4) | 0.4 (1.2) |
| Years adopted (SD) | 7.9 (4.8) | 3.8 (2.2) | 6.6 (4.6) |
| Still practicing 2019 % (n) | 69.0 (29) | 94.7 (18) | 77.0 (47) |
| Planning continued use % (n) | 66.6 (28) | 94.7 (18) | 75.4 (46) |
| **HYVs** | | | |
| Farmers adopted % (n) | 30.9 (73) | 25.3 (58) | 28.2 (131) |
| Years from introduction to adoption (SD) | 0.2 (0.5) | 0.2 (0.8) | 0.2 (0.6) |
| Years adopted (SD) | 7.3 (5.4) | 5.7 (3.5) | 6.6 (4.6) |
| Still practicing 2019 % (n) | 94.5 (69) | 100.0 (58) | 96.9 (127) |
| Planning continued use % (n) | 94.5 (69) | 100.0 (58) | 96.9 (127) |

Note: [1] n = 236, [2] n = 229, [3] N = 465

Table 13.3 Mean benefit ratings for each 1M5R technology

| | n | All | n | An Giang | n | Can Tho | t | df | p | d |
|---|---|---|---|---|---|---|---|---|---|---|
| **AWD** | 161 | 5.13 (0.63) | 80 | 4.92 (0.62) | 81 | 5.34 (0.57) | -4.503 | 159 | <0.001 | 0.710 |
| **Combine harvester** | 463 | 5.21 (0.67) | 234 | 5.10 (0.68) | 229 | 5.31 (0.66) | -3.269 | 461 | 0.001 | 0.304 |
| **Drum seeder** | 46 | 5.12 (0.71) | 28 | 4.95 (0.75) | 18 | 5.39 (0.56) | -2.127 | 44 | 0.039 | 0.642 |
| **HYVs** | 127 | 5.24 (0.83) | 69 | 4.93 (0.92) | 58 | 5.62 (0.49) | -5.123 | 125 | <0.001 | 0.913 |

Note: Number of items for each benefit = 24

Table 13.4 Mean ratings of perceived benefits of 1M5R technologies

| Technology benefits | AWD [1] | Combine harvester [3] | Drum seeder [4] | HYVs [5] | Factor loadings | | |
|---|---|---|---|---|---|---|---|
| | Mean (SD) | | | | 1 | 2 | 3 |
| High yield | 5.01 (1.09) | 4.55 (1.64) * | 5.00 (1.38) | 5.42 (1.09) ** | -.082 | **.698** | .438 |
| High income | 5.10 (1.01) | 5.17 (1.09) ** | 5.09 (1.05) | 5.39 (0.94) * | .483 | .045 | **.487** |
| Fits my cropping pattern | 5.50 (0.75) *** | 5.62 (0.61) *** | 5.50 (0.78) * | 5.57 (0.81) *** | **.731** | .133 | -.277 |
| Satisfies my preferences | 5.46 (0.65) * | 5.57 (0.67) | 5.59 (0.81) | 5.51 (0.87) ** | **.701** | .057 | -.178 |
| Replaced different technology(ies) | 5.27 (0.99) *** | 5.49 (0.92) *** | 5.20 (1.30) * | 5.31 (1.11) *** | .308 | **.572** | -.341 |
| Less lodging | 5.56 (0.62) * | 4.76 (1.62) | 5.54 (0.66) | 5.52 (0.81) *** | -.022 | **.731** | .269 |
| More free time | 5.35 (0.83) *** | 5.57 (0.66) *** | 5.24 (1.09) | 5.41 (0.88) *** | **.567** | .167 | -.436 |
| Fewer damages from drought | 3.48 (1.19) | 4.10 (1.55) | 4.52 (1.50) | 3.60 (1.55) | -.180 | **.833** | .148 |
| Fewer damages from snails | 3.95 (1.52) | 2.04 (1.62) | 3.36 (1.50) | 3.60 (1.01) | .036 | .273 | **.809** |
| Fewer damages from insects | 4.93 (1.15) | 2.72 (1.98) | 4.76 (1.52) | 5.28 (1.12) | -.295 | .288 | **.717** |
| Fewer damages from rats | 3.72 (1.53) | 2.25 (1.72) * | 2.92 (1.63) | 3.42 (1.59) | -.105 | .424 | **.750** |
| Fewer damages from diseases | 4.96 (1.12) | 2.80 (1.99) | 5.00 (1.39) | 5.26 (1.10) | **.646** | -.103 | .034 |
| Fewer damages from weeds | 4.04 (1.49) | 2.61 (1.91) | 3.48 (1.91) | 4.58 (1.61) * | **.798** | .032 | -.085 |
| Easy to apply | 5.74 (0.52) | 5.78 (0.50) ** | 5.76 (0.57) | 5.69 (0.65) ** | **.768** | .186 | .076 |
| Less expensive | 5.45 (0.79) * | 5.56 (0.65) | 5.51 (0.90) | 5.52 (0.79) * | **.769** | -.012 | .295 |
| Labor shortage | 3.79 (1.21) | 4.22 (1.61) | 4.32 (1.16) | 4.07 (1.07) | **.788** | .100 | -.013 |
| Labor costs are lower | 5.53 (0.75) *** | 5.65 (0.65) *** | 5.30 (1.17) | 5.48 (0.97) *** | **.794** | -.160 | -.032 |
| Labor hours are lower | 5.38 (0.86) ** | 5.55 (0.68) *** | 5.17 (1.18) | 5.35 (1.04) *** | **.784** | .084 | -.186 |
| Weather conditions allowed use | 5.26 (1.00) *** | 5.52 (0.82) ** | 5.50 (0.81) | 5.50 (0.94) *** | -.028 | **.823** | .042 |
| Technology is easily available | 5.28 (0.74) * | 5.59 (0.62) * | 5.58 (0.58) | 5.42 (0.88) *** | .258 | **.746** | .132 |
| Technology is suitable for my field conditions | 5.29 (0.77) *** | 5.60 (0.62) *** | 5.56 (0.66) | 5.47 (0.87) *** | .206 | **.679** | .187 |
| Plants die less | 5.22 (0.94) ** | 4.85 (1.53) * | 5.40 (0.94) | 5.46 (0.84) *** | -.082 | **.698** | .438 |
| The environment has improved | 5.35 (0.82) *** | 5.25 (1.11) *** | 5.00 (1.33) | 5.23 (1.09) ** | .483 | .045 | **.487** |
| Assured market/buyer for my harvested grains | 3.68 (1.70) ** | 4.44 (1.69) | 3.96 (1.72) * | 4.58 (1.76) *** | **.731** | .133 | -.277 |

Note: [1] n = 161, [2] n = 354, [3] n = 463, [4] n = 46, [5] n = 127; 6-point Likert-type scale: 1 = not applicable at all, 6 = very applicable, * p = ≤0.05, ** p = <0.01, *** p = <0.001 for t-test analysis comparing both provinces; Confirmatory factor analysis: n = 458; Highest factor loadings are bold; Cronbach's α factor 1 = 0.927, factor 2 = 0.836, factor 3 = 0.820

The majority of the interviewed farmers used two recommended technologies (46.2 %, n = 215). Around a third indicated using three technologies (32.7 %, n = 152). The remaining used four or more technologies (14.0 %, n = 65). Only 7.1 % (n = 33) used just one technology. Nevertheless, there were significantly more farmers from An Giang Province (n = 26) using only one technology compared to the farmers in Can Tho Province (n = 7) ($\chi^2(1) = 10.939$, $p = 0.001$, $r = 0.576$). In general, most farmers applied the selected technologies in all three rice cropping seasons (81.1 %, n = 377). Yet, more farmers in Can Tho Province (89.1 %, n = 204) used the technologies in all seasons in comparison with the farmers in An Giang Province (73.3 %, n = 173). But this discrepancy was not statistically significant. The most adopted technology was combine harvester, which was used by almost all farmers in this study. A considerable difference in the number of farmers using drum seeders ($\chi^2(1) = 8.672$, $p = 0.003$, $r = 0.377$) was found between the two provinces. Significantly more farmers in An Giang Province used a drum seeder compared to the neighboring province. Regarding the adoption time between the two provinces, there were differences in length between the provinces. Farmers in An Giang Province adopted drum seeders ($t(59) = 3.551$, $p = 0.001$, $d = 0.982$) and HYVs ($t(129) = 2.023$, $p = 0.045$, $d = 0.356$) for significantly longer than farmers in Can Tho Province.

Two other technologies were adopted by few farmers, mechanical transplanter (1.3 %, n = 6) and ecologically-based rodent management (1.7 %, n = 8). These two technologies were not further investigated because the number of adopters was insignificant.

Farmers' highest-rated benefit statement for all five technologies was "easy to apply" with an average rating of 5.75 (SD = 0.54). Other highly rated statements included "fits my cropping pattern" (5.56, SD = 0.71), "satisfies my preferences" (5.52, SD = 0.74), "less expensive" (5.51, SD = 0.76), "labor costs are lower" (5.49, SD = 0.87), "technology is suitable for my field conditions" (5.48 SD = 0.73), and "technology is easily available" (5.47, SD = 0.71). The lowest rated statement were "fewer damages from rats" (3.04, SD = 1.62), "fewer damages from snails" (3.16, SD = 1.46), "fewer damages from weeds" (3.65, SD = 1.73), "fewer damages from drought" (3.91, SD = 1.47), "labor shortage" (4.05, SD = 1.33), "assured market/buyer for my harvested grains" (4.10, SD = 1.73), and "fewer damages from insects" (4.47, SD = 1.44) (Figure 13.1).

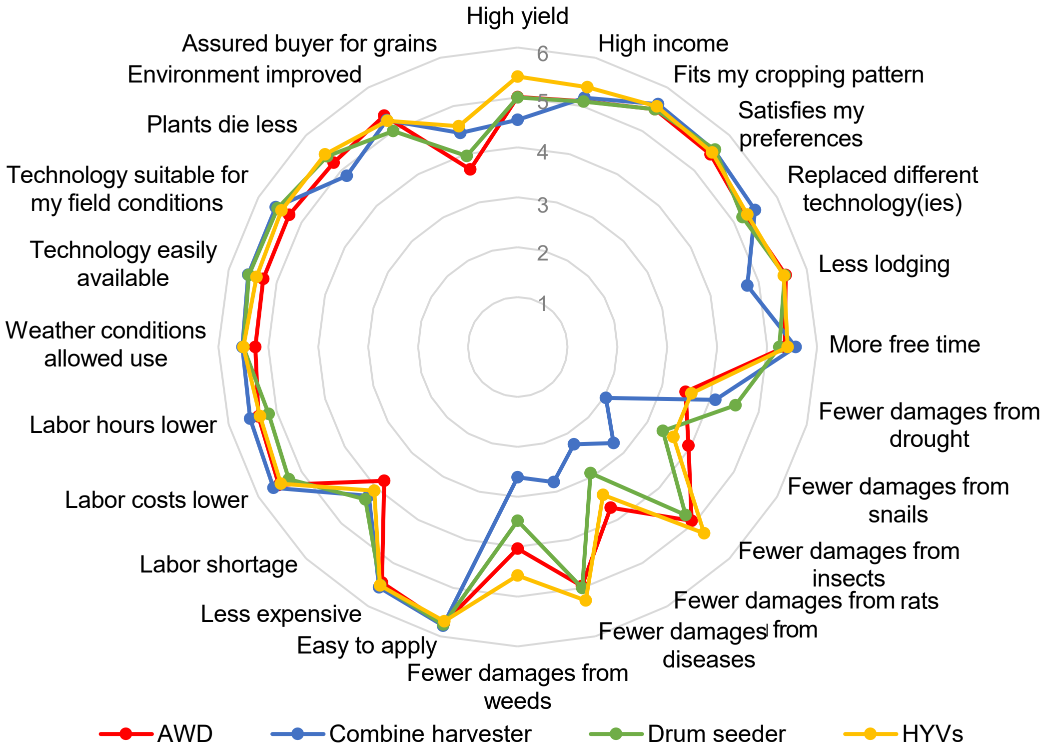



Figure 13.1 Radar chart of benefit ratings for selected 1M5R technologies

**AWD.** Over a third of farmers adopted AWD and plan on continuing its use. The average length of adoption was more than six years and the technology was highly rated. No significant differences between the two provinces were found in adoption behavior. However, differences between the farmers in the two provinces regarding the perceived benefits of the technology were present. Farmers in Can Tho Province rated all benefits of AWD higher than An Giang farmers except for one statement – "Fewer damages from rats" – but this difference was not statistically significant. In total, 14 statements were rated significantly apart between the farmers in the two provinces. Farmers in Can Tho Province demonstrated a considerably higher average rating with a strong effect.

**Combine harvester.** Almost all farmers adopted a combine harvester in both provinces and have been using this technology on average for almost nine years. The technology received the second-highest overall rating after HYVs. Most statements were rated differently between the two provinces and 14 were statistically significantly apart. The majority of the benefit statements were rated higher by the farmers in Can Tho Province, who demonstrated a significantly higher overall benefit rating in comparison with An Giang farmers.

**Drum seeder.** Rather few farmers used a drum seeder, but there was a significant discrepancy between the two provinces. Considerably more farmers in An Giang Province adopted a drum seeder compared to Can Tho Province ($\chi^2(1) = 8.672$, $p = 0.003$, $r = 0.377$). In general, the difference in the average technology benefit rating was significantly apart between the two provinces. Farmers in Can Tho Province rated all benefits of using a drum seeder higher than the farmers in the neighboring province. However, statistically considerable differences were only found for "fits my cropping pattern" ($t(44) = -2.443$, $p = 0.019$, $d = 0.738$), "replaced different technologies" ($t(44) = -2.670$, $p = 0.011$, $d = 0.827$), and "assured market/buyer for my harvested grains" ($t(44) = -2.352$, $p = 0.027$, $d = 0.937$).

**HYVs.** Almost a third of the farmers in An Giang and Can Tho Province adopted HYVs. The average time of adoption until 2019 was almost seven years. HYVs received the highest mean rating compared to the other three technologies. Farmers in Can Tho Province rated all benefit statements higher than An Giang farmers; 19 ratings were significantly apart. Overall, the mean benefit rating was considerably higher in Can Tho Province compared to An Giang Province. The effect size was very strong. Additionally, a weak positive correlation between the reception of financial support and the use of HYVs ($r = 0.343$, $p = <0.001$) was found.

A confirmatory factor analysis over three factors was conducted. The goal was to examine the different aspects of the perceived benefits related to the critical attributes that are necessary for technology adoption (Chapter 4.1). The three factors explained 62.4 % of the variance and concerned the three main benefits of adopting 1M5R technologies. Factor 1 ($m = 5.52$, $SD = 0.49$, $n = 10$) describes farmers' positive application experiences with the technologies and compatibility with their farming practice and preferences. Hence, this is the compatibility factor of the 1M5R technologies. Reliability analysis of the compatibility factor resulted in a Cronbach's α of 0.927 ($n = 10$). Factor 2 ($m = 4.71$, $SD = 0.8$, $n = 7$) portrays the positive reductions that have led to beneficial outcomes due to the adoption of the technologies. Concretely, farmers experienced increased yield as well as improved plant and environmental health. Moreover, this led farmers to take the decision to replace other technologies for the 1M5R technologies. Therefore, this factor can be regarded as the relative advantage factor. Reliability analysis of the items resulted in a Cronbach's α of 0.836 ($n = 7$). Factor 3 demonstrates farmers' perceived benefits of reducing damages due to 1M5R technology adoption. Thus, this is the damage reduction factor. Cronbach's α was 0.770 ($n = 4$). However, excluding the item "High income" increased Cronbach's α to 0.820 ($m = 3.48$, $SD = 1.28$, $n = 3$). This statement was not related to damage reduction. It showed a moderate factor loading on factors 1 and 3, which further indicated that this item does not fit in either factor category. Lastly, due to high multicollinearity of over 0.8 with "fewer damages from insects" (0.926), the item "fewer damages from diseases" was removed from the confirmatory factor analysis. Additionally, the items "fewer damages from snails" and "labor shortage" were also excluded from the analysis because of high multicollinearity with the statement "fewer damages from rats" (0.863) and "fewer damages from drought" (0.867), respectively.

### 13.3.3 Agronomic Results, Input Cost Allocation, and Perceived Input Savings

The majority of the farmers cultivated rice during three seasons (77.4 %, n = 359). However, there was a significant difference in the number of farmers cultivating a third season between the two provinces ($\chi^2(1) = 6.153$, $p = 0.013$, $r = 0.131$). Considerably more farmers in Can Tho Province also indicated planting rice during the 2018 autumn-winter season in comparison with farmers in An Giang Province. A detailed description of the agronomic results by season and province is presented in Table 13.5. Input cost per element and perceived input savings since the adoption of 1M5R technologies by province are displayed in Figure 13.2. Additionally, a detailed depiction of farmers' different input costs and savings, as well as corresponding t-test analyses to compare the two provinces, is shown in Table 13.6.

Table 13.5 Agronomic results by season and province

| | An Giang | | Can Tho | | All | |
|---|---|---|---|---|---|---|
| | n | Mean (SD) | n | Mean (SD) | n | Mean (SD) |
| **Cultivation area (ha)** | | | | | | |
| Summer-autumn season 2018 | 231 | 2.5 (2.4) | 217 | 2.0 (2.1) | 448 | 2.3 (2.3) |
| Autumn-winter season 2018 | 156 | 2.7 (2.5) | 203 | 2.1 (2.2) | 359 | 2.4 (2.4) |
| Winter-spring season 2018-2019 | 228 | 2.4 (1.9) | 226 | 2.0 (2.2) | 454 | 2.2 (2.1) |
| Annual 2018-2019 | 235 | 2.5 (2.1) | 229 | 2.0 (2.1) | 464 | 2.2 (2.1) |
| **Yield (t/ha)** | | | | | | |
| Summer-autumn season 2018 | 231 | 6.5 (1.1) | 217 | 6.7 (1.0) | 448 | 6.6 (1.1) |
| Autumn-winter season 2018 | 156 | 6.8 (1.2) | 203 | 6.5 (1.0) | 359 | 6.6 (1.1) |
| Winter-spring season 2018-2019 | 228 | 7.2 (1.3) | 226 | 7.5 (1.1) | 454 | 7.3 (1.2) |
| Annual 2018-2019 | 235 | 6.8 (1.1) | 229 | 6.9 (0.8) | 464 | 6.9 (1.0) |
| **Seed rate (kg/ha)** | | | | | | |
| Summer-autumn season 2018 | 231 | 161.1 (40.3) | 217 | 168.9 (30.9) | 448 | 164.9 (36.2) |
| Autumn-winter season 2018 | 156 | 168.7 (49.0) | 203 | 172.1 (32.7) | 359 | 170.7 (40.6) |
| Winter-spring season 2018-2019 | 228 | 163.6 (41.2) | 226 | 163.2 (31.0) | 454 | 163.4 (36.5) |
| Annual 2018-2019 | 235 | 163.3 (39.8) | 229 | 167.3 (29.1) | 464 | 165.3 (34.9) |
| **Rice income ('000 VND/ha)** | | | | | | |
| Summer-autumn season 2018 | 231 | 30'759.0 (7069.1) | 217 | 32'304.1 (7083.1) | 448 | 31'507.4 (7110.1) |
| Autumn-winter season 2018 | 156 | 34'862.2 (8129.5) | 203 | 31'714.9 (6924.6) | 359 | 33'082.5 (7623.0) |
| Winter-spring season 2018-2019 | 228 | 34'386.9 (8928.1) | 223 | 39'178.6 (7132.7) | 451 | 36'756.1 (8429.7) |
| Annual 2018-2019 | 235 | 32'952.7 (7404.5) | 229 | 34'545.1 (5556.9) | 464 | 33'738.6 (6599.3) |
| **Input cost ('000 VND/ha)** | | | | | | |
| Summer-autumn season 2018 | 228 | 17'506.8 (13'301.2) | 217 | 15'709.3 (3816.6) | 445 | 16'630.3 (9917.1) |
| Autumn-winter season 2018 | 155 | 15'544.9 (5754.0) | 203 | 15'818.3 (2901.3) | 358 | 15'700.0 (4366.1) |
| Winter-spring season 2018-2019 | 226 | 16'482.3 (6510.4) | 226 | 15'827.2 (3626.5) | 452 | 16'154.7 (5273.9) |
| Annual 2018-2019 | 233 | 16'686.4 (7970.0) | 229 | 15'678.0 (3058.7) | 462 | 16'186.5 (6070.3) |

Farmers' average annual rice cultivation area was 2.2 ha (SD = 2.1) The size of the rice farming area did not vary much between the seasons, but differences between the two provinces were present. An Giang farmers had significantly larger rice cultivation areas than Can Tho farmers ($t(462) = 2.609$, $p = 0.009$, $d = 0.242$). Farmers in Can Tho Province ($m = 3.4$, $SD = 2.5$, $n = 26$) rented more land than farmers in the neighboring province ($m = 2.4$, $SD = 1.9$, $n = 30$). However, this difference was not statistically significant ($t(54) = -1.696$, $p = 0.096$). Farmers rented land through leasehold (12.1 %, n = 56). The mean annual yield reached 6.9 t/ha (SD = 1.0). It was not considerably apart between provinces ($t(462) = -1.595$, $p = 0.111$) but discrepancies per season were relevant. Can Tho farmers achieved significantly higher yields in the 2018 summer-autumn season ($t(446) = -2.360$, $p = 0.019$, $d = 0.223$) and the 2018-2019 winter-spring season ($t(452) = -2.933$, $p = 0.004$, $d = 0.275$) than An Giang farmers. Yet, in the 2019 autumn-winter season, it was the opposite ($t(357) = 2.433$, $p = 0.015$, $d = 0.259$). Farmers perceived an average yield increase of 0.46 t/ha (SD = 1.37, n = 287) since using 1M5R technologies. No significant differences between provinces were found ($t(285) = 0.188$, $p = 0.851$). Farmers' annual seed rate was 165.3 kg/ha (SD = 34.9) and did not fluctuate considerably between seasons. Only in the 2018 summer-autumn season, Can Tho farmers had a significantly higher seed rate than farmers in An Giang Province ($t(446) = -2.286$, $p = 0.023$, $d = 0.216$). Since applying the 1M5R technologies, farmers perceived a seed rate decrease of 73.7 kg/ha (SD = 44.2, n = 380) on average. No significant differences between provinces were found ($t(378) = -0.162$, $p = 0.872$). Regarding rice income per hectare, farmers in Can Tho Province demonstrated significantly higher annual rice income per hectare ($t(462) = -2.615$, $p = 0.009$, $d = 0.243$) and rice income per season during the 2018 summer-autumn season ($t(446) = -2.310$, $p = 0.021$, $d = 0.218$) as well as in the 2018-2019 winter-spring season ($t(449) = -6.289$, $p = <0.001$, $d = 0.592$). Nevertheless, farmers in An Giang Province had a considerably higher income in the 2018 autumn-winter season ($t(357) = 3.956$, $p = <0.001$, $d = 0.421$). Farmers did not show significant differences in input cost during the three rice seasons and annual average (2018 summer-autumn season: $t(443) = 1.917$, $p = 0.056$; 2018 autumn-winter season: $t(356) = -0.586$, $p = 0.558$, winter-spring season 2018-2019: $t(450) = 1.322$, $p = 0.187$; 2018-2019 annual average: $t(460) = 1.789$, $p = 0.074$).

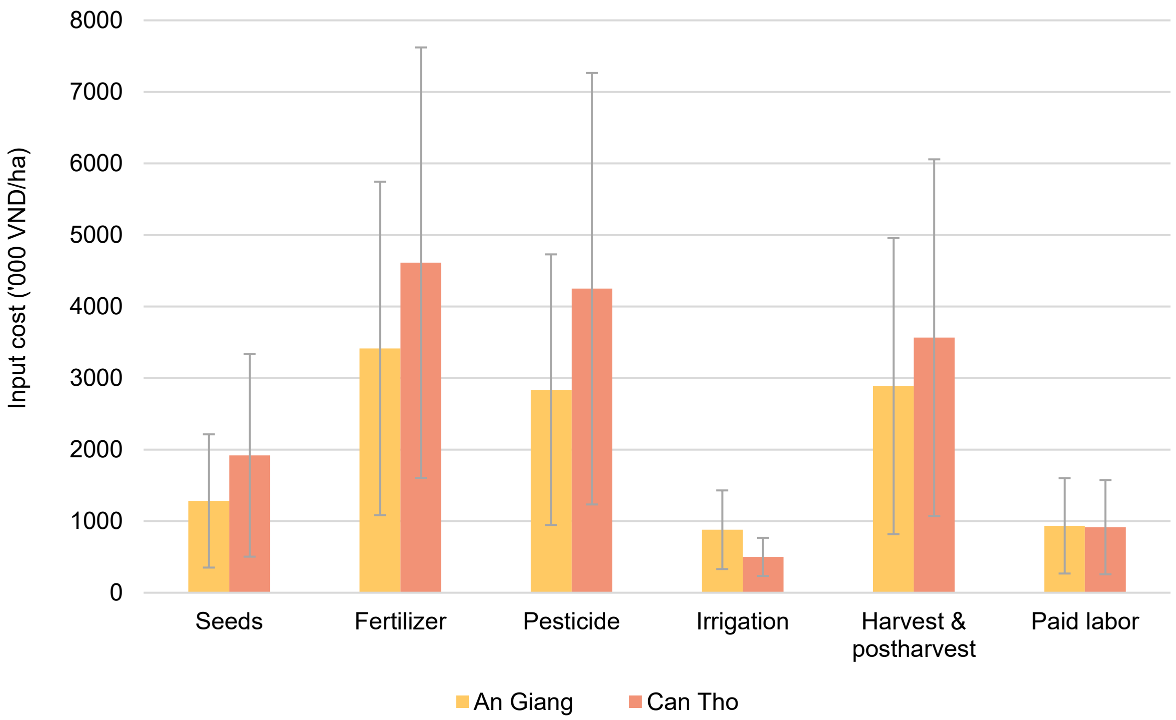



Figure 13.2 Annual input cost per element by province with the standard deviation

Farmers' three highest input cost pillars were fertilizer, pesticide, and harvest-postharvest activities. Generally, farmers in Can Tho Province spent significantly more per hectare on these three elements than farmers in An Giang Province. Can Tho farmers also perceived higher savings in fertilizer cost, pesticide cost, and harvest-postharvest activities, but the differences were not statistically significant. The most mentioned elements of perceived input savings by the farmers were seeds (66.5 %, n = 300), fertilizer (54.4 %, n = 241), and pesticides (63.8 %, n = 293). On average, farmers saved 25.8 % (SD = 8.8, n = 352) of their input cost since using 1M5R technologies. No significant differences in perceived savings were found between the two provinces except for irrigation. However, only two farmers in Can Tho Province reported perceived savings which renders this outcome rather insignificant overall. Nonetheless, most farmers used irrigation on their fields (94.0 %, n = 436). Perceived savings on harvest-postharvest activities (1.7 %, n = 8), irrigation (3.8 %, n = 14), and paid labor (13.4 %, n = 31) were only perceived by few farmers.

Table 13.6 Mean annual input cost per hectare and perceived input savings since the adoption of 1M5R technologies

| | n | All | n | An Giang | n | Can Tho | t | df | p | d |
|---|---|---|---|---|---|---|---|---|---|---|
| **Seeds** | | | | | | | | | | |
| Cost '000 VND/ha (SD) | 451 | 1599.8 (1561.1) | 226 | 1282.1 (1242.2) | 225 | 1919.1 (1772.5) | -4.421 | 449 | <0.001 | 0.416 |
| Perceived savings % (SD) | 300 | 28.1 (14.0) | 150 | 27.5 (15.9) | 150 | 28.7 (11.7) | -0.782 | 298 | 0.435 | 0.090 |
| **Fertilizer** | | | | | | | | | | |
| Cost '000 VND/ha (SD) | 443 | 4023.3 (3561.8) | 218 | 3414.2 (2859.1) | 225 | 4613.5 (4050.1) | -3.590 | 441 | <0.001 | 0.341 |
| Perceived savings % (SD) | 241 | 22.1 (10.5) | 119 | 21.0 (10.4) | 122 | 23.3 (10.6) | -1.710 | 239 | 0.089 | 0.220 |
| **Pesticide** | | | | | | | | | | |
| Cost '000 VND/ha (SD) | 459 | 3535.7 (3747.3) | 232 | 2837.9 (3155.5) | 227 | 4248.8 (4155.6) | -4.120 | 457 | <0.001 | 0.383 |
| Perceived savings % (SD) | 293 | 27.2 (15.1) | 149 | 25.9 (15.4) | 144 | 28.6 (14.6) | -1.521 | 291 | 0.129 | 0.178 |
| **Irrigation** | | | | | | | | | | |
| Cost '000 VND/ha (SD) | 372 | 663.7 (833.1) | 160 | 879.9 (971.2) | 212 | 500.5 (668.8) | 4.458 | 370 | <0.001 | 0.467 |
| Perceived savings % (SD) | 14 | 32.8 (26.6) | 12 | 23.3 (11.2) | 2 | 90.0 (14.1) | -7.592 | 12 | <0.001 | 5.799 |
| **Harvest-postharvest activities** | | | | | | | | | | |
| Cost '000 VND/ha (SD) | 462 | 3222.0 (3121.4) | 234 | 2887.9 (3073.1) | 228 | 3564.9 (3140.1) | -2.342 | 460 | 0.020 | 0.218 |
| Perceived savings % (SD) | 8 | 53.9 (19.8) | 8 | 53.9 (19.8) | 0 | 0.0 | n/a | n/a | n/a | n/a |
| **Paid labor** | | | | | | | | | | |
| Cost '000 VND/ha (SD) | 243 | 926.1 (809.9) | 131 | 934.8 (833.4) | 112 | 916.0 (785.1) | 0.179 | 241 | 0.858 | 0.023 |
| Perceived savings % (SD) | 31 | 26.8 (9.3) | 18 | 26.5 (10.6) | 13 | 27.2 (7.4) | -0.208 | 29 | 0.837 | 0.076 |

Note : SD = Standard deviation

### 13.3.4 Perceptions of Change in Rice Farming Practices and Dimensions of Change

Farmers' most important perceived change in their rice farming practice was the change to certified seeds and reducing postharvest losses as well as decreasing the use of insecticides and chemical fertilizer (Table 13.7). These aspects did not show statistically significant differences between the two provinces. The least important changes were perceived for different rice straw usage and collecting rice straw as well as planting trees or shrubs or other plants alongside fields. Significant differences in perceived changes of farming practice were found for seven out of 21 statements between the two provinces.

Farmers in Can Tho Province rated the difficulty to reduce seeds ($t(463) = 2.161$, $p = 0.031$, $d = 0.200$) considerably lower than farmers in An Giang Province. Thus, Can Tho farmers perceived that the reduction of the seed rate was not as difficult compared to farmers in the neighboring province. In addition, farmers in Can Tho Province rated using more organic fertilizer ($t(463) = 4.654$, $p = <0.001$, $d = 0.432$), doing rice straw collecting ($t(463) = 2.909$, $p = 0.004$, $d = 0.270$), and planting trees and shrubs ($t(463) = 2.517$, $p = 0.012$, $d = 0.234$) considerably lower than An Giang farmers. Farmers in An Giang Province rated the statements on the difficulty to use less rodenticide ($t(463) = -2.840$, $p = 0.005$, $d = 0.263$) and fungicide ($t(463) = -2.197$, $p = 0.029$, $d = 204$) lower than farmers in Can Tho Province. Hence, An Giang farmers found it easier to reduce these two inputs compared to Can Tho farmers. Finally, farmers in An Giang Province perceived a smaller change in electricity use for agricultural practices than farmers in the neighboring province. Can Tho rated the statement significantly higher ($t(463) = -5.826$, $p = <0.001$, $d = 540$).

A confirmatory factor analysis over four factors was conducted to examine the different aspects of farmers' perceived practice changes. The factors focused particularly on the different impacts that the 1M5R input reduction program aims to achieve. The four factors explained 49.2 % of the variance. The first factor ($m = 3.84$, $SD = 0.58$, $n = 10$) includes the main reduction elements of the policy program, namely the use of certified seeds, reduction of the seed rate, fertilizer as well as pesticide use, and irrigation hours. Therefore, it can be interpreted as the 1M5R factor, although postharvest losses are not included in this factor. Reliability analysis of the 1M5R factor resulted in a Cronbach's $\alpha$ of 0.745 ($n = 10$). Factor 2 ($m = 4.22$, $SD = 0.73$, $n = 6$) includes the other input reductions farmers changed since using the 3R3G and 1M5R technologies, e.g., reduced postharvest losses as well as water, electricity, and fuel usage. In addition, two items related to soil health – using more organic fertilizer and reduced soil erosion – are included in this factor. This factor can consequently be described as the added benefits factor. Reliability analysis of the items in the added benefits factor resulted in a Cronbach's $\alpha$ of 0.486 ($n = 6$). Factor 3 was not further analyzed because it comprised of just two items which does not allow for a conclusive interpretation. Hence, it was not further examined. Factor 4 can be regarded as the rice straw factor as all statements related to sustainable rice straw practices are included in this factor ($m = 2.08$, $SD = 1.15$, $n = 3$). Cronbach's $\alpha$ was 0.533. Ultimately, the factors added benefits and rice straw demonstrated a low reliability ($\alpha < 0.7$) (Ursachi, Horodnic, Zait 2015: 681). No significant differences between farmers in An Giang and Can Tho Province were present for the 1M5R factor ($t(463) = -0.829$, $p = 0.407$) as well as for the rice straw factor ($t(463) = 1.955$, $p = 0.051$). Nevertheless, the added benefits factor ($t(463) = -2.430$, $p = 0.015$, $d = 0.225$) was rated considerably differently by the two farmer groups. Farmers in Can Tho Province ($m = 4.31$, $SD = 0.73$) rated this factor higher than farmers in An Giang Province ($m = 4.14$, $SD = 0.72$).

Table 13.7 Mean ratings of the perceived farming practice changes since the adoption of 1M5R technologies and factor loadings of the rotated component matrix of the confirmatory factor analysis

| Perceived changes in farming practice since adopting 1M5R technologies | Mean rating (SD) | | | Factor loadings | | | |
|---|---|---|---|---|---|---|---|
| | All [1] | An Giang [2] | Can Tho [3] | 1 | 2 | 3 | 4 |
| It was difficult for me to use fewer seeds. *, + | 2.97 (1.92) | 3.16 (2.00) | 2.77 (1.83) | **-.426** | .121 | -.011 | .124 |
| It was easy for me to change to certified seeds. | 5.16 (1.14) | 5.11 (1.22) | 5.21 (1.05) | **.366** | -.245 | .025 | -.036 |
| It was easy for me to use less chemical fertilizer. | 4.08 (1.53) | 4.08 (1.51) | 4.08 (1.55) | **.745** | -.212 | .129 | .008 |
| I have used more organic fertilizer. ***, + | 2.25 (1.47) | 2.55 (1.56) | 1.93 (1.30) | .039 | **.291** | .206 | .220 |
| It was easy for me to use less herbicide. | 3.52 (1.66) | 3.48 (1.60) | 3.56 (1.72) | **.708** | .297 | -.234 | .182 |
| It was easy for me to use less insecticide. | 4.13 (1.45) | 4.01 (1.46) | 4.26 (1.43) | **.834** | -.156 | .044 | .065 |
| It was difficult for me to use less rodenticide. **, + | 3.55 (1.66) | 3.33 (1.62) | 3.77 (1.68) | **.677** | .306 | -.176 | .100 |
| It was easy for me to use less molluscicide. | 3.32 (1.64) | 3.22 (1.56) | 3.42 (1.72) | **.663** | .449 | -.206 | .099 |
| It was difficult for me to use less fungicide. *, + | 4.04 (1.43) | 3.90 (1.41) | 4.19 (1.43) | **.818** | -.123 | .078 | .000 |
| It was difficult for me to reduce my water use. + | 2.97 (1.55) | 2.87 (1.56) | 3.08 (1.53) | -.132 | **.497** | .024 | -.079 |
| I have been doing fewer irrigation hours. | 3.86 (1.48) | 3.80 (1.50) | 3.92 (1.45) | **.605** | .075 | .052 | .020 |
| I have used more fuel for my agricultural machinery. + | 2.69 (1.54) | 2.67 (1.53) | 2.72 (1.56) | -.016 | **.655** | .184 | -.036 |
| I have used less electricity for my agricultural practices. *** | 3.62 (1.76) | 3.17 (1.66) | 3.40 (1.74) | .340 | **.440** | -.154 | -.251 |
| My soils have been more prone to erosion. + | 2.56 (1.49) | 2.45 (1.46) | 2.67 (1.52) | -.018 | **.519** | .091 | .084 |
| I leave my fields fallow during one rice season. | 2.62 (1.80) | 2.67 (1.86) | 2.57 (1.74) | .057 | .068 | .064 | **.329** |
| I have noticed fewer postharvest losses. | 4.21 (1.51) | 4.17 (1.46) | 4.25 (1.55) | **.568** | -.017 | .170 | -.129 |
| It has been difficult for me to reduce my postharvest losses. + | 2.81 (1.53) | 2.77 (1.58) | 2.85 (1.48) | -.067 | **.486** | .035 | .239 |
| I have been collecting my rice straw. ** | 1.98 (1.63) | 2.19 (1.73) | 1.76 (1.48) | -.069 | -.075 | .062 | **.866** |
| I have used my rice straw for mulching, cattle fee, mushroom production, biogas production or other. | 1.65 (1.36) | 1.70 (1.38) | 1.61 (1.32) | -.060 | .050 | .034 | **.833** |
| I have planted trees and/or shrubs. * | 1.93 (1.53) | 2.11 (1.64) | 1.75 (1.38) | .076 | .173 | **.886** | .133 |
| I have also planted other plants – not rice – between or alongside my fields. | 1.79 (1.42) | 1.89 (1.49) | 1.69 (1.34) | .048 | .154 | **.905** | .121 |

Note: [1] N = 465, [2] n = 236, [3] n = 229; 6-point Likert-type scale: 1 = completely disagree, 6 = fully agree; * p = ≤0.05, ** p = <0.01, *** p = <0.001 for t-test analysis comparing both provinces; + reverse coded for mean calculation; highest factor loadings are bold; Cronbach's α factor 1 = 0.745, factor 2 = 0.486, factor 4 = 0.533

In order to find out about the changes that may have occurred since adopting the recommended practices and technologies, farmers rated statements of 12 dimensions of change. The objective of these questions was to examine farmers' perceived changes in different aspects of their living conditions.

**Agricultural production.** Changes in agricultural production were evaluated using 13 items (Table 13.8). Reliability analysis of the items resulted in a Cronbach's α of 0.827. The mean score for agricultural production was 4.31 (SD = 0.86, n =13). Farmers indicated small to moderate changes concerning production. They mostly agreed that they were able to decrease the seed rate, use recommended rice varieties, save money due to avoided production costs, and that their rice quality improved. Farmers generally used certified seeds due to rather disagreeing on not using certified seeds. Overall, they reduced postharvest losses and used fewer inputs. Thus, they decreased production costs since adopting the recommended technologies. No significant differences between the two provinces were found except for the item "I use recommended rice varieties" (t(463) = -2.276, p = 0.023, d = 0.211). Farmers in Can Tho Province (m = 4.67, SD = 1.48) rated this statement significantly higher than farmers in An Giang Province (m = 4.34, SD = 1.67).

Table 13.8 Mean ratings of the items in the dimension agricultural production

| Agricultural production | Mean | Std. Deviation |
|---|---|---|
| My yield has increased a lot. | 3.84 | 1.37 |
| I have produced higher quality rice. | 4.33 | 1.31 |
| Rice farming has become more difficult. + | 2.89 | 1.61 |
| I use recommended rice varieties. * | 4.50 | 1.59 |
| I do not use certified seeds. + | 2.30 | 1.76 |
| I have reduced my water use. | 3.95 | 1.52 |
| Working on farm is not as hard anymore. | 4.06 | 1.58 |
| I have been able to save money due to avoided production costs. | 4.42 | 1.33 |
| My seed rate has decreased. | 4.79 | 1.42 |
| I spend more money on production costs. + | 2.62 | 1.58 |
| My fertilizer use has decreased. | 4.13 | 1.51 |
| I now apply more pesticides. + | 2.47 | 1.46 |
| I have fewer postharvest losses. | 4.26 | 1.46 |

Note: N = 465; 6-point Likert-type scale: 1 = completely disagree, 6 = fully agree; * p = ≤0.05, ** p = <0.01, *** p = <0.001 for t-test analysis comparing both provinces; + reverse coded for mean calculation

**Physical capital.** Six items were used to evaluate the perceived changes in physical capital. The reliability analysis of the statements resulted in a Cronbach's α of 0.761 (Table 13.9). The mean score for the physical capital dimension was 2.66 (SD = 1.11, n = 6). In general, farmers rather disagreed with the statements regarding changes in physical capital. The only item with an average rating close to agreeing was "I can afford to buy pesticide safety equipment". Farmers rated the statement "I have been able to buy new farming equipment" significantly apart (t(463) = -3.201, p = 0.001, d = 0.297). Can Tho farmers' (m = 3.01, SD = 1.82) rated the item closer to agreeing than An Giang farmers (m = 2.48, SD = 1.72). Additionally, the item "I was able to have my house renovated and improved" was rated considerably closer to agreeing by the farmers in An Giang Province (m = 3.00, SD = 1.77) than by the farmers in Can Tho Province (m = 2.69, SD = 1.59) (t(463) = 1.986, p = 0.048, d = 0.184).

Table 13.9 Mean ratings of the items in the dimension physical capital

| Physical capital | Mean | Std. Deviation |
|---|---|---|
| I have been able to buy new farming equipment. *** | 2.74 | 1.79 |
| I have been able to upgrade or build new farm buildings (e.g., tractor shed). | 1.95 | 1.36 |
| I can afford to buy pesticide safety equipment. | 3.68 | 1.76 |
| I rent more land for rice production. | 2.65 | 1.80 |
| I was able to have my house renovated and improved. * | 2.84 | 1.69 |
| I have been able to build a new house. | 2.10 | 1.47 |

Note: N = 465; 6-point Likert-type scale: 1 = completely disagree, 6 = fully agree; * p = ≤0.05, ** p = <0.01, *** p = <0.001 for t-test analysis comparing both provinces

**Human capital.** The dimension human capital was evaluated using four items. The mean rating was 4.33 (SD = 1.15, n = 4) and reliability resulted in a Cronbach's α of 0.843 (Table 13.10). Farmers perceived an improvement of the human capital since using the recommended practices and technologies. In particular, they were able to gain knowledge through technology adoption. Significant differences between the two provinces were found for the statement "I have been able to provide a better workforce" (t(463) = -2.579, p = 0.010, d = 0.239). Farmers in Can Tho Province (m = 3.84, SD = 1.67) agreed more strongly with this statement than farmers in An Giang Province (m = 3.44, SD = 1.69).

Table 13.10 Mean ratings of the items in the dimension human capital

| Human capital | Mean | Std. Deviation |
|---|---|---|
| I have gained a lot of knowledge. | 4.78 | 1.18 |
| I have been able to provide a better workforce. ** | 3.64 | 1.69 |
| I have changed my farming habits. | 4.56 | 1.32 |
| I am now able to express concerns about my farming practices. | 4.32 | 1.33 |

Note: N = 465; 6-point Likert-type scale: 1 = completely disagree, 6 = fully agree; * p = ≤0.05, ** p = <0.01, *** p = <0.001 for t-test analysis comparing both provinces

**Social capital.** Four statements were used to analyze the social capital dimension. The mean rating score was 3.84 (SD = 1.18, n = 4) (Table 13.11). Reliability analysis of the statements resulted in a Cronbach's α of 0.826. Overall, farmers perceived a positive change in their social capital and generally agreed with the statements. No significant differences in rating the items were found between the two provinces.

Table 13.11 Mean ratings of the items in the dimension social capital

| Social capital | Mean | Std. Deviation |
|---|---|---|
| I can now provide advice to fellow farmers on how to improve their farming practices. | 4.03 | 1.44 |
| I can now organize farmers into groups to work together to improve farming practices. | 3.07 | 1.54 |
| The best management practices have been widely adopted by the rice farmers in my community. | 4.10 | 1.42 |
| I can now communicate with other farmers about my experience in using best management practices. | 4.15 | 1.42 |

Note: N = 465; 6-point Likert-type scale: 1 = completely disagree, 6 = fully agree

**Food security.** For the dimension food security, six statements were examined. Reliability analysis resulted in a Cronbach's α of 0.815. The mean rating score was 3.95 (SD = 0.91, n = 6) (Table 13.12). Farmers perceived beneficial changes to their food habits in relation to the adoption of the practices and technologies. They rated the statement "My family can eat more vegetables" the highest. A considerably different rating between the two provinces was found for the item "My family can eat more meat" (t(463) = -2.282, p = 0.023, d = 0.212). Farmers in Can Tho Province (m = 4.18, SD = 1.28) rated this statement significantly higher than farmers in An Giang Province (m = 3.90, SD = 1.40).

Table 13.12 Mean ratings of the items in the dimension food security

| Food security | Mean | Std. Deviation |
|---|---|---|
| My family's eating habits have not changed at all. + | 3.50 | 1.46 |
| My family can eat more meat. * | 4.04 | 1.35 |
| My family can eat more fruit. | 4.37 | 1.18 |
| My family can eat more vegetables. | 4.47 | 1.16 |
| My family eats more kinds of food. | 4.25 | 1.33 |
| The portion sizes of our meals have increased. | 4.04 | 1.37 |

Note: N = 465; 6-point Likert-type scale: 1 = completely disagree, 6 = fully agree; * p = ≤0.05, ** p = <0.01, *** p = <0.001 for t-test analysis comparing both provinces; + reverse coded for mean calculation

**Financial capital.** Three statements were used to ask farmers about their perceived changes in financial capital (Table 13.13). The reliability of the scale demonstrated a Cronbach's α of 0.746 (n = 3). Farmers slightly disagreed with the first two statements and rather agreed to the third item. For this last statement, farmers in An Giang Province (m = 3.44, SD = 1.75) showed a higher approval rating than farmers in Can Tho Province (m = 3.02, SD = 1.68) (t(463) = 2.599, p = 0.010, d = 0.241). In general, farmers neither strongly agreed nor disagreed with the perceived changes in financial capital (m = 3.01, SD = 1.46).

Table 13.13 Mean ratings of the items in the dimension financial capital

| Financial capital | Mean | Std. Deviation |
|---|---|---|
| I have been able to provide financial support to others. | 2.88 | 1.84 |
| I have been able to take out a loan. | 2.91 | 1.82 |
| I have been able to save money due to increase in income. ** | 3.23 | 1.73 |

Note: N = 465; 6-point Likert-type scale: 1 = completely disagree, 6 = fully agree; * p = ≤0.05, ** p = <0.01, *** p = <0.001 for t-test analysis comparing both provinces

**Cultural capital.** Three items were used for the dimension cultural capital (Table 13.14). Reliability analysis resulted in a Cronbach's α of 0.752. Farmers generally agreed with the statements and the average rating score was 3.75 (SD = 1.32, n = 3). However, the third item, "I was able to participate in religious pilgrimages", was rated considerably lower than the other two statements. Furthermore, significant differences were found between the two provinces for two items. Farmers in Can Tho Province (m = 4.38, SD = 1.48) rated the statement "I am able to participate in community activities" significantly higher than farmers in An Giang Province (m = 3.83, SD = 1.66) (t(463) = -3.755, p = <0.001, d = 0.348). Also, "I was able to participate in religious pilgrimages" received a considerably higher rating by Can Tho farmers (m = 3.12, SD = 1.76) compared to An Giang farmers (m = 2.64, SD = 1.67) (t(463) = -3.029, p = 0.003, d = 0.281).

Table 13.14 Mean ratings of the items in the dimension cultural capital

| Cultural capital | Mean | Std. Deviation |
|---|---|---|
| I am able to participate in community activities. *** | 4.10 | 1.60 |
| I can now provide more donations/pledges for community activities. | 4.28 | 1.49 |
| I was able to participate in religious pilgrimages. ** | 2.88 | 1.73 |

Note: N = 465; 6-point Likert-type scale: 1 = completely disagree, 6 = fully agree; * p = ≤0.05, ** p = <0.01, *** p = <0.001 for t-test analysis comparing both provinces

**Poverty.** Six items were included in the dimension poverty and reliability analysis resulted in a Cronbach's α of 0.796 (n = 6) (Table 13.15). The mean score for the poverty dimension was 4.41 (SD = 0.95). Farmers were able to reduce their poverty level. They agreed to being able to purchase new items such as a mobile phone or home furniture. They also had more money in general. In particular, farmers in Can Tho Province (m = 4.31, SD = 1.40) rated the statement "I have more money than before" significantly higher than farmers in the neighboring province (m = 4.03, SD = 1.43) (t(465) = -2.105, p = 0.036, d = 0.195).

Table 13.15 Mean ratings of the items in the poverty dimension

| Poverty | Mean | Std. Deviation |
|---|---|---|
| I can buy fashionable clothes for my children. | 4.23 | 1.43 |
| I was able to buy a mobile phone. | 4.44 | 1.35 |
| I was able to buy new furniture for the family home. | 4.58 | 1.22 |
| I have more money than before. * | 4.17 | 1.42 |
| My family has more money to spend. | 4.12 | 1.36 |
| I have lost a lot of money. + | 2.05 | 1.35 |

Note: N = 465; 6-point Likert-type scale: 1 = completely disagree, 6 = fully agree; * p = ≤0.05, ** p = <0.01, *** p = <0.001 for t-test analysis comparing both provinces + reverse coded for mean calculation

**Land tenure.** The dimension land tenure was analyzed using four statements (Table 13.16). The reliability of the scale showed a Cronbach's α of 0.518 (n = 4). By removing the statement "I had to sell some of my land", Cronbach's α increased to 0.847 (n = 3). Farmers generally disagreed with the statements and the mean score was 2.34 (SD = 1.42). The statement "I have been able to buy land for building a house" received the lowest level of agreement. No significant differences between the farmers in the two provinces were found in rating the land tenure items.

Table 13.16 Mean ratings of the items in the dimension land tenure

| Land tenure | Mean | Std. Deviation |
|---|---|---|
| I have been able to expand my rice production by renting other land. | 2.66 | 1.76 |
| I had to sell some of my land. + | 1.62 | 1.16 |
| I have been able to buy more land for farming other crops, vegetables, or fruit. | 2.29 | 1.59 |
| I have been able to buy land for building a house (or rented the land where the house is). | 2.09 | 1.49 |

Note: N = 465; 6-point Likert-type scale: 1 = completely disagree, 6 = fully agree; + reverse coded and deleted for further analysis

**Health.** In order to examine the dimension of health change, farmers were asked to rate five items (Table 13.17). The reliability analysis resulted in a Cronbach's α of 0.657 (n = 5). However, by excluding "I have more health issues", it increased to 0.723 and the average rating score was 4.67 (SD = 0.92, n = 4). Farmers perceived a positive change in their health since using the recommended practices and technologies. The highest-rated statement was "I can afford private health insurance". No significant differences were found between the farmers in the two provinces regarding the rating of the health statements.

Table 13.17 Mean ratings of the items in the health dimension

| Health | Mean | Std. Deviation |
|---|---|---|
| My health has improved a lot. | 4.36 | 1.29 |
| I have more health issues. + | 2.72 | 1.61 |
| I can immediately seek healthcare without waiting for government support. | 4.60 | 1.38 |
| I can afford private health insurance. | 5.26 | 1.06 |
| My family members have become healthier. | 4.49 | 1.20 |

Note: N = 465; 6-point Likert-type scale: 1 = completely disagree, 6 = fully agree, + reverse coded item and deleted for further analysis

**Employment.** The average score for employment was 2.60 (SD = 1.43) and included three items (Table 13.18). The reliability analysis resulted in a Cronbach's α of 0.704. Farmers rather disagreed with the statements. No significant differences between the two provinces were found.

Table 13.18 Mean ratings of the items in the dimension employment

| Employment | Mean | Std. Deviation |
|---|---|---|
| I was able to take on other paid work. | 2.95 | 1.90 |
| My wife/husband was able to take on other paid work. | 2.49 | 1.77 |
| I was able to employ more farm workers. | 2.38 | 1.74 |

Note: N = 465; 6-point Likert-type scale: 1 = completely disagree, 6 = fully agree

**Natural capital.** For analyzing farmers' perceived environmental changes, 20 items were used (Table 13.19). Farmers were shown pictures of beneficial indicator and pest indicator species in rice fields to have a clearer understanding of biodiversity changes. Additionally, two items asking about plant biodiversity and the environment, in general, were included in the scale. Reliability analysis resulted in a Cronbach's α of 0.690 and the mean rating was 3.34 (SD = 0.45, n = 20). Overall, farmers perceived slight changes in their natural capital. They most strongly agreed with the statements "The environment has improved overall", "There are more dragonflies in my fields", and "I have seen more butterflies in my fields". Conversely, the items with the lowest agreement were "I have seen more bats", "There are more wildflowers around my fields", and "There are more trees and shrubs on my farm". The only item that was rated significantly apart was "I see more wasps in my fields" ($t(463) = -2.866$, $p = 0.004$, $d = 0.266$). Can Tho farmers ($m = 3.45$, $SD = 1.55$) agreed significantly more with this statement than An Giang farmers ($m = 3.05$, $SD = 1.49$).

In order to examine the perceived changes of beneficial indicator species and pests indicator species, two scales were created. The beneficial indicator species scale consisted of items mentioning wasps, flies, dragonflies, birds, frogs, fish, bats, snakes, spiders, trees and shrubs, wildflowers, and improved environment. The reliability analysis of the beneficial indicator species scale resulted in a Cronbach's α of 0.599 and an average rating of 3.30 (SD = 0.63, n = 12). No significant differences were found for the average rating of the beneficial indicator species scale between the farmers in the two provinces ($t(463) = -1.348$, $p = 0.178$). The pest indicator species scale consisted of items mentioning rats, crickets, bugs, beetles, butterflies, stemborers, moths, and planthoppers. It showed a Cronbach's α of 0.593 and a mean score of 3.42 (SD = 0.61, n = 8). No considerable differences were found between the farmers in the two provinces for the ratings of the pest indicator species scale (t(463) = -1.684, p = 0.093).

Table 13.19 Mean ratings of the items in the dimension natural capital

| Natural capital | Mean | Std. Deviation |
|---|---|---|
| I see more wasps in my fields. ** [1] | 3.25 | 1.53 |
| I see fewer flies in my fields. [+, 1] | 3.39 | 1.54 |
| There are more dragonflies in my fields. [1] | 3.79 | 1.54 |
| I have seen fewer birds around my fields. [+, 1] | 3.22 | 1.60 |
| I have seen fewer frogs in my fields. [+, 1] | 2.99 | 1.49 |
| There are more fish in my fields. [1] | 3.17 | 1.51 |
| I have seen fewer rats in my fields. [+, 2] | 3.39 | 1.59 |
| There are more crickets in my fields. [2] | 2.86 | 1.40 |
| I have seen more bats in my fields. [1] | 1.88 | 1.26 |
| I have seen more bugs in my fields. [2] | 3.33 | 1.30 |
| There are fewer beetles in my fields. [+, 2] | 3.33 | 1.53 |
| I have seen more butterflies in my fields. [2] | 3.70 | 1.29 |
| I have seen fewer snakes in my fields. [+, 1] | 3.50 | 1.87 |
| There are more stemborers in my fields. [2] | 3.40 | 1.39 |
| I have seen fewer moths in my fields. [+, 2] | 3.49 | 1.25 |
| I have seen fewer spiders in my fields. [+, 1] | 3.06 | 1.60 |
| I see more planthoppers in my fields. [2] | 3.25 | 1.43 |
| There are more trees and shrubs on my farm. [1] | 2.44 | 1.62 |
| There are more wildflowers around my fields. [1] | 2.31 | 1.47 |
| The environment has overall improved. [1] | 3.87 | 1.75 |

Note: N = 465; 6-point Likert-type scale question format with species corresponding pictures; * p = ≤0.05, ** p = <0.01, *** p = <0.001 for t-test analysis comparing both provinces; [+] reverse coded item; [1] beneficial indicator species, [2] pest indicator species

## 13.4 Discussion

The present study examined rice farmers' 1M5R technology adoption behavior and perceived benefits of the program's recommended technologies. Furthermore, the subsequent perceived changes, in particular, agronomic changes, including savings on inputs, and multiple livelihood dimensions were analyzed. Farmers from two neighboring provinces were studied because the technologies were introduced at different times. The farmers in An Giang Province were first introduced to 1M5R in 2009, while farmers in Can Tho Province were introduced to the program in 2010 (Connor et al. 2020a: 12; Flor et al. 2021). Besides, the farmers in the two provinces had already been introduced to the 3R3G national policy program beforehand. Thus, they possibly had been introduced to several technologies already (Huelgas, Templeton, Castanar 2008: 4). Farmers' average length of technology adoption was over eight years, with a minimum of 6.5 years for AWD and a maximum of 8.7 years for combine harvester. The time from introduction to adoption was short for all technologies and happened within a couple of months. This can be attributed to effective training and extensive promotion campaigns in which farmers were able to test the technologies on demonstration plots and field trials (Huelgas, Templeton, Castanar 2008: 3; Josephson et al. 2020: 4). As a result, many farmers were familiar with 1M5R technologies and quickly decided to adopt at least one. These aspects have been shown to be curial for taking the decision to adopt a new technology or change a traditional practice. Trialability is an essential part of the adoption-decision process. Farmers can experience if the technology fits their needs and if it is compatible with their environment (Rogers 2003: 169; Dearing 2009: 4; Mwangi, Kariuki 2015: 210). Overall, the findings show that An Giang farmers used the recommended technologies for longer. Considerably more An Giang farmers switched from 3R3G to 1M5R in comparison with the farmers in Can Tho Province. This is in alignment with the official information of the DARD regarding the adoption of the two programs in the provinces (Josephson et al. 2020: 22). Most farmers in An Giang Province fully transferred from 3R3G to 1M5R, whereas a little more than half of the Can Tho farmers switched the program. Nevertheless, more than double the number of farmers were trained in Can Tho Province on 3R3G compared to An Giang Province. The number of trained farmers for 1M5R is similar in both provinces. Around 12'000 farmers in An Giang Province and more than 13'000 farmers in Can Tho Province were trained on 1M5R. Of these, around 8000 farmers in both provinces have adopted 1M5R practices and technologies (Josephson et al. 2020: 22).

Most adopted technologies were still practiced by the interviewed farmers. Additionally, their plans to continue using the technologies were generally positive, with the exception of An Giang farmers who adopted a drum seeder. A third of these farmers said that they would not continue using this technology. Regardless, all technologies received high mean benefit scores (>5.0). Famers' highest-rated statement overall was "easy to apply". This is a positive result because ease of use is essential during the persuasion phase of farmers' decision process (Rogers 2003: 169–170; Dearing 2009: 4). In comparison to other studies looking at benefit perceptions of technologies, similar results regarding the most important aspects for long-term adoption were found (Davis 1989; Mottaleb 2018; Tu et al. 2018; Connor et al. 2020a; Wehmeyer, de Guia, Connor 2020). For example, in South China, farmers who adopted an input reducing technology also rated ease of use the highest benefit of adoption, followed by "satisfies my preferences" and "fits my cropping pattern" (Wehmeyer, de Guia, Connor 2020: 7–8; Chapter 8.3.1). HYVs and combine harvester were the technologies with the highest mean benefit rating. However, significant differences were present between the two provinces regarding the length of adoption and the rating of the perceived benefits. An Giang farmers adopted the two technologies earlier and rated the benefits lower than Can Tho farmers. Connor et al. found the same tendency regarding the 1M5R input reduction recommendations and the use of certified seeds (2020a: 7–8). Moreover, this trend was also found for the other technologies as well as for the livelihood dimensions of change. Can Tho farmers generally agreed more strongly with the positive change statements.

The subsequent confirmatory factor analysis demonstrated that the perceived benefits were in line with the objectives of the 1M5R program. The three factors showed good to high reliability (<0.770). The compatibility factor includes the positive changes of the program with high factor loadings on perceived improvements of personal preferences. Thus, this result indicates that farmers have properly perceived the program's objectives and found it compatible with their farming practices. The relative advantage factor of this study depicts how relevant this step is in the decision-making process for adopting a new technology (Rogers 2003: 169–170). Farmers have been able to achieve good rice yields and a slight yield increase since using 1M5R technologies. At the same time, they perceived improved environmental conditions and plant health as well as reduced pressure from drought through technology adoption. Consequently, farmers experienced that their rice was produced more sustainably without yield losses, and thus profit reduction. From an economic perspective, this indicates that farmers were convinced that switching to a recommended technology would improve their revenue. Farmers rated the benefit statements "less expensive" and "high income" highly. It has been shown that economic risk is a major barrier to adoption, especially for smallholder farmers (Smith, Siciliano 2015: 22; Wang et al. 2020: 5). In addition, farmers' perceptions of environmental aspects indicate that they are aware of environmental changes and their influence on rice production. This is particularly important in the context of climate change. Correspondingly, multiple studies have shown that farmers are aware of climate change and environmental degradation (Abid et al. 2016: 447–448; Cullen, Anderson 2017: 531; Connor et al. 2020b: 2; Karki, Burton, Mackey 2020: 80). They depict that agroecological factors play an important role in the adoption of new practices or technologies. Lastly, the damage reduction factor demonstrates that farmers perceived a beneficial change in their fields in terms of pests. Hence, the three factors show that the adoption of the 1M5R technologies positively influenced farmers' personal and environmental situation as well as their agricultural profitability. Moreover, the findings of this study suggest that farmers adhere to technologies when they are satisfied with the positive economic return. This is further exemplified by the well-perceived savings on input costs in combination with facilitated application and a good fit for personal characteristics. These findings are in accordance with the literature (Davis 1989; Mwangi, Kariuki 2015; Tu et al. 2018; Wehmeyer, de Guia, Connor 2020; Connor et al. 2021a). Overall, this study shows that the recommended technologies have been accepted and applied by farmers for multiple years due to a positive perception of the benefits and changes. 3R3G and 1M5R supported the transition from economically and environmentally damaging rice production to more sustainable rice production in line with the principles of the sustainable rice platform (SRP 2019b: 5–6; Demont, Rutsaert 2017: 3).

In this study, special attention was given to perceived agronomic changes because the perception of economic risk and financial development are crucial elements to assess during the adoption-decision process (Mwangi, Kariuki 2015: 2010; Smith, Siciliano 2015: 22; Abid et al. 2016: 449). The changes in input cost since the adoption of the 1M5R technologies were specifically analyzed. For the main elements of rice farming, namely seeds, fertilizer, and pesticides, more than half of the farmers perceived considerable savings. In this regard, the recommended technologies strongly improved farmers' input efficiency as they reported yield increases while reducing inputs. They also indicated that they decreased their seed rate by more than 70 kg/ha on average. Nonetheless, the mean seed rate of more than 160 kg/ha remains considerably above the program's requirements. This indicates that although farmers have been applying the 1M5R recommendations and technologies, they are not able to attain the appropriate amounts. Such results were also found in Chapter 12.3.3 and Stuart et al. (2018a: 108). Hence, there clearly is incomplete adoption. This is demonstrated by the discrepancy between actual adoption and complete realization. However, it is suggested that due to the generally substantial reduction of the seed rate over time, farmers will continue to decrease the amount step by step to reach the recommendations (Connor et al. 2020a: 13). In general, the agronomic results were similar in both provinces, with the exception that Can Tho farmers had much higher input costs for seeds, fertilizer, pesticides, and harvest-postharvest activities. An Giang farmers only had significantly higher irrigation costs, but this cost element was rather small compared to the others. The confirmatory analysis on farmers' perceived changes in rice farming practices resulted in four factors, of which one factor remained pertinent. The 1M5R factor indicated good reliability and indicates that farmers perceived relevant improvements due to the adoption of the technologies. They rated the statements focusing on the 1M5R recommended reductions generally higher than other statements, e.g., "It was easy for me to change to certified seeds", "I have noticed fewer postharvest losses", or "It was easy for me to use less insecticide". Thus, farmers were able to reduce their input use through the adoption of the recommended practices and technologies. Consequently, farmers experienced a beneficial change in their agricultural production through the adoption of the 1M5R practices and technologies, echoing the previous results of this study and others. This can be interpreted as a positive sign for continued and long-term adoption.

Twelve dimensions of change were examined to determine the changes in living conditions farmers experienced since using the recommended technologies. Overall, farmers perceived beneficial personal, social, and financial changes, including better health, higher human and social capital as well as improved food security and lower poverty levels. Studies have shown that the adoption of new technologies or practices can improve other aspects of farmers' lives, and thus promote continued use (Rosa da Conceição, Börner, Wunder 2015: 243; Arega, Gelan, Jeyabalasingh 2018: 77; Wehmeyer, de Guia, Connor 2020: 1). In the context of climate change adaptation, this is a relevant aspect for future technology dissemination strategies. Nevertheless, other dimensions of change, such as physical capital, employment, and land tenure, did not receive high ratings. Moreover, environmental differences were not strongly perceived either. This could be due to the fact that environmental changes take longer to come into effect. Similar results were found in Wehmeyer, de Guia, and Connor (2020: 13) and Connor et al. (2021: 10). Chinese and Indonesian rice farmers rated the same statements in the natural capital dimension. However, it is important to stress that rice farmers in the Mekong River Delta still use very high amounts of inputs. This is harmful to the environment. Although farmers were able to reduce their inputs due to 3R3G and 1M5R adoption, they continue to overuse inputs. This is in line with the results in Chapter 12.3.3 and the current literature on the programs' adoption (Willett, Barroga 2016; Nguyen 2017; Stuart et al. 2018; Connor et al. 2020a; Josephson et al. 2020). Beneficial environmental shifts remain a determining factor for persisting rice cultivation. Therefore, more research is needed to understand the barriers behind the continued excessive use of inputs. Furthermore, the findings of this study suggest that although the technologies have not been adopted by the farmers at the same time, annual agronomic results did not differ much between the two provinces. However, the perceptions of the technologies were overall higher and more positively rated by Can Tho farmers. A possible explanation could be that these farmers adopted the technologies for a shorter period in which the impacts are still very visible. Also, the transition from 3R3G to 1M5R is ongoing in Can Tho Province. Over a third of the farmers stated that they still follow 3R3G guidelines. Additionally, more Can Tho farmers had three rice seasons per year, and hence used the technologies more often than An Giang farmers.

Overall, the findings of this study demonstrate that rice farmers in the provinces of An Giang and Can Tho are using 1M5R technologies and have perceived beneficial changes from adoption. The adoption time in combination with the highly-rated benefits shows that the technologies are suitable for farmers' practices and will continue to remain an essential part of their farming routine. Hence, farmers have been producing rice more sustainably through improved mechanization and modernization. Nevertheless, this study also reveals that farmers have not been able to reach 1M5R input recommendations despite the long adoption time of several years. In this regard, more research is needed to examine the barriers to achieving these objectives. Actions have been taken in collaboration with private sector actors. They engage in close monitoring of production processes, provide farmers with certified seeds, and monitor their input use as well as assure to buy their paddy (Demont, Rutsaert 2017: 6). Lastly, this study highlights that the adoption of sustainable agricultural technologies not only has a positive impact on farmers' economic situation but also benefits other livelihood dimensions.

**Limitations.** Some limitations need to be considered when interpreting the results. The present study was conducted in only two provinces of the Mekong River Delta. It does, therefore, not represent all rice farmers in the Mekong River Delta or Vietnam as a whole. Furthermore, the study region was selected based on purposive geographic sampling by the local government. Nevertheless, farmer sampling was conducted randomly. The agronomic and socioeconomic information entirely relies on recall and self-reported measures. In this regard, the results are susceptible to biases, such as recall bias and social desirability bias. Finally, it was not possible to analyze the data in a gender disaggregate manner because 95 % of the participants were male. Investigating the differences in the technology adoption rate, the perceptions of the benefits, and generally perceived livelihood changes between gender could not be conducted. For future studies, efforts need to be also taken to include female farmers.

# Part IV

# Synthesis

# 14 Synthesis

The objective of this research was to examine the impact of the CORIGAP project on rice farmers' productivity levels, input-out efficiency, and profitability as well as their social situation and environmental footprint. Therefore, an assessment of three CORIGAP project countries was performed to evaluate the agronomic and socioeconomic developments as well as change perceptions of farmers in China, Myanmar, and Vietnam. This final chapter offers a synthesis of the main results of the country analyses in the context of the four relevant perspectives for this thesis. These perspectives are geographical-environmental, policy, agronomic, and psychosocial (Chapter 6.1). The first part of the synthesis summarizes the empirical findings of each country analysis. The second part discusses the results for the assessment of CORIGAP's impact overall. It presents the implications for further development projects centering around the diffusion of sustainable agriculture practices and technologies. The chapter closes with concluding remarks.

## 14.1 Major Findings

This thesis was designed as an explorative study to evaluate the effect of the CORIGAP project in three selected countries. In China, farmers were interviewed about their perceptions of 3CT and the changes they have experienced since using the technology. In Myanmar, farmers' agronomic and socioeconomic progress due to the introduction of sustainable farming practices and technologies was analyzed. Lastly, in Vietnam, farmers' agronomic performance in the context of 1M5R recommended practices and technologies was examined first. Second, farmers' perceptions of four 1M5R technologies for sustainable rice farming were explored. These study regions have in common that they lie in Southeast Asia, that rice remains the staple food crop in the region, and that efforts for sustainable and climate-smart rice farming were supported by the CORIGAP project. These countries, however, also differ strongly from each other with regard to their socio-political and socio-cultural differences as well as historical evolution and environmental circumstances. Each region required a customized technology diffusion strategy to promote agricultural development for long-lasting change. Therefore, a multifactorial analysis including socio-cultural-political, environmental-geographical, and social-behavioral aspects was conducted.

**China.** Rice farmers in South China use high amounts of agricultural inputs to achieve high yields. They often rely on the recommendations given to them during the Green Revolution. Rice yields have been increasing steadily since the 1960s. However, nowadays, farmers are progressively confronted with stagnating yield growth due to environmental degradation caused by unsustainable natural resource management. This problem is exacerbated by the harmful effects of climate change. In this regard, 3CT was developed to reduce fertilizer and pesticide use by incentivizing farmers to apply fertilizer only at specific times during the season. Concretely, the three controls are 1) control of nitrogen fertilizer application quantity and timing, 2) control of unproductive tillers and a set number of maximum tillers, and 3) control of fungicide and other pesticide applications. Farmers who adopt 3CT benefit from stable rice yields and increased profitability, lower input cost and labor hours, reduced risk of lodging, and improved environmental conditions. 3CT was released for large-scale dissemination in Guangdong Province in 2007. A broad diffusion strategy was launched to disseminate the technology. Additionally, 3CT was included in a World Bank project from 2014 to 2018. This further accelerated the diffusion the innovation. As of today, more than 300'000 farmers participated in activities promoting 3CT.

The objective of the study on 3CT was to evaluate the effect of 3CT adoption on the three main pillars of sustainability, namely, economic, social, and environmental. In total, 142 farmers participated in the survey. All farmers adopted 3CT and planned on continuing its use. They rated the benefits very highly. Notably, the technology's ease of use and good fit were the most important benefits of adoption. Farmers also perceived improved profitability and yield increases due to the adoption. They additionally experienced positive livelihood changes, such as improved health and food security as well as increased human and social capital. Overall, the study demonstrated that farmers adopted 3CT not only for its economic benefits but also for the beneficial social aspects, e.g., reduced labor hours, simplified farming, and reduced poverty levels. Nevertheless, environmental improvements were not perceived much by farmers. Most probably, this is due to the relatively short period of adoption of only a couple of years. Still, farmers already perceived small changes. Therefore, a positive trend is projected regarding improving biodiversity levels and the reduction of non-point source pollution.

**Myanmar.** In Myanmar, rice farming remains a significant source of income and employment for the rural population. Therefore, the modernization of the rice sector is considered an important engine of growth for overall economic development. The government launched a rice sector development strategy in 2015 to transform rice farming and advance the country's transition after decades-long restrictions. Myanmar was once the world's largest rice producer and leading rice exporter. However, due to the implementation of restrictive governmental policies, Myanmar's rice sector has been struggling ever since. Economic restrictions have been mostly lifted today, but the modernization of rice farming is only advancing slowly. Policies are challenging to apply and agricultural extension continues to be sparse. Farmers often do not have the necessary knowledge and financial means to use modern farming practices and technologies. Nevertheless, since the political transition from 2010/11, Myanmar has been able to achieve some success. It has been able to become a net rice exporting country again due to increased rice yields based on improved rice farming practices.

The activities of the CORIGAP project started at the beginning of Myanmar's political transition. In this regard, the objective of the study was to examine how farmers' agronomic and socioeconomic performance evolved from 2012 to 2017. A household baseline survey was conducted in 2012 before the introduction of sustainable best management practices and technologies. Farmers were separated into a treatment and control group to evaluate the differences between the two groups after the CORIGAP interventions. Furthermore, the cropping pattern – rice-rice and rice-pulse – was included as a relevant farmer characteristic. By 2017 when the household endline survey was conducted, farmers had mixed. The earlier farmer groups had to be reclassified, resulting in an adopters group and non-adopters group. In the end, 160 farmers remained of the data analysis. The results showed that the two farmer groups did not differ significantly from each other regarding their socioeconomic situation and agronomic performance. Both groups increased their profitability and achieved higher yields over the course of five years. However, considerable differences were found between the two cropping patterns. Rice-pulse farmers had significantly higher rice yields than rice-rice farmers but would have lower incomes and credits. Overall, the impact of the CORIGAP project on farmers' rice yields could not clearly be shown because the mediation models did not result in full or partial mediation through the farmer group. Still, the findings demonstrate that agricultural progress in Myanmar between 2012 and 2017 has strongly benefitted farmers. CORIGAP's alignment with the national rice sector strategy supported the promotion of sustainable rice practices and technologies for agricultural development.

**Vietnam.** Vietnam has become a major rice-producing and rice exporting country due to economic reforms starting in the late 1980s. It is considered a prime example of agriculture serving as an engine of growth for overall economic development. Rice farming has greatly evolved through broad modernization efforts. Particularly in the Mekong River Delta, rice farmers today achieve by far the highest productivity levels in the country. Most of the surplus rice is destined for the export market. In this regard, rice exports have become essential for maintaining the region's economic stability. Nevertheless, Vietnam's rice sector has been dealing with difficulties in reaching consistent production quantities due to long-term input overuse. This has led to environmental degradation. In addition, climate change threatens rice farming as a whole in the Mekong River Delta. It is also becoming less profitable for farmers to cultivate rice due to rising input costs and diminishing returns. Therefore, national policy programs have been launched to incentivize farmers to use fewer inputs to reduce their environmental footprint and achieve better agricultural efficiency to improve their profitability. The 3R3G and subsequent 1M5R integrated practice and technology packages were launched in the mid-2000s in several provinces of the Mekong River Delta. More than 130'000 farmers have been reached so far.

The CORIGAP project in Vietnam has focused on further promoting 1M5R recommendations, particularly in the provinces of An Giang and Can Tho. For this thesis, two aspects were analyzed. First, an agronomic study in Can Tho Province based on household data from 2015 and 2019 was conducted. Second, a 1M5R technology perception study was performed in An Giang and Can Tho Province. The findings of the agronomic study showed that most farmers were following 1M5R guidelines. The most adopted technologies were AWD, combine harvesters, drum seeders, and improved varieties. Most farmers were able to reduce their input use and achieve higher rice yields. CORIGAP project farmers used significantly fewer inputs than control farmers, but their productivity levels were lower than control farmers'. Nonetheless, the results demonstrated that CORIGAP project farmers were able to maintain their profitability due to diminished input costs. Hence, they were able to achieve yield consistency and livelihood stability by producing rice more sustainably. Lastly, the study found that farmers still use high amounts of inputs largely above the 1M5R recommendations. In the second study, farmers' perceptions on AWD, combine harvester, drum seeder, and HYVs were investigated. Most farmers adopted two to three technologies and planned on continuing their application. Combine harvester was adopted by almost all farmers, followed by AWD and HYVs. Ease of use was the highest-rated benefit for all four technologies. Considerable differences between the farmers in An Giang and Can Tho Province were found. In general, Can Tho farmers rated the benefits higher and perceived more livelihood changes than An Giang farmers. Lastly, farmers perceived positive social changes, such as improved health and increased levels of human capital, but they did not perceive impactful changes to the environment since using 1M5R technologies. This could be due to the fact that farmers still use high amounts of inputs and are not able to reduce them to the 1M5R recommended quantities. Thus, more time and effort are needed for environmental regeneration to withstand the challenges of climate change better.

## 14.2 Implications

For assessing the impact of the CORIGAP project and the overall implications of this thesis' findings, four different perspectives are discussed to evaluate the significance for future development initiatives. Subsequently, recommendations for future development activities related to agricultural development are given.

**Geographical-environmental implications.** The geographical setting in Southeast Asia and the focus on rice farming in this thesis defined the main scope of the research. This thesis demonstrated that supporting farmers in improving their practices and adopting new technologies is crucial in reducing rice production's adverse effects on the environment. Specifically, the reduction of inputs had a considerable positive environmental and economic impact. The results align with the body of research and recommendations for achieving sustainable agriculture through climate-smart natural resource use. Rice farming remains one of the most exhaustive agriculture systems because it is a major source of GHG emissions in plant agriculture. In particular, methane emissions are of great concern. Excessive water use in rice fields is the primary anthropogenic source of methane. In total, rice farming accounts for 11 % of the total anthropogenic methane emissions (Smith et al. 2008: 792; de Miranda et al. 2015: 2009-2010,2012; Sander et al. 2020: 1–2).

Since Asia contributes about 90 % of global rice production and several major rice producing and exporting countries are located in Southeast Asia, the region's environmental footprint is large (GRiSP 2013: 40; Sander et al. 2020: 1). Consequently, the rice sector in Southeast Asia is not only a contributor to the region's natural character and driver for economic growth and social stability. It is also environmentally highly impactful on a global scale. As a result, the systematic transformation of harmful rice cultivation practices to more sustainable and climate-smart rice agriculture would have a significant worldwide impact. This is especially relevant as climate change-related issues have become one of the most pressing challenges of the 21st century. Smallholder farmers are expected to be hit particularly hard by environmental problems while already facing multiple economic and social constraints. Rice farming employs the majority of smallholders in Asia and is crucial for regional and global food security (Rapsomanikis 2015: 1; Segal, Minh 2019: 5).

In this context, changing farmers' rice practices in Southeast Asia can have a considerable positive effect on environmental regeneration, global food security, and climate change mitigation. For example, farmers using 3CT in Guangdong Province were able to reduce non-point source pollution due to lower nitrogen fertilizer use. In Myanmar, farmers were introduced to sustainable practices and new innovations to avoid the same detrimental environmental trajectories in China and Vietnam. In Vietnam, farmers reduced their general input use through the adoption of sustainable practices and input-saving technologies. Overall, the recommended CORIGAP practices and technologies have supported farmers not only economically. They also ensure that the beneficial natural circumstances for rice farming will continue to be present in the future. Hence, the significance of this research is that through the dissemination of sustainable rice farming practices and technologies, farmers can maintain advantageous environmental conditions and limit the negative impacts of rice farming. In addition, farmers were able to remain profitable while reducing the burden on the environment. Ultimately, this is one of the most important elements to achieving an advantageous framework for sustainable development in which environmental, social, and economic factors are considered.

**Policy implications.** In order for widespread sustainable change to occur, a supportive policy environment is necessary. The outcomes of this research showed that well-implemented policies are an important pillar for innovation diffusion. The national policies in China and Vietnam proved to be successful as large numbers of farmers were reached through policy instructed extension and information activities. The integration of 3CT into the Chinese national strategy for sustainable agricultural development made it possible to implement targeted regional policies that support the scaling out of the technology. In Vietnam, the regional policy structures facilitated the introduction and promotion of 3R3G and 1M5R in different provinces in the Mekong River Delta. Additionally, in the three study regions, international funding, e.g., from the World Bank, multiplied the potential of the diffusion of innovation concurrently with the favorable policy environment. In Myanmar, the changing political landscape enabled a new policy orientation. This resulted in a precise development strategy for advancing the country's rice sector. The study findings demonstrated that farmers were able to benefit from these new policies directly. Over the course of five years, their productivity and profitability increased.

Three aspects have been shown to be necessary for the diffusion of innovation. First, good extension services require well-formulated policies and an enabling environment (Contado 1997; Sharma 2002: 3131). Since agricultural extension is such a crucial element for technology dissemination and diffusion of knowledge, advancing policies, including the upgrading and long-term financing of extension services, is critical. The CORIGAP project supported the progress of existing extension programs and introduced new extension elements. These included learning alliances and participatory varietal selection trials. Furthermore, a knowledge innovation strategy combined with an outreach scheme was emphasized in the second project phase. This strengthened the quality of the agricultural extension systems in the project countries. Second, financing and credit possibilities for farmers, specifically for smallholders, are crucial for agricultural development (Sharma 2002: 3130; Shah, Khan, Khan 2008: 713; Dossou et al. 2020: 1). Government policies can have a significant impact on farmers' financial capital. It has been shown that farming practices, profitability, and farm reinvestment improve when solutions such as microfinancing loans or insurances assure farmers' liability (Shah, Khan, Khan 2008: 713). Third, policymaking is crucial for improving market access and developing rural infrastructure. This is important to enhance farmers' position in the rice value chain (International Finance Corporation 2014: 1–3). Overall, the CORIGAP project's holistic approach was demonstrated to be effective because it tackled these key policy issues through its adaptive research and multilevel collaboration.

**Agronomic implications.** Farmers in this research generally improved their agronomic situation. In all three countries, increased rice productivity and greater profitability were reported. These results suggest that the CORIGAP project was able to reduce yield gaps in China, Myanmar, and Vietnam through more sustainable rice cultivation. Hence, the project's main objective was accomplished: farmers' livelihoods improved while the negative impact of intensive low-land rice farming on the environment decreased. In China and Vietnam, farmers reduced their input costs due to savings on seeds, fertilizers, and pesticides. Thus, they were able to achieve better input-output efficiency. In Myanmar, farmers were able to increase profits due to the concise use of inputs, specifically fertilizer, for productivity growth. One important aspect to consider is that farmers generally had more financial means due to the adoption of recommended practices and technologies. As a result, they could invest more into their farm to accelerate the modernization process and save farming time through better TFP (Yang, Zhu 2010: 4; Coomes et al. 2019: 22). It has been shown that a beneficial economic environment stimulates the reinvestment into the own farm business, which enhances the agronomic factors considerably (Ojo, Baiyegunhi 2020: 1; Connor et al. 2021b: 1). Subsequently, increased mechanization and reduced human labor requirements encourage farmers to look for other activities outside of farming and diversify their income sources. This can then lead to decreasing poverty levels and accelerate rural development (Nolte, Ostermeier 2017: 439). In this regard, the impact of the CORIGAP project advanced farmers' economic possibilities not only in the agriculture sector but also in other sectors. This implies additional socioeconomic changes. The three study regions of this thesis are agronomically different and deal with multiple issues related to agronomic development. Nevertheless, the CORIGAP project was able to address these differences so that positive change was significant in each country. Ultimately, the major challenge for farmers in Southeast Asia remains climate change and the uncertainties it entails, specifically regarding agronomic implications. Therefore, climate change adaptation through the adoption of climate-smart agriculture practices and technologies are key for remaining resilient and continuing rice farming under economically stable circumstances.

**Psychosocial implications.** Farmers' opinions were included in the progression of innovation diffusion strategies through an adaptive research methodology. This was relevant because the impact of the CORIGAP project is intended to continue after the project's ending. Hence, this thesis investigated farmers' perspectives on the recommended technologies. The agronomic and socioeconomic changes for long-term adoption were evaluated. Farmers in China and Vietnam were generally very satisfied with the recommended practices and technologies. As discussed in Chapter 4, these elements are crucial for farmers' adoption decision process. They positively perceived the five critical attributes Rogers describes in his theory. Concretely, they experienced a relative advantage when using a new practice or technology compared to traditional ones. They found that the innovations were simple to use and compatible with their farming methods. Also, the benefits of the adoption were clearly visible. Additionally, farmers were able to test the recommended practices and technologies during trainings or workshops before taking the decision to adopt them fully. Hence, it can be assumed that the CORIGAP project influenced the diffusion of innovation. Nevertheless, the exact effect of the project could not be determined. Mediation analyses did not result in significant mediation through the farmer group, for example, in Myanmar and Vietnam. Conclusively, the findings indicate that the efforts of the CORIGAP project benefited farmers as an additional development project embedded in an overall enabling policy environment.

The CORIGAP project determined its actions based on adoption-diffusion theory. The results of this research demonstrate that this approach was successful. Farmers expressed positive feedback on the recommended practices and technologies. Additionally, farmers mostly confirmed that they would continue using them. They perceived notable economic and social changes to their lives. For example, farmers in China and Vietnam became more profitable due to decreased input costs. They also experienced that their human and social capital improved. Furthermore, other important livelihood dimensions, such as food security, health, or financial capital, were enhanced due to the adoption of the CORIGAP recommended practices and technologies. This is in alignment with the theory. Economic factors play a role in the adoption-decision process, but other factors also influence farmers' long-term adoption decisions. This is a significant consideration for advancing sustainable agricultural development since it necessitates long-lasting modifications in order for the system to be transformed. Lastly, the results indicated that environmental changes had not yet been perceived much by farmers. This is most certainly the case because the regeneration of ecological factors, such as biodiversity, needs more time. Hence, it is of particular importance that farmers do not decide to disadopt the new technologies and practices after the ending of the project. Long-term use is crucial for environmental improvements to occur.

**Recommendations.** The CORIGAP project was able to attain its objectives throughout its first and second project phase. The recommendations for future development projects focusing on the sustainable development of rice-farming systems should center around harnessing this evolution. In this regard, the CORIGAP project can be considered an effective continuation of a previous development project financed by the SDC. It was able to apply the IRRC recommendations and lessons learned to advance the transformation of rice farming in South and Southeast Asia. The findings and lessons learned from the CORIGAP project should likewise be used for the continued promotion of sustainable agriculture and rural development. Specifically, the project's application of adoption-diffusion theory using a country-by-country approach to innovation dissemination could be applied in other country settings and development contexts. The CORIGAP project has also demonstrated to be adaptable to diverse geographies with different political systems and environmental conditions, especially due to its use of adaptive research methods. Since the project was implemented in just six countries, the potential remains large for similar initiatives in rice-based and other agricultural systems. Furthermore, the project outcomes could be included in other current or planned SDC development projects. The broad outreach activities involved stakeholders from research, the public and private sector, as well as the farmer and civil society organizations. This comprehensive approach proved to be effective for innovation diffusion. Finally, the CORIGAP project has displayed the importance of understanding development as a multifaceted and multi-stage process. In particular, this is relevant considering sustainable development because the pillars of sustainability are interconnected. Sustainable economic growth requires a favorable socio-political setting and a natural environment that offers the necessary resources. On these grounds, recommendations for the four perspectives of this thesis are formulated (Figure 14.1).

| **Geographical-environmental recommendations** | **Policy recommendations** |
|---|---|
| • Expand the learnings of the CORIGAP project to other regions and agroecosystems by using research-based information on development needs.<br>• Include geographical and environmental specificities in project planning and evaluate the outcomes based on these.<br>• Foster knowledge dissemination about environmental issues, notably unsustainable natural resource management, climate change, and its adverse effects. | • Continue the inclusion of multiple stakeholders through activities such as learning alliances to foster their participation in the policy-making process.<br>• Focus on research-driven activities that connect farmers to policymakers and the private sector for better value chain inclusion.<br>• Advance the successful diffusion strategy through additional scaling out of extension policies into other regions or countries. |
| **Agronomic recommendations** | **Psycho-social recommendations** |
| • Advance tailored solutions through approaches, such as SSNM, to achieve further yield gap reductions and mitigate negative implications on the environment.<br>• Check for farmers' correct application of best management practices and technologies to utilize their full potential.<br>• Maintain household-level assessments to document change and the evolution of agronomic parameters for sustainable rice farming. | • Support farmers willingness to continue the adoption of the recommended practices and technologies by maintaining regular extension activities.<br>• Offer regular trainings to extension officers in order to provide up-to-date agronomic recommendations and assure knowledge dissemination.<br>• Address farmers' issues with the adopted practices and technologies by providing support to reduce possible rejection or disadoption. |

Figure 14.1 Recommendations for future research and project activities
Concept: H. Wehmeyer (2021)

### 14.2.1 Limitations and Weaknesses

The results of this research have some limitations and weaknesses. Their relative importance in relation to the overall findings is addressed to interpret this study accurately. In addition, the measures that were taken to tackle these limitations are identified. These should be taken into consideration for future projects and research endeavors related to innovation diffusion.

**Self-reporting and social desirability bias.** The data for this thesis are based on self-reported information. It is not possible to verify the accuracy of the responses. Farmers' answers on multiple cropping seasons were collected, but these generally did not take place immediately before the survey. Therefore, interpreting the findings necessitates an understanding that the information comes from farmers' recollections from a time period ranging from several weeks to months, depending on the survey. Farmers might not remember all the details correctly. In this context, it is important to consider that social desirability bias can also affect farmers' answers, especially regarding the socio-cultural and political circumstances of the study regions. For example, the very positive results of the study in South China need to be interpreted considering these circumstances. Börger considers that China today is a society with mild repression (2012: 153). This can potentially bias responses in survey interviews on politically sensitive topics. Consequently, the influence of social desirability bias on survey responses can be expected to be comparably strong (Börger 2012: 153-154). In anticipation of such biases, the questionnaires were designed accordingly and the CommCare application was programmed to limit some possible over- or underestimations. For instance, the items in the perception scales were formulated to capture farmers' opinions differently. Also, numerical minima and maxima were set to reduce the likelihood of unrealistic agronomic results.

**Sample selection, size, and methods.** The sampling for all three country analyses was dependent on national partners. They decided on the study townships and communes, of which a farmer list was used to sample the farmers randomly. Additionally, some farmers might not have been on the farmer lists due to political circumstances. They were possibly removed from the lists beforehand, for example, if they decided not to adopt the state-recommended practices and technologies. Hence, the country farmer samples in this thesis do not necessarily describe all farmers in the selected study regions and townships. It, therefore, needs to be taken into account that an accurate representation could not be fully attained because of country-specific regulations and political contexts. This weakness is specifically relevant for the interpretation of the findings on adoption behavior. Another aspect that the national partners fixed was the survey days to interview the farmers. This limited the sample size. Nevertheless, with the introduction of a CAPI application for the survey interviews, data collection could be accelerated. It allowed for faster questioning and sped up the farmer interviews, especially during CORIGAP-Pro. In China and Vietnam, more farmers were interviewed than initially anticipated in the survey plan. Finally, the method of farmer sampling for the households surveys was based on random control trials. Yet, random control trials over multiple years are not applicable in this context and require a different approach. This was clearly shown in the example of the Myanmar country analysis. Farmers did not remain in the predefined farmer groups and technology diffusion took place organically. Additionally, it is not ethical not to introduce certain farmers to new practices and technologies, who are given the opportunity to improve their living conditions and livelihoods, while excluding others.

**Definition of project objectives.** The CORIGAP project measured its success of innovation diffusion on the number of farmers reached. However, it remains unclear if the more than 750'000 farmers reached by 2020 apply the recommended practices and technologies. This number refers to the farmers who participated in CORIGAP-related trainings. Therefore, the effective impact of CORIGAP on farmers' adoption of new practices and technologies needs to be interpreted carefully. The results of the three country analyses suggest that many farmers have been applying some of the technologies and practices. Also, farmers have benefitted from participating in the trainings. But it is not possible to conclude from approximately 1000 interviewed farmers in this thesis how well the CORIGAP recommended practices and technologies are being applied by farmers in general. Overall, national monitoring systems should be implemented to observe the actual adoption rate over time to capture long-term innovation diffusion effects. Furthermore, development projects should not solely focus on quantitative objectives. They should also aim to achieve qualitative evaluation to accomplish a sustainable, long-lasting impact on farmers' change in behavior. This research did not specifically investigate behavior change in a large sample. More funds would be needed to do so.

## 14.3 Conclusions

This thesis assessed the SDC-funded CORIGAP project through three country analyses: It examined the project's impact on the diffusion of sustainable rice cultivation practices and technologies in Southeast Asia. The CORIGAP project was able to demonstrate a positive effect on different scales and in multiple contexts. Overall, it achieved its objectives. Farmers in China, Myanmar, and Vietnam experienced beneficial changes to their living conditions, improved agronomic factors, and now cultivate rice more environmentally friendly. They were able to maintain yields combined with profitability growth due to the adoption of sustainable farming practices and technologies. Farmers were generally satisfied with the recommended practices and technologies and will continue to use them. Hence, long-term sustainable change was achieved through the CORIGAP interventions financed by the SDC. This demonstrates that the Swiss development efforts have had a considerable impact on assuring sustainable agriculture and food security in Southeast Asia. Ultimately, the well-established networks and learnings from the preceding IRRC were used in CORIGAP to advance Switzerland's positive impact on improving sustainable development.

The CORIGAP project's final phase started in 2021 and will come to an end in 2022. In these two years, the project activities will focus on capturing the lessons learned and complete the required SDC contributions. In Phase III, the acquired knowledge will be synthesized to form specific guidelines for each country. Given the success of the CORIGAP project in the countries regarding policy implementation, the recommendations are expected to be considered by policymakers and other relevant stakeholders to advance national initiatives. The activities included in Phase III will further enable NARES partners and policymakers to continue scaling the CORIGAP outputs. They will also encourage planners of other projects to include similar activities in their initiatives (IRRI 2021: 8-9; SDC 2021c). Ultimately, Switzerland's funding of the IRRC and CORIGAP in South and Southeast Asia will have lasted 25 years. It will have had a significant positive and long-lasting impact on farmers, institutions, and governments.

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# Appendix

## Household baseline and endline survey questionnaire

**INTERNATIONAL RICE RESEARCH INSTITUTE (IRRI)**

**CLOSING RICE YIELD GAPS IN ASIA (CORIGAP)**
**BASELINE HOUSEHOLD SURVEY (Country, Year)**

**Part A.**
*NOTE: Duplicate parts II-II per season*

Respondent No.:_____________
Interviewer: ________________
Date of Interview: ___________
Name of Farmer: __________________
Village: _________________________
Sub-district: _____________________
District: _________________________
Province: ______________________
Mobile No.: ______________________

Respondent/s Interviewed: _____ Farmer
_____ Farmer's Spouse

Do you practice any of the ff (*for Vietnam only*):
☐ 1=1M5R ☐ 2=SFLF ☐ 3=VietGAP
☐ 4=GlobalGAP ☐ 99=AWD (or other technology, specify): ______________
If yes, did you practice it during the last two seasons:
☐ 1=Yes ☐ 2=No

**I. Socio-demographic Characteristics**

1. Sex: ☐ 1=Male ☐ 2=Female
2. Civil Status:
   ☐ 1=Single ☐ 2=Married ☐ 3=Widow/Widower ☐ 4=Separated ☐ 99=Others (specify) __________
3. Age: _____
4. Education (years): _____
5. If married, age of spouse: _____
6. Number of years spent on farming: _____
7. Education of spouse (years): _____
8. Number of household: Male _____ Female _____
   (family and non-family members living permanently in the household and taking food from the same kitchen)
9. Number of dependents: Male _____ Female _____

9.1 Number of dependent(s) working in rice farming: ________ Age(s):____________

10. Are you a member of an organization: ☐ 1=Yes ☐ 2=No
    If yes, name of organization(s) and position: ___________________________________________________
11. Is your spouse a member of an organization: ☐ 1=Yes ☐ 2=No
    If yes, name of organization(s) and position: ___________________________________________________
12. Non-Rice Income

| Source* | Amount ($/year) | Remarks |
|---|---|---|
| Income from farmer: | | |
| | | |
| | | |
| | | |
| | | |
| Income from farmer's spouse: | | |
| | | |
| | | |
| | | |
| | | |
| Income from members of the household: (children, working relatives, etc.) | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| Total | | |

*Source: 1=Salary earner at private firms with regular payment (e.g., factory/office worker) ), 2=Salary earner at public facilities (government employee, public school teacher), 3=Casual wage earner (irregular payment), 4=Wages from farm labor, 5=Selling farm products, 6=Selling non-agricultural goods, 7=Selling/raising livestock/fish, 8=Carpentry, 9=Construction, 10=General store owner, 11=Miller, 12=Cottage industry, 13=Taylor/sewer, 14=Transport business, 15=Rental of agricultural equipment/machine,16=Trader/merchant, 17=Rental of non-agricultural equipment, 18=Vendor/seller, 19=Fabricator, 20=Charcoal making

## II. Farm Characteristics and Cropping Pattern

| Parcel No. | Area (ha) | Tenure Status[1] | Land Rent ($/ha) | If tenure status is 2 or 3 and land rent is in kind, specify the land rental Ratio (%) | Method of crop establishment 1=TPR-Hand 2=TPR-Mach 3=DSR-Dry 4=DSR-Wet | Date of Planting | | Date of Harvest | | Variety | | Seed Type/ Class[2] | Seed Source[3] | Quantity of Seeds (kg) | Price of Seeds ($/kg) | Topo-graphy[4] | Soil Type[5] | Source of Irrigation[6] (multiple answers allowed) | Irrigation Fee (specify unit[7]) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Month | Week | Month | Week | Name | Maturity (days) | | | | | | | | |
| 1 | | | | | | | | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | | | | | | | | |

[1]Tenure Status: 1=Owner-cultivator 2=Share-tenant 3=Leasehold (fixed rent) 99=Others (specify) __________

[2]Seed Type/Class: 1=Hybrid Seeds 2=Registered Seeds 3=Certified Seeds 4=Farmer's Own Seeds 5=Farmer Exchange 99=Others (specify) __________

[3]Seed Source: 1=Own harvest 2=Exchange/co-farmer 3=Seed grower 4=Input dealer 5=Government agencies (DOA) 6=Private companies (specify) __________ 7=Landowner 99=Others (specify) __________

[4]Topography: 1=Flat 2=Undulated

[5]Soil Type: 1=Clay 2=Loam 3=Sandy 4=Sandy Loam 99=Others (specify) __________

[6]Source of Irrigation: 1=Deep Well Pump (amount pumped, L) 2=Shallow Tube Well (amount pumped, L) 3=Pumped from River/Canal/Dam (amount pumped, L) 4=Gravity (amount pumped, L) 5= Rainfall (each rainfall event, L; total amt/season, L) 6=Combination 99=Others (specify) __________

[7]Irrigation unit: 1=$/season 2=$/ha 3=$/hour 99=Others (specify) __________

Notes:

[a]One parcel is a unit of a rice plot.

- A set of contiguous parcels/rice plots that may be different sizes BUT bounded by a permanent structure is still considered as one parcel.
- Rice plots that are distantly located from each other are considered different/separate parcels.

[b]TPR-Hand=Manually Transplanted Rice, TPR-Mach=Mechanically Transplanted Rice, DSR-Dry=Dry Direct-seeded Rice, DSR-Wet=Wet Direct-seeded Rice

[c]If seed source is own harvest or exchange, indicate the cost of the seed if sold at the time of seedbed preparation (imputed cost).

[d]Explain if source of irrigation is more than one (account water volume used from each source): ______________________________________________

## III. Production and Disposal (from the largest/most important parcel)

Area of largest/most important parcel: __________ ha
Total/Gross Production (fresh paddy): __________ kg
Moisture content of paddy at harvest: __________%

| Item | Moisture Content (%) | Quantity (kg) | Price ($/kg) | Product Outlet[1] | Remarks |
|---|---|---|---|---|---|
| 1. Quantity Sold (right after harvest or drying) | | | | | Why?[2] |
| As fresh paddy | | | | | |
| As dried paddy | | | | | |
| As milled rice (Milling recovery: _____ %) | | | | | |
| 2. Stored to sell later (as dried paddy) | | | | | |
| 3. Kept for home consumption (as dried paddy) | | | | | |
| 4. Kept for seeds (as dried paddy) | | | | | |
| 5. Paid to creditor in kind only | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| Payment for inputs | | | | | |
| Payment for services | | | | | |
| (indicate sharing arrangement) | | | | | |
| Payment for the harvester | | | | | |
| Payment for the thresher | | | | | |
| Payment for the permanent hired laborer | | | | | |
| Payment for the other laborer | | | | | |
| 6. If tenant, land rental/landlord's share in kind only | | | | | |
| 7. If lessee, leaser's share in kind only | | | | | |
| 8. Irrigation fee in kind only | | | | | |
| 9. Others (specify) | | | | | |

[1]Product outlet: 1=Government 2=Traders/Stores 3=Cooperatives 4=Millers 5=Creditors 99=Others (specify) __________
[2]Reason for selling: 1=Owe money 2=Have always sold right away 3=Cannot store 99=Others (specify) __________
Note: The sum of the production disposal may be less than (if not equal to) the gross production. The sum should not be greater than the total harvested paddy.

## IV. Rice Production Inputs and Costs (consider the largest/most important parcel only)

### A. Seed and Seedbed Preparation:

If not applicable, proceed to B

1. Method of seed cleaning: ☐ 1=Floating ☐ 2=Blower ☐ 3=Hand winnowing ☐ 4=Washing ☐ 99=Others (specify) __________
2. Did you treat your seeds before planting? ☐ 1=Yes ☐ 2=No If yes, why? ____________________________ If yes, what type of seed treatment: ☐ 1=For germination ☐ 2=Pest and diseases
3. How do you dispose waste from seed treatment (for pest and diseases)? ☐ 1= Waterways ☐ 2= Bury in the soil ☐ 99= Others (specify) __________

Fill in the table with information for the largest/most important parcel only. If No or N/A, fill in the table with information for the entire farm:

| Seed and seedbed preparation (Date or Days Before Seeding or Days before transplanting) | Family | | | | | | Hired | | | | | | Wage Rate per day | | | Total Payment if Contract ($) | Cost for Food and Other Items, if any | Seed treatment | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Male | | | Female | | | Male | | | Female | | | Male | Female | In Kind[1] | | | Chemical[2] | Quantity Applied | | | Source[4] |
| | Person | Total Days | Hours/day | Person | Total Days | Hours/day | Person | Total Days | Hours/day | Person | Total Days | Hours/day | In Cash ($/ person) | | | | | | Total Quantity | Unit[3] | kg or ml per unit | |
| | | | | | | | | | | | | | | | | | | | | | | |
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[1]Please indicate the unit of payment (e.g., 10 kg rice paddy/ha)
[2]Chemical: 1=Bio N 2=Insecticide [Furadan, others (specify) __________] 3=Bactericide 4=Fungicide 5=Water 6=Salt solution 99=Others (specify) __________
[3]Possible units: bag, sack, sachet, carton, box, bottle
[4]Source: 1=Purchase 2=Government agencies (DOA) 3=Traders 4=Neighbors 99=Others (specify) ___________

Questions if transplanted:
4. Seedbed area __________ (ha)
5. Total rice area it can cover __________ (ha)
6. Did you apply fertilizer, insecticide and herbicide during seedbed preparation and seeding care? ☐ 1=Yes ☐ 2=No If no, proceed to B, Land Preparation
7. Fertilizer, Insecticide and Herbicide application for seedbed preparation and seedling care:
8. Did you prepare a separate seedbed for the largest parcel? ☐ 1=Yes ☐ 2= No
9. Method of seedbed preparation: ☐ 1=Mat nursery ☐ 2=Wet bed ☐ 99=Others (specify) ________
10. Power used for seedbed preparation: ☐ 1=Man/Animal ☐ 2=Hand tractor ☐ 99=Others (specify) ___________

| Brand | Quantity Applied | | | Cost ($/unit) | Family | | | | | | Hired | | | | | | Wage Rate per day | | | Total Payment if Contract ($) | Cost for Food and Other Items, if any |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Male | | | Female | | | Male | | | Female | | | Male | Female | | | |
| | Total Quantity | Unit[1] | kg or ml per unit | | Person | Total Days | Hours/day | Person | Total Days | Hours/day | Person | Total Days | Hours/day | Person | Total Days | Hours/day | In Cash ($/ person) | | In Kind[2] | | |
| | | | | | | | | | | | | | | | | | | | | | |
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[1]Possible units: bag, sack, sachet, carton, box, bottle [2]Please indicate the unit of payment (e.g., 10 kg rice paddy/ha)

## B. Land Preparation (consider the largest/most important parcel only):

| Activity | Date/Days Before Seeding or | Power Used[1] | Ownership[2] | If rented, payment for machine[3] ($) | Fuel & Oil Cost | | Family | | | | | | Hired | | | | | | Wage Rate per day | | | Total Payment if Contract ($) | Cost for Food and Other Items, if any |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Male | | | Female | | | Male | | | Female | | | Male | Female | | | |
| | | | | | Total Quantity (L) | Cost ($/L) | Person | Total Days | Hours/day | Person | Total Days | Hours/day | Person | Total Days | Hours/day | Person | Total Days | Hours/day | In Cash ($/person) | | In Kind[4] | | |
| Cutting of rice straw stubbles | | | | | | | | | | | | | | | | | | | | | | | |
| Burning of rice straw stubbles | | | | | | | | | | | | | | | | | | | | | | | |
| Addition of organic materials[5] | | | | | | | | | | | | | | | | | | | | | | | |
| 1st Plowing | | | | | | | | | | | | | | | | | | | | | | | |
| 2nd Plowing | | | | | | | | | | | | | | | | | | | | | | | |
| Cleaning and | | | | | | | | | | | | | | | | | | | | | | | |

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| repairing of dikes | | | | | | | | | | | | | | | | | | | | | | | |
| 1st Puddling | | | | | | | | | | | | | | | | | | | | | | | |
| 2nd Puddling | | | | | | | | | | | | | | | | | | | | | | | |
| Leveling | | | | | | | | | | | | | | | | | | | | | | | |
| Canal maintenance | | | | | | | | | | | | | | | | | | | | | | | |
| Others (specify): | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | |

[1]Power used: ☐ 1=Hand/Manual ☐ 2=Carabao/Cow ☐ 3=Hand tractor 4=Big tractor ☐ 99=Others (specify) ___________
[2]Ownership: ☐ 1=Owned ☐ 2=Rented ☐ 3=Borrowed
[3]For rentals, please indicate the rental rate. If fuel and oil cost are excluded from the rent, please indicate expenses on the fuel and oil cost column
[4]Please indicate the unit of payment (e.g., 10 kg/ha)
[5]Straw, manure, compost (mostly cattle manure, mostly poultry manure, mostly kitchen scrap, specify)
If power is owned (specify): Power used: __________ Acquisition date: __________ Lifespan (in years): __________ Acquisition cost ($): __________

## C. Crop Establishment (consider the largest/most important parcel only):

1. Did you plant synchronously (within one month) with other farmers in your area: ☐ 1=Yes ☐ 2=No
2. Did you fallow synchronously (within one month) with other farmers in your area: ☐ 1=Yes ☐ 2=No
3. Number of days of flooding before crop establishment: _____ days
4. If transplanted, age of seedling at transplanting: _____ days No. of plants per hill: _____ Spacing used: __________cm (Note: 1 inch=2.54 cm)
5. If power is owned (specify): Power used: __________ Acquisition date: __________ Lifespan (in years): __________ Acquisition cost ($): __________

| Activity | Power Used[1] | Ownership[2] | If rented, payment for machine[3] ($) | Fuel & Oil Cost | | Family | | | | | | Hired | | | | | | Wage Rate per day | | | Total Payment if Contract ($) | Cost for Food and Other Items, if any |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Male | | | Female | | | Male | | | Female | | | Male | Female | | | |
| | | | | Total Quantity (L) | Cost ($/L) | Person | Total Days | Hours/day | Person | Total Days | Hours/day | Person | Total Days | Hours/day | Person | Total Days | Hours/day | In Cash ($/person) | | In Kind[4] | | |
| Pulling & rolling of seedlings | | | | | | | | | | | | | | | | | | | | | | |
| Transport of seedlings | | | | | | | | | | | | | | | | | | | | | | |
| Distribution of seedlings | | | | | | | | | | | | | | | | | | | | | | |
| Manual transplanting | | | | | | | | | | | | | | | | | | | | | | |
| Mechanical transplanting | | | | | | | | | | | | | | | | | | | | | | |
| Thinning | | | | | | | | | | | | | | | | | | | | | | |
| Replanting | | | | | | | | | | | | | | | | | | | | | | |
| Others (specify): | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | |
| Manual broadcasting | | | | | | | | | | | | | | | | | | | | | | |
| Mechanical | | | | | | | | | | | | | | | | | | | | | | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| broadcasting | | | | | | | | | | | | | | | | | | | | | | |
| Seed drill machine | | | | | | | | | | | | | | | | | | | | | | |
| Drum seeding | | | | | | | | | | | | | | | | | | | | | | |
| Others (specify): | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | |

[1]Power used: ☐ 1=Hand/Manual ☐ 2=Carabao/Cow ☐ 3=Hand tractor ☐ 4=Big tractor ☐ 99=Others (specify) __________
[2]Ownership: 1=Owned 2=Rented 3=Borrowed
[3]For rentals, please indicate the rental rate. If fuel and oil cost are excluded from the rent, please indicate expenses on the fuel and oil cost column
[4]Please indicate the unit of payment (e.g. 10 kg/ha)

## D. Fertilizer Application (consider the largest/most important parcel only)

Questions 1-3 if organic fertilizer is applied:
1. What are the components of organic inputs? ☐ 1=Animal, nutrient content: _____ ☐ 2=Plant, nutrient content: _____ ☐ 3=Mixture, nutrient content: _____
2. For organic fertilizer/inputs were they ☐ 1=Home-made ☐ 2=Purchased commercially?
3. Were organic inputs applied by ☐ 1=Incorporation ☐ 2=Broadcast ☐ 99=Others (specify) _______
4. Was there occurrence of water overflow after fertilizer application? ☐ 1=Yes ☐ 2=No If yes, when? _________ days after application
5. Was there occurrence of soil drying after fertilizer application? ☐ 1=Yes ☐ 2=No If yes, when? __________ days after application

| Activity & Type/Kind of Fertilizer[1] | Date/Days Before Seeding or Transplanting | Water level (cm) | Quantity Applied | | | Cost ($/unit) | Family | | | | | | Hired | | | | | | Wage Rate per day | | In Kind[3] | Total Payment if Contract ($) | Cost for Food and Other Items, if any |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Male | | | Female | | | Male | | | Female | | | Male | Female | | | |
| | | | Total Quantity | Unit[2] | Kg or ml per unit | | Person | Total Days | Hours/day | Person | Total Days | Hours/day | Person | Total Days | Hours/day | Person | Total Days | Hours/day | In Cash ($/person) | | | | |
| 1st Application | | | | | | | | | | | | | | | | | | | | | | | |
| a. | | | | | | | | | | | | | | | | | | | | | | | |
| b. | | | | | | | | | | | | | | | | | | | | | | | |
| c. | | | | | | | | | | | | | | | | | | | | | | | |
| 2nd Application | | | | | | | | | | | | | | | | | | | | | | | |
| a. | | | | | | | | | | | | | | | | | | | | | | | |
| b. | | | | | | | | | | | | | | | | | | | | | | | |
| c. | | | | | | | | | | | | | | | | | | | | | | | |
| 3rd Application | | | | | | | | | | | | | | | | | | | | | | | |
| a. | | | | | | | | | | | | | | | | | | | | | | | |
| b. | | | | | | | | | | | | | | | | | | | | | | | |
| c. | | | | | | | | | | | | | | | | | | | | | | | |
| 1st Application | | | | | | | | | | | | | | | | | | | | | | | |
| a. | | | | | | | | | | | | | | | | | | | | | | | |
| b. | | | | | | | | | | | | | | | | | | | | | | | |
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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2nd Application | | | | | | | | | | | | | | | | | | | | | | | |
| a. | | | | | | | | | | | | | | | | | | | | | | | |
| b. | | | | | | | | | | | | | | | | | | | | | | | |
| c. | | | | | | | | | | | | | | | | | | | | | | | |

[1]Type/Kind of Fertilizer: 1= Urea (46-0-0) 2= Muriate of Potash (0-0-60) 3=TSP (18-46-0) 4=Ammonium Phosphate (16-20-0) 5=Ammonium Sulfate (21-0-0) 6=Complete (15-15-15) 8=Foliar 9=Commercial organic (compost mostly cattle manure, compost mostly poultry manure, compost mostly kitchen scrap, specify) ______11=Manure (cattle, poultry, pig, specify) 10=Rice straw 99=Others (specify) _______
[2]Possible units: bag, sack, sachet, carton, box, bottle
[3]Please indicate the unit of payment (e.g. 10 kg rice paddy/ha)

## E. Irrigation and Water Management

1. Location of farm with respect to source of water: ☐ 1=Upstream ☐ 2=Middle ☐ 3=Downstream
2. How many days water stays in the field after each irrigation? __________
3. Do you encounter flooding (completely submerged plants) ☐ 1=Yes ☐ 2=No
4. How often in wet season crop? Number of times ____ At what crop stage? ☐ 1=Vegetative ☐ 2=Reproductive (31-65 days before harvest ☐ 3=Ripening (1-30 days before harvest)
5. Is there a problem with water regulation or distribution of water? ☐ 1=Yes ☐ 2=No If yes, specify the problem: __________________________________________
6. Number and duration of drying events (light soil cracking) prior to crop establishment: _______________
7. Number of irrigation per week: __________

| Date/Days After Seeding or Transplanting | Status of soil before irrigatiing[1] | Depth of water (in) | Ownership[2] | If rented, payment for machine[3] ($) | Fuel/electricity consumption per water application[3] | | Family | | | | | | Hired | | | | | | Wage Rate per day | | | Total Payment if Contract ($) | Cost for Food and Other Items, if any |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Male | | | Female | | | Male | | | Female | | | Male | Female | | | |
| | | | | | Total Quantity (L) | Cost ($/unit) | Person | Total Days | Hours/day | Person | Total Days | Hours/day | Person | Total Days | Hours/day | Person | Total Days | Hours/day | In Cash ($/person) | | In Kind[4] | | |
| | | | | | | | | | | | | | | | | | | | | | | | |
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[1]Status of soil before irrigating: 1=Flooded (has standing water) 2=Saturated (soil is wet but no standing water) 3=Dry 4=Cracked
[2]Ownership: 1=Owned 2=Rented 3=Borrowed
[3]If electricity was used in irrigating the field, please specify the cost involved
[4] Please indicate the unit of payment (e.g. 10 kg rice paddy/ha)

## F. Pest Management (consider the largest/most important parcel only)

| Type of pest control (weeds, insects, fungi, snails, rats) | Total Number of Applications | Brand Name and active ingredient | Date/Days Before Seeding or Transplanting | Quantity Applied | | | Cost ($/unit) | Family | | | | | | Hired | | | | | | Wage Rate per day | | | Total Payment if Contract ($) | Cost for Food and Other Items, if any |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Male | | | Female | | | Male | | | Female | | | Male | Female | | | |
| | | | | Total Quantity | Unit[3] | Kg or ml per unit | | Person | Total Days | Hours/day | Person | Total Days | Hours/day | Person | Total Days | Hours/day | Person | Total Days | Hours/day | In Cash ($/person) | | In Kind[4] | | |
| | | | | | | | | | | | | | | | | | | | | | | | | |
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[1]Cultural Method: 1=Handpicking2=Handweeding 3=Rotary weeding 4=Rat hunting 5=Community trap barrier system 6=Bird scaring 99=Others (specify) __________

[2]Chemical Pesticide: 1=Manual broadcasting 2=Knapsack spraying 3=Boom spraying 99=Others (specify) ___________

[3]Possible units: bag

[4]Please indicate the unit of payment (e.g. 10 kg/ha)

## G. Harvesting and Postharvest Activities (consider the largest/most important parcel only)

| Activity | Power Used[2] | Ownership[3] | If rented, payment for machine[4] ($) | Fuel & Oil Cost | | Family | | | | | | Hired | | | | | | Wage Rate per day | | | Total Payment if Contract ($) | Cost for Food and Other Items, if any |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Male | | | Female | | | Male | | | Female | | | Male | Female | | | |
| | | | | Quantity (L) | Cost ($/L) | Person | Total Days | Hours/day | Person | Total Days | Hours/day | Person | Total Days | Hours/day | Person | Total Days | Hours/day | In Cash ($/person) | | In Kind[5] | | |
| Harvesting | | | | | | | | | | | | | | | | | | | | | | |
| Threshing/Cleaning | | | | | | | | | | | | | | | | | | | | | | |
| Hauling/ Transporting[1] | | | | | | | | | | | | | | | | | | | | | | |
| a. From ___ to ___ | | | | | | | | | | | | | | | | | | | | | | |
| Distance ____ km | | | | | | | | | | | | | | | | | | | | | | |
| b. From ___ to ___ | | | | | | | | | | | | | | | | | | | | | | |
| Distance ____ km | | | | | | | | | | | | | | | | | | | | | | |
| c. From ___ to ___ | | | | | | | | | | | | | | | | | | | | | | |
| Distance ____ km | | | | | | | | | | | | | | | | | | | | | | |
| Drying | | | | | | | | | | | | | | | | | | | | | | |
| Milling | | | | | | | | | | | | | | | | | | | | | | |
| Storing | | | | | | | | | | | | | | | | | | | | | | |
| Others (specify): | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | |

[1]Hauling destination: 1=Farm 2= House 3=Storage area 4=Drying area 5=Main road 99=Others (specify) __________
[2]Power used: 1=Hand/Manual 2=Carabao/Cow 3=Machine 4=Solar (only for drying) 5=Mechanical dryer 99=Others (specify) ___________
3Ownership: 1=Owned 2=Rented 3=Borrowed
[4]For rentals, please indicate the rental rate. If fuel and oil cost are excluded from the rent, please indicate expenses on the fuel and oil cost column
[5]Please indicate the unit of payment (e.g. 10 kg/ha)

If power is owned (specify): Power used: __________ Acquisition date: __________ Lifespan (in years): __________ Acquisition cost ($): __________

## E. Postharvest Practices

1. How long do you leave the harvested paddy unthreshed? __________ days

2. How do you dry the grains? ☐ 1=Arrange in bundles in the field ☐ 2=Spread in mats along the roadway ☐ 3=Spread in mats near the house ☐ 4=Drying pad ☐ 5=Machine ☐ 6=Combination (specify) ________

3. How long does it take after threshing until it gets dried? ________ days (with ideal sunlight conditions) ________ days (normal/average conditions)

4. What practices do you apply while drying? (multiple answers allowed)

☐ 1=Spread paddy thinly (2-4 cm) ☐ 2=Spread paddy (> 5cm) ☐ 3=Mix paddy every 30min-1hr
☐ 4=Mix paddy a few times a day ☐ 5=Do not mix during the da ☐ 6=Bring in when it rains
☐ 7=Cover when it rains ☐ 8=Cover during midday (heat) ☐ 9=Check moisture level with moisture meter
☐ 10=Check temperature level

5. How do you test for dried rain?

☐ 1=Color ☐ 2=Feel ☐ 3=Moisture (tooth) ☐ 4=Moisture meter ☐ 99=Others (specify) ___

6. Do you encounter problems in drying? ☐ 1=Yes ☐ 2=No

If yes, what are they? ☐ 1=Rain ☐ 5=Grain yellowing ☐ 2=Birds ☐ 6=Mold
☐ 3=Rodents ☐ 7=Cracking of grain ☐ 4=People stealing ☐ 99=Others

7. How are the grains cleaned?

☐ 1=Hand winnowing ☐ 2=Fan winnowing ☐ 3=Grain cleaner ☐ 99=Others (specify)______

8. Do you encounter problems in cleaning grains? ☐ Yes ☐ No

If yes, what are they? ________________________________________

9. How do you store seeds? ☐ Bag (specify) Material: ☐ 1=Jute ☐ 2=Plastic ☐ 99=Others (specify) _____
Size: ☐ 1=40kg ☐ 2=80kg ☐ 99=Others (specify) _____
☐ Granary
☐ Container (specify) Material: ☐ 1=Sealed hermetic ☐ 2=Closed but not sealed
☐ IRRI Super bags ☐ Others (specify

10. How long do you store seeds? ________ days

11. How do you store grain? ☐ Bag (specify) Material: ☐ 1=Jute ☐ 2=Plastic ☐ 99=Others (specify) _____
Size: ☐ 1=40kg ☐ 2=80kg ☐ 99=Others (specify) _____
☐ Granary
☐ Container (specify) Material: ☐ 1=Sealed hermetic ☐ 2=Closed but not sealed
☐ IRRI Super bags ☐ Others (specify)_______

12. How much and when do you sell grains and purchase seeds? (kg)

| Month after harvest | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sales | | | | | | | | | | | | |
| Purchase | | | | | | | | | | | | |

13. Do you have a separate method of storing seeds and grains? ☐ 1=Yes ☐ 2=No

14. Do you encounter problems in storing seeds and grains? ☐ 1=Yes ☐ 2=No

If yes, what are they? ☐ 1=Molds ☐ 2=Insects ☐ 3=Discoloration/yellowing ☐ 4=Loss of germination
☐ 5=Odor development/loss of freshness ☐ 6=Rodents ☐ 7=Difficult to control moisture level

15. What do you do about the problems? ☐ 1=Clean storage area and around and keep it clean ☐ 2=Store off the ground
☐ 3=Check weekly insect infestation level ☐ 4=Fumigate ☐ 5=Rat traps ☐ 99=Others (specify) ________

16. How often do you mill? __________ days

16. Where do you mill? ☐ 1=Home ☐ 2=Village Mill
☐ 3=Commercial Mill

17. Is there available postharvest equipment ☐ 1=Yes ☐ 2=No

18. Post Harvest Equipment (please check)

| Equipment | Have you ever seen? | Have you used? | Will Reduce losses? | Do you own? | Will give better quality? | Would you get a higher price? | If own, who uses (male/female)? |
|---|---|---|---|---|---|---|---|
| Reaper | | | | | | | |
| Moisture Meter | | | | | | | |
| Thresher | | | | | | | |
| Combine harvester | | | | | | | |
| Paddy Dryer | | | | | | | |
| Granary | | | | | | | |
| Household silo | | | | | | | |
| Super bag or cocoon | | | | | | | |
| Grain Cleaner | | | | | | | |

19. Does reduction of quality, result in price penalty? ☐ Yes ☐ No If yes, by how much? ____ %

**Perception survey questionnaire: China**

# Farmers Perceptions of Sustainable Development (FPSD) – China

## Introduction and consent

**Project Title:** Closing Rice Yield Gaps in Asia with Reduced Environmental Footprint (CORIGAP-Pro)

You are invited to join a research study where our team aims to monitor and evaluate the effects CORIGAP to your livelihood and the environmental and economic changes to your household due to your adoption of the Three Controls Technology. If you decide to participate, you will be asked to provide some farm- and household-related information as well as few personal details. We will take necessary steps to keep information about you confidential, and to protect it from unauthorized disclosure, tampering, or damage. We think this survey takes 30 to 40 minutes.

Do you consent to be interviewed? □ Yes □ No Signature: ___________________

## 1. Details on Three Controls Technology adoption

Have you been using it in your own field since it was first introduced? □ Yes □ No
What year did you start using the Three Controls Technology in your field? ___________
In which cropping season did you first use the Three Controls Technology on?
□ Early rice season □ Late rice season
What kind of variety do you use? □ Inbred □ Hybrid
For how many early rice seasons have you used the Three Controls Technology? ___________
For how many late rice seasons have you used the Three Controls Technology? ___________
Please confirm which specific seasons below you used the Three Controls Technology on (tick all that apply):
□ Early rice season 2018 □ Late rice season 2018 □ Non-rice season 2018/2019
Do you plan to continue using the Three Controls Technology in the coming seasons? □ Yes □ No
What benefits and advantages have you experienced since you started using the Three Controls Technology?
Please rate the reasons from 1 to 6; where 1 means not applicable at all and 6 means very applicable.

| Benefits | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| High yield | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| Fits my cropping pattern | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| Satisfies my preferences | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| Replaced different technology(ies) | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| Less lodging | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| More free time | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| Less damages (pest, drought) | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| Easy to apply | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| Less expensive | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| Labor shortage | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| Labor costs are lower | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| Labor hours are lower | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| Weather conditions allowed use | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| Technology is easily available | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| Technology is suitable for my field conditions | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| Plants die less | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| Other: | | | | | | |

Please indicate how applicable the reasons are for not using the Three Controls Technology anymore.
Please rate the reasons from 1 to 6; where 1 means not applicable at all and 6 means very applicable.

| Reasons | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Low yield | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| Doesn't fit cropping pattern | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| Doesn't satisfy my preferences | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| Not needed any longer | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |

| | | | | | | |
|---|---|---|---|---|---|---|
| Replaced different technology(ies) | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| Increased lodging | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| Personal time constraints (too busy) | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| Damage (pest, drought) | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| Too difficult to apply | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| Too expensive | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| Labor shortages | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| Labor costs are too high | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| Labor hours are too high | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| Weather conditions did not allow use | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| Technology is not available | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| Technology is not suitable for my field conditions | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| Plants died | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| Other: | | | | | | |

## 2. Agronomic information on selected rice season

### Area cultivated

How many mu of land did you cultivate in total for rice in the early rice season using 3CT? __________

Do you also cultivate on rented land? □ Yes (If yes, we will ask further how much the rent is)

□ No (If no, we will skip the succeeding question regarding rent)

If you cultivate on rented land, how large is the land you rent? __________ (mu)

If you cultivate on rented land, on what basis did you pay for the land rent?

□ Yuan per mu □ Kilogram of dried paddy per mu □ Shared harvest with the renter (in %)

Depending based on payment: How much did you pay for the rent? __________ (Yuan per mu or Kg per mu)

In percent, how much of the paddy produced went to the renter? _______ (%)

How many kilograms of dried paddy in total did you produce per mu? __________

What is your usual way of farming? □ Rice – rice – fallow □ Rice – rice – other crop

What other crops did you cultivate during the non-rice season 2017/2018 (December-February)?

□ Vegetables □ Maize □ Potato □ Watermelon □ Other: __________________

### Input Cost Group

Which of these items did you pay for in kind? (tick all that apply)

- □ Seeds
- □ Fertilizer
- □ Pesticide
- □ Herbicide
- □ Irrigation
- □ Hauling and transportation
- □ Renting machine for land preparation
- □ Renting machine for planting
- □ Renting machine for harvesting
- □ Paid labor

Please indicate how many kilogram per mu did you spend to pay for the following:

- □ Seeds: __________
- □ Fertilizer: __________
- □ Pesticide: __________
- □ Herbicide: __________
- □ Irrigation: __________
- □ Hauling and transportation (per season): __________
- □ Renting machine for land preparation: __________
- □ Renting machine for planting: __________
- □ Renting machine for harvesting: __________
- □ Paid labor: __________

Which of these items did you pay for in cash (Yuan)? (tick all that apply)

- □ Seeds:
- □ Fertilizer
- □ Pesticide
- □ Herbicide
- □ Irrigation
- □ Hauling and transportation
- □ Renting machine for land preparation
- □ Renting machine for planting
- □ Renting machine for harvesting
- □ Paid labor

Please indicate how much cash did you spend to pay for the following (Yuan per mu):

- ☐ Seeds: __________
- ☐ Fertilizer: __________
- ☐ Pesticide: __________
- ☐ Herbicide: __________
- ☐ Irrigation: __________
- ☐ Hauling and transportation (per season): __________
- ☐ Renting machine for land preparation: __________
- ☐ Renting machine for planting: __________
- ☐ Renting machine for harvesting: __________
- ☐ Paid labor: __________

How many kilograms of seeds did you buy per mu? __________

**Production Disposal Group**

If you did nothing else after drying, how many kilograms of dried paddy did you sell as it is? __________
If you dried and milled, how many kilograms of dried paddy did you mill for selling? __________
How many kilograms of dried paddy did you sell as seeds? __________
How many kilograms of milled rice will yield from 100 kilogram of dried paddy? __________ (% milling recovery)

**Selling price**

Please indicate the prevailing selling prices for the following in the early rice season:
Dried paddy selling price (Yuan per Kilogram): __________
Milled rice selling price (Yuan per Kilogram): __________
Seeds selling price (Yuan per Kilogram): __________

➔ SAME SET OF QUESTIONS ON PRODUCTION ASKED FOR LATE RICE SEASON, IF APPLICABLE:

## 3. Changes in the farm due to adoption of the Three Controls Technology

If you will look back to the time when you were NOT using the Three Controls Technology in your previous early rice cropping seasons, did you observe any changes in your farm now that you are using it?
Please indicate if any of the following has increased [+], decreased [-] or stayed the same [=].

| Categories of change | + | – | = |
|---|---|---|---|
| Area cultivated | ❒ | ❒ | ❒ |
| Quantity of harvest per mu | ❒ | ❒ | ❒ |
| Input costs | ❒ | ❒ | ❒ |

What was the size of your field back then BEFORE you used the Three Controls Technology? __________mu
How many kilograms of dried paddy per mu were you producing BEFORE you adopted the technology? __________
Which of the following inputs did you have the LESS COST since you used the technology? (tick all that apply)

- ☐ Seeds:
- ☐ Fertilizer
- ☐ Pesticide
- ☐ Herbicide
- ☐ Irrigation
- ☐ Hauling and transportation
- ☐ Renting machine for land preparation
- ☐ Renting machine for planting
- ☐ Renting machine for harvesting
- ☐ Paid labor

With reference to your current input costs, please estimate by how much in percent (%) you SPENT LESS on the following items since you used the Three Controls Technology:

- ☐ Seeds: __________
- ☐ Fertilizer: __________
- ☐ Pesticide: __________
- ☐ Herbicide: __________
- ☐ Irrigation: __________
- ☐ Hauling and transportation: __________
- ☐ Renting machine for land preparation: __________
- ☐ Renting machine for planting: __________
- ☐ Renting machine for harvesting: __________
- ☐ Paid labor: __________

**Farmer's perception on their rice farming**

Please rate the following statements from 1 to 6 based on your level of agreement; where 1 means completely disagree and 6 means fully agree. Since I've been using the Three Controls Technology…

| item | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| I have used more seeds per mu | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| I have used less chemical fertilizer | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| I have used more organic fertilizer | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| I have used less herbicides | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| I have used less pesticides (such as insecticides, fungicides, etc.) | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| I have used more water for irrigation | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| I have been doing less irrigation hours | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| I have used more fuel for my agricultural machinery | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| I have used less electricity for my agricultural practices | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| My soils have been more prone to erosion | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| I leave my fields fallow during the non-rice season | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| I have been collecting my rice straw | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| I have used my rice straw for mulching, cattle fee, mushroom production, biogas production or other | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| I have planted trees and/or shrubs | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| I have also planted other plants – not rice – between or alongside my fields | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |

Where do you receive information about new farming practices and technologies?

☐ Government ☐ Village head ☐ Village farmer groups ☐ My children
☐ Neighboring farmers ☐ Internet ☐ WeChat ☐ Television ☐ Radio
☐ Other: ___________

**Farmer's perception on income**

Do you think you had an increase in income since you used the Three Controls Technology on your rice farming?

☐ Yes ☐ No

By how much your rice income has increased since you adopted the Three Controls Technology?

Please indicate your estimated total income increase of your total land area in Yuan per mu: ____________

**Knowledge about the Three Controls Technology**

Please rate the following statements from 1 to 6 based on your level of agreement; where 1 means completely disagree and 6 means fully agree.

| item | Completely disagree | 2 | 3 | 4 | 5 | Fully agree |
|---|---|---|---|---|---|---|
| I know pretty much about the Three Controls Technology. | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| I do not feel very knowledgeable about the 3CT | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| Among my circle of fellow farmers, I am one of the experts on the Three Controls Technology. | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| Compared to most other people, I know less about the Three Controls Technology. | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| When it comes to the 3CT, I really do not know a lot. | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |

**Satisfaction of the Three Controls Technology**

| item | Completely disagree | 2 | 3 | 4 | 5 | Fully agree |
|---|---|---|---|---|---|---|
| I expected that it would be easy for me to follow the technology. | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| It has been easy for me to follow the technology exactly. | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| I received a good explanation about the technology. | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| I am not sure the technology was worth the trouble it took implement it. | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| The technology has been great for the environment. | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| My fellow farmers are just as happy using the technology as me. | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| The technology has become standard practice for me. | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |

**Expectations on the Three Controls Technology**

| item | Completely disagree | 2 | 3 | 4 | 5 | Fully agree |
|---|---|---|---|---|---|---|
| The technology did not work out the way I expected it to. | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| My expectations on my financial development since using the technology have been met. | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| The technology exceeded my expectations on productivity increase. | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I expect to see more positive changes when I continue using the technology. | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |

**Dimensions of change**

Please rate the following statements from 1 to 6 based on your level of agreement; where 1 means completely disagree and 6 means fully agree.

*1. Agricultural Production:* Since I have been using the Three-Controls Technology …

| item | Completely disagree | 2 | 3 | 4 | 5 | Fully agree |
|---|---|---|---|---|---|---|
| ...my yield has increased a lot | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| ...I have produced higher quality rice | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| ...rice farming has become more difficult | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| ...working on farm is not as hard anymore | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| ...I have been able to save money due to avoided production costs | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| ...I spent more money to pay on production costs | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| ...my fertilizer use has decreased | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| ...I now apply more fertilizer at a later growth stage | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |

*2. Facilities and Equipment:* Since I have been using the Three-Controls Technology …

| item | Completely disagree | 2 | 3 | 4 | 5 | Fully agree |
|---|---|---|---|---|---|---|
| ...I have been able to buy new farming equipment. | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| ...I have been able to upgrade or build new farm buildings (e.g. tractor shed) | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| ...I rent more land for rice production | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| ...I was able to have my house renovated and improved | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| ...I have been able to build a new house | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |

*3. Social Recognition:* Since I have been using the Three-Controls Technology …

| item | Completely disagree | 2 | 3 | 4 | 5 | Fully agree |
|---|---|---|---|---|---|---|
| ...I can now provide advice to fellow farmers on how to improve their farming practices | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| ...I can now organize farmers into groups to work together to improve farming practices | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| ...I can now communicate with other farmers about my experience in using best management practices | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |

*4. Knowledge and Knowledge Sharing:* Since I have been using the Three-Controls Technology …

| item | Completely disagree | 2 | 3 | 4 | 5 | Fully agree |
|---|---|---|---|---|---|---|
| ...I have gained a lot of knowledge | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| ...I have been able to provide better workforce | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| ...I have changed my farming habits | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| ...I am now able to express concerns about my farming practices | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |

*5. Food security:* Since I have been using the Three-Controls Technology …

| item | Completely disagree | 2 | 3 | 4 | 5 | Fully agree |
|---|---|---|---|---|---|---|
| ...my family's eating habits have not changed at all | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| ...my family can eat more meat | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| ...my family can eat more fruits | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| ...my family can eat more vegetables | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| ...my family eats more kinds of food | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |

*6. Health Change:* Since I have been using the Three-Controls Technology …

| item | Completely disagree | 2 | 3 | 4 | 5 | Fully agree |
|---|---|---|---|---|---|---|
| ...my health has improved a lot | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| ...I have more health issues | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| ...my family members have become healthier | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |

*7. Wealth Change:* Since I have been using the Three-Controls Technology …

| item | Completely disagree | 2 | 3 | 4 | 5 | Fully agree |
|---|---|---|---|---|---|---|
| ...I can buy fashionable clothes for my children | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| ...I was able to buy a mobile phone | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| ...I was able to buy new furniture for the family home | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| ...I have more money than before | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| ...I have lost a lot of money | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |

*8. Natural Capital:* Since I have been using the Three-Controls Technology …

| item | Completely disagree | 2 | 3 | 4 | 5 | Fully agree |
|---|---|---|---|---|---|---|
| ...I see more wasps in my fields | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| ...I see fewer flies in my fields | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| ...there are more dragonflies in my fields | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| ...I have seen fewer birds around my fields | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| ...I have seen fewer frogs in my fields | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| ...there are more fish in my fields | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| ...I have seen fewer rats in my fields | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| ...there are more crickets in my fields | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| ...I have seen more bats in my fields | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| ...I have seen more bugs in my fields | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| ...there are fewer beetles in my fields | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| ...I have seen more butterflies in my fields | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| ...I have seen fewer snakes in my fields | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| ...there are more stemborers in my fields | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| ...I have seen fewer moths in my fields | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| ...I have seen fewer spiders in my fields | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| ...I see more planthoppers in my fields | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| ...there are more trees and shrubs on my farm | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| ...there are more wildflowers around my fields | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |

## 4. Non-rice income

Does your household have sources of income other than from rice production? (salary from employment, farm labor, income from other crops, family garden, store, etc.) □ Yes □ No
If yes, how much of your household's total income is from non-rice? Provide an approximate percentage:____(%)
If no, does this mean that your household, including all members of your family, depends on income from rice 100%?
□ Yes □ No

What other non-farming income does your household have? Please specify other sources of your income (tick all that apply).

- ☐ Salary earner at private firms with regular payment (e.g., factory/office worker)
- ☐ Salary earner at public facilities (government employee, public school teacher)
- ☐ Casual wage earner (irregular payment)
- ☐ Wages from farm labor
- ☐ Selling farm products, livestock, fish
- ☐ Selling non-agricultural goods
- ☐ Selling products from family garden
- ☐ General store owner
- ☐ Construction
- ☐ Miller
- ☐ Taylor/sewer
- ☐ Transport business
- ☐ Rental of agricultural equipment/machine
- ☐ Rental of non-agricultural equipment
- ☐ Other: ___________________________________

Who owns this income? □ Farmer □ Spouse □ Son □ Daughter □ Other: __________

## 5. Financial support for agricultural production and insurance

Do you borrow money for agricultural production purposes? □ Yes (If yes, proceed) □ No (If no, skip)
If yes, who do you receive this money from?
☐ Bank □ Microfinance institution □ Relatives/neighbors □ Other: ____________
For how many years have you borrowed money for agricultural production? __________
For what do you receive the money for agricultural production for? (tick all that apply)
□ Purchase of agricultural machinery (e.g. tractor, harvester, etc.) □ Inputs (i.e. fertilizer and pesticides)
☐ Farm infrastructure (e.g. sheds, irrigation canal, etc.) □ Other: ______________________
How much money do you borrow per cropping season? __________ Yuan
Did you avail crop insurance? □ Yes (If yes, proceed) □ No (If no, skip)
Since when have you had crop insurance? __________
How much insurance premium do you pay per mu? __________ Yuan per mu

## 6. Demographic information

Township: □ Hengli □ Ruhu □ Luzhou
Village: □ 1 □ 2 □ 3 □ 4 □ 5 □ 6
Age: ___________ Gender: ☐ Male ☐ Female
Civil Status: ☐ Married ☐ Single ☐ Widow/er ☐ Separated
What is the size of your farm? ___________ mu
Number of full years farming: ___________ (If first year farming, enter 1. Otherwise, enter whole number.)
Are you the head of the household? □ Yes □ No
What is your relationship with the household head?
☐ Wife □ Son □ Daughter □ Sibling □ Others
How many persons currently live in your house? ___________
How many children do you have? ___________
How many of your children are 15 years and younger? ___________
How many of your children are 16 years and older? ___________
What is your first child (second child, third child, etc.) 16 years and older doing?
☐ Senior secondary school □ University □ Work □ Farming Other: ______________
Do any of your children work in the city? □ Yes □ No
What will happen with your land if you are not be able to farm anymore?
☐ My children might continue farming on it □ My children might rent it out
☐ I might rent it out □ Other:______________________________

**Perception survey questionnaire: Vietnam**

## Farmers Perceptions of Sustainable Development (FPSD) – Vietnam

You are invited to join a research study where our team aims to measure the effects of CORIGAP, which is funded by the Swiss Agency for Development and Cooperation (SDC), to your livelihood and the environmental and economic changes to your household due to your adoption of the 1 Must Do – 5 Reductions (1M5R) and 3 Reductions – 3 Gains (3R3G) related farming practices. The information from this survey will inform a PhD thesis conducted for the University of Basel, Switzerland. The interview will involve the collection of some personal information, farming practices, and livelihoods.

I, *(name)*________ hereby consent that Mr/Ms *(name of interviewer)*______ may interview and collect information from me and my field using the Survey Questionnaire.

- My participation to the interview is voluntary
- I understand that I shall provide my personal information such as my personal information, the occurrences I encountered, attitudes, and practices; my perceptions about rice seed sector.
- All information will be treated confidentially, it will not be possible to identify single farmers and data will be presented in an aggregated form
- I have been informed that while the information gained during the study may be published and the data may be shared with IRRI members for further processing and analysis, no personal information will be divulged.
- Data will be stored at IRRI, Under the Data Privacy Act, the personal information can be retained only for as long as necessary for the fulfillment of the purposes (as per above) for which the data was obtained (ref: Section 11(e), Chapter III, Data Privacy Act).
- The information collected will be subject to the data privacy laws of Vietnam as well as the data privacy act of 2012 of the Philippines

I have been informed of my rights as a data subject, including the right to object, to access, and to correction of my personal information. Hence, I understand that all personal data I provide will be kept confidential and be protected by International Rice Research Institute through appropriate security measures for data protection. For any misuse of the information I provided, my complaints will be addressed by the International Rice Research Institute through Dr. Melanie Connor; (m.connor@irri.org) I can also file a complaint with the National Privacy Commission of the Philippines in accordance with the DPA.

I hereby certify that this Consent was read to me in the language known to me and that I likewise understand and am fully aware of its meaning.

Name:________________ Signature/Thumb mark:________________ Date:_______________

## 1. Sociodemographic information

### Farmer details

| | | | | |
|---|---|---|---|---|
| Province: | ☐ An Giang | ☐ Can Tho | ☐ Long An | ☐ Tien Giang |
| Project: | ☐ 1M5R | ☐ 3R3G | ☐ SRP | ☐ SKEP |

| Commune in An Giang | Commune in Can Tho | Commune in Long An | Commune in Tien Giang |
|---|---|---|---|
| ☐ 1 | ☐ 1 | ☐ 1 | ☐ 1 |
| ☐ 2 | ☐ 2 | ☐ 2 | ☐ 2 |
| ☐ 3 | ☐ 3 | ☐ 3 | ☐ 3 |
| ☐ 4 | ☐ 4 | | |
| ☐ 5 | ☐ 5 | | |
| ☐ 6 | ☐ 6 | | |

Age: ___________

Gender: ☐ Male ☐ Female

Civil Status: ☐ Married ☐ Single ☐ Widow/er ☐ Separated

What is the size of your farm? ___________ ha

How many parcels do you have? ___________

What is the size of your largest parcel? ___________ha

How close is the nearest market from your largest parcel (main field)? ___________km

How close is the main water source to your largest parcel (main field)? ___________km

Number of full years farming: ___________ (If first year farming, enter 1. Otherwise, enter whole number.)

Who decides on the pest management practices used on your cultivated area?

☐ Myself ☐ Land owner (if rented) ☐ Labor service provider

☐ Input (money, fertilizer, pesticides, etc.) provider ☐ Farmer cooperative ☐ Farmer group

What is your highest level of education attained?

☐ No school at all ☐ Primary school ☐ Secondary school ☐ High school

☐ Bachelor's degree ☐ Post-graduate degree (Masters/PhD)

Are you the head of the household? ☐ Yes ☐ No

What is your relationship with the household head?

☐ Wife ☐ Son ☐ Daughter ☐ Sibling ☐ Others

How many persons currently live in your house? ___________

How many children do you have? ___________

How many of your children are 15 years and younger? ___________

How many of your children are 16 years and older? ___________

What is your first child (second child, third child, etc.) 16 years and older doing?

☐ Senior secondary school ☐ University ☐ Work ☐ Farming

☐ Other: ________________________________________

What will happen with your land if you are not be able to farm anymore?

☐ My children might continue farming on it ☐ My children might rent it out

☐ I might rent it out ☐ Other: ________________________________________

## 1.2. Non-rice income

Does your household have sources of income other than from rice production? (salary from employment, farm labor, income from other crops, family garden, store, etc.) ☐ Yes ☐ No

If yes, how much of your household's total income is from non-rice? Approximate percentage. __________ (%)

If no, does this mean that your household, including all members of your family, depends on income from rice 100%?

☐ Yes ☐ No

What other non-farming income does your household have? Please specify other sources of your income. (Tick all that apply)

- ☐ Salary earner at private firms with regular payment (e.g., factory/office worker)
- ☐ Salary earner at public facilities (government employee, public school teacher)
- ☐ Casual wage earner (irregular payment)
- ☐ Wages from farm labor
- ☐ Selling farm products, livestock, fish
- ☐ Selling non-agricultural goods
- ☐ Selling products from family garden
- ☐ General store owner
- ☐ Trader/merchant
- ☐ Fabricator
- ☐ Construction
- ☐ Carpentry
- ☐ Miller
- ☐ Taylor/sewer
- ☐ Transport business
- ☐ Rental of agricultural equipment/machine
- ☐ Rental of non-agricultural equipment
- ☐ Other: ________________________________________

Who owns this income?

☐ Farmer ☐ Spouse ☐ Son ☐ Daughter ☐ Other: ___________

### 1.3. Financial support for agricultural production and insurance

Do you borrow money for agricultural production purposes? □ Yes (If yes, proceed) □ No (If no, skip)
If yes, who do you receive this money from? (Tick all that apply)
□ Bank □ Microfinance institution □ Input provider □ Trader
□ Relatives/neighbors □ Other: ______________________________
For how many years have you borrowed money for agricultural production? __________
For what do you receive the money for agricultural production for? (Tick all that apply)
□ Purchase of agricultural machinery (e.g. tractor, harvester, etc.) □ Inputs (i.e. fertilizer and pesticides)
□ Farm infrastructure (e.g. sheds, irrigation canal, etc.) □ Other: ________________________
How much money do you borrow per cropping season? __________ Dong
Did you avail crop insurance? □ Yes (If yes, proceed) □ No (If no, skip)
Since when have you had crop insurance? __________
How much insurance premium do you pay per ha? __________ Dong per ha

## 2. Details on farming practices and technology adoption

~~Please confirm in which specific seasons below you cultivate rice (tick all that apply)~~:
□ Main season 2018 □ Summer-autumn season 2018 □ Winter-spring season 2018-2019

### 2.1. Adoption of best management practices

Which of the following practices have you adopted? (Tick all that apply)
□ Reduction of seed rate □ Reduction of fertilizer use □ Reduction of water use
□ Management of water use □ Using certified seeds □ Reduction of pesticides
When did you start *selected practice*? ___________
In which cropping season did you use *selected technology*? (Tick all that apply)
□ Main season 2018 □ Summer-autumn season 2018 □ Winter-spring season 2018-2019
I apply *selected practice* on:
□ On largest parcel only □ All my parcels □ On selected parts of largest parcel
□ On selected parts of my smaller parcels □ Only on my smaller parcels
Please indicate why you decided to apply *insert selected practice* (tick all that apply)
□ The extension worker promoted it □ An agricultural company promoted it
□ I am part of a farming cooperative and it is a requirement □ I saw other farmers using it
□ The head of farmers promoted the use
Who provided the information about *selected practice* (Tick all that apply)
□ Technical change agents □ IRRI researchers □ University researchers
□ MARD extension agent □ DARD extension agent □ NGOs
□ Agrochemical retailer or technician □ Trader, rice buyer □ Credit agency
□ Miller □ Consumer □ Other farmers (including farming family members)
□ Farmer cooperative □ Non-farming family members □ Other: _______________

Do you use the following technologies? (Tick all that apply)

- □ High yielding variety
- □ Drum seeder
- □ Mechanical transplanter
- □ Laser levelling
- □ Alternate wetting and drying (AWD)
- □ Ecologically-based rodent management
- □ Combined harvester
- □ Solar bubble drier
- □ IRRI super bag
- □ Flatbed drier
- □ Hermetic storage bag
- □ Broadcasting

When did you start using *technology*? ___________

In which cropping season did you use *selected technology*? (Tick all that apply)
☐ Main season 2018 ☐ Summer-autumn season 2018 ☐ Winter-spring season 2018-2019
I apply *selected technology*on:
☐ On largest parcel only ☐ All my parcels ☐ On selected parts of largest parcel
☐ On selected parts of my smaller parcels ☐ Only on my smaller parcels
Please indicate why you decided to apply *selected technology* (tick all that apply)
☐ The extension worker promoted it ☐ An agricultural company promoted it
☐ I am part of a farming cooperative and it is a requirement ☐ I saw other farmers using it
☐ The head of farmers promoted the use
Who provided the information about *selected technology* (Tick all that apply)
☐ Technical change agents ☐ IRRI researchers ☐ University researchers
☐ MARD extension agent ☐ DARD extension agent ☐ NGOs
☐ Agrochemical retailer or technician ☐ Trader, rice buyer ☐ Credit agency
☐ Miller ☐ Consumer ☐ Other farmers (including farming family members)
☐ Farmer cooperative ☐ Non-farming family members ☐ Other: ________________
What rice variety are you currently using?
☐ Main season 2018:______ ☐ Summer-autumn season 2018:______ ☐ Winter-spring season 2018-2019:_____
What rice varieties have you used before?
☐ Main season 2018:______ ☐ Summer-autumn season 2018:______ ☐ Winter-spring season 2018-2019:_____

## 2.2. Benefits and drawbacks of selected technologies

Which of the following technologies do you plan on using in the next seasons? (Tick all that apply)

☐ High yielding variety
☐ Drum seeder
☐ Mechanical transplanter
☐ Laser levelling
☐ Alternate wetting and drying (AWD)
☐ Ecologically-based rodent management
☐ Combined harvester
☐ Solar bubble drier
☐ IRRI super bag
☐ Flatbed drier
☐ Hermetic storage bag
☐ Broadcasting

What benefits and advantages have you experienced since you started using *selected technology*?
Please rate the reasons from 1 to 6; where 1 means not applicable at all and 6 means very applicable.

| Benefits | 1 | 2 | 3 | 4 | 5 | 6 | NA |
|---|---|---|---|---|---|---|---|
| 1. High yield | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| 2. High income | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| 3. Fits my cropping pattern | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| 4. Satisfies my preferences | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| 5. Replaced different technology(ies) | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| 6. Less lodging | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| 7. More free time | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| 8. Fewer damages from drought | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| 9. Fewer damages from snails | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| 10. Fewer damages from insects | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| 11. Fewer damages from rats | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| 12. Fewer damages from diseases | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| 13. Fewer damages from weeds | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| 14. Easy to apply | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| 15. Less expensive | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| 16. Labor shortage | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| 17. Labor costs are lower | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| 18. Labor hours are lower | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| 19. Weather conditions allowed use | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 20. Technology is easily available | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 21. Technology is suitable for my field conditions | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 22. Plants die less | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 23. The environment has improved | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 24. Assured market/buyer for my harvested grains | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Other: | | | | | | | |

Which of the following technologies did you decide to or plan to not use anymore?

- ☐ High yielding variety
- ☐ Drum seeder
- ☐ Mechanical transplanter
- ☐ Laser levelling
- ☐ Alternate wetting and drying (AWD)
- ☐ Ecologically-based rodent management
- ☐ Combined harvester
- ☐ Solar bubble drier
- ☐ IRRI super bag
- ☐ Flatbed drier
- ☐ Hermetic storage bag
- ☐ Broadcasting

Please indicate how applicable the reasons are for not using *selected technology* anymore.
Please rate the reasons from 1 to 6; where 1 means not applicable at all and 6 means very applicable.

| **Drawbacks** | **1** | **2** | **3** | **4** | **5** | **6** | **NA** |
|---|---|---|---|---|---|---|---|
| 1. Low yield | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 2. Doesn't fit cropping pattern | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 3. Doesn't satisfy my preferences | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 4. Not needed any longer | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 5. Replaced by different technology(ies) | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 6. Increased lodging | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 7. Personal time constraints (too busy) | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 8. Damage (pest, drought) | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 9. Too difficult to apply | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 10.Too difficult to understand | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 11. Too expensive | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 12. Labor shortages | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 13. Labor costs are too high | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 14. Labor hours are too high | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 15. Weather conditions did not allow use | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 16. Technology is not suitable for my field conditions | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 17. Plants died | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 18. No market for the variety | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 19. No market for rice grains | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 20. The environment has deteriorated | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Other: | | | | | | | |

## 3. Cropping seasons

### *Selected season*: Area cultivated

How many hectares of land did you cultivate in total (owned and rented) for rice in the *selected season* using *selected technologies*? _________

How many hectares do you cultivate for other crops? ________

How many kilograms of rice seeds do you use per ha? ________

If you cultivate on rented land, how large is the land you rent? _________ (ha) (Smaller than total cultivated area)

What is the tenure status of the ha of rented land? □ Leasehold: _____ fixed rent) □ Share tenancy:_______ (%)

If you cultivate on rented land, on what basis did you pay for the land rent?

☐ In-cash: Dong per ha □ In-cash: Dong per farm □ In-kind: Kilogram per ha

☐ In-kind: Kilogram per farm □ Shared harvest with the renter (in %)

How much did you pay for the rent? _____ (Dong/ha) How much did you pay for the rent? ______ (Dong/farm)

How much did you pay for the rent? _____ (kg/ha)  How much did you pay for the rent? ______ (Kg/farm)
In percent, how much of the paddy produced went to the renter? __________ (%)
Did you irrigate your main field? □ Yes □ No

- How many times did you irrigate in *insert season*? ___________
- How high was the irrigation water level in cm? ___________

### 3.2. *Selected season*: Production

What do you cultivate? (Tick all that apply)
☐ Rice □ Sugar cane □ Soybean □ Maize □ Cassava
☐ Vegetables □ Other: ___________________________________________
How do you measure your rice harvest per season? □ Kilogram per ha □ Kilogram per farm
How many kilograms of fresh paddy did you produce per ha on all your parcels? __________
How many kilograms of fresh paddy did you produce per farm? __________
Please indicate what your rice produce is used for? (Tick all that apply)
☐ Family consumption □ Domestic sale □ Export □ Others
To whom do you sell your harvest? *if farmers chooses sale and export*
☐ Directly to consumers □ Trader (middle man) □ Miller □ Farmer cooperative
☐ Credit provider □ Rice dealer
What do you sell? □ Fresh paddy □ Dried paddy
How do you sell your *insert choice from before* □ Buyer collects paddy from me □ I take my paddy to the buyer
How far is it away from your field (in kilometers)? _______*if chosen that paddy is taken to buyer*

### 3.3. *Selected season*: Input cost group

Which of these items did you pay for in kind? (Tick all that apply)

☐ Seeds
☐ Fertilizer
☐ Fungicide
☐ Herbicide
☐ Insecticide
☐ Molluscicide
☐ Rodenticide
☐ Irrigation
☐ Hauling and transportation
☐ Renting machine for land preparation
☐ Renting machine for planting
☐ Renting machine for harvesting
☐ Paid labor

Please indicate how many kilograms per ha did you spend to pay for the following:

☐ Seeds: __________
☐ Fertilizer: __________
☐ Fungicide: __________
☐ Herbicide: __________
☐ Insecticide: __________
☐ Molluscicide: __________
☐ Rodenticide: __________
☐ Irrigation: __________
☐ Hauling and transportation: __________
☐ Renting machine for land preparation: __________
☐ Renting machine for planting: __________
☐ Renting machine for harvesting: __________
☐ Paid labor: __________

Which of these items did you pay for in cash (Dong)? (Tick all that apply)

☐ Seeds
☐ Fertilizer
☐ Fungicide
☐ Herbicide
☐ Insecticide
☐ Molluscicide
☐ Rodenticide
☐ Irrigation
☐ Hauling and transportation
☐ Renting machine for land preparation
☐ Renting machine for planting
☐ Renting machine for harvesting
☐ Paid labor

Please indicate how much cash did you spend to pay for the following (Dong per ha):

- ☐ Seeds: __________
- ☐ Fertilizer: __________
- ☐ Fungicide: __________
- ☐ Herbicide: __________
- ☐ Insecticide: __________
- ☐ Molluscicide: __________
- ☐ Rodenticide: __________
- ☐ Irrigation: __________
- ☐ Hauling and transportation: __________
- ☐ Renting machine for land preparation: __________
- ☐ Renting machine for planting: __________
- ☐ Renting machine for harvesting: __________
- ☐ Paid labor: __________

How many kilograms of seeds did you buy per ha? __________

### 3.4. *Selected season*: Production disposal group

To which of the following did you allot your production of fresh paddy? (Tick all that apply)

☐ Sold immediately as fresh paddy ☐ Dried and milled for home consumption

☐ Dried and stored as seed stock ☐ Dried for selling

How many kilograms of fresh paddy did you sell immediately as fresh paddy? __________

How many kilograms of fresh paddy did you set aside for home consumption? __________

How many kilograms of fresh paddy did you set aside as seed stock? __________

How many kilograms of fresh paddy did you dry for selling? __________

How many kilograms of dried paddy will yield from 100 kilogram of fresh paddy? __________ (% drying recovery)

As which of the following did you sell your dried paddy? (Tick all that apply)

☐ Sold as regular dried paddy ☐ Sold as seeds ☐ Sold as milled rice

How many kilograms of dried paddy did you sell as it is? __________

How many kilograms of dried paddy did you sell as seeds? __________

How many kilograms of dried paddy did you mill for selling? __________

How many kilograms of milled rice will yield from 100 kilogram of dried paddy? __________ (% milling recovery)

### 3.5. *Selected season*: Selling price

Please indicate the prevailing selling prices for the following in the first rice season:

Fresh paddy selling price (Dong/kg): __________ Dried paddy selling price (Dong/kg): __________

Milled rice selling price (Dong/kg): __________ Seed selling rice (Dong/kg): __________

## 4. Changes in the farm due to adoption of best management practices

If you will look back to the time when you were NOT using *selected practices*, did you observe any changes in your farm since you have been using them?

Please indicate if any of the following has increased [+], decreased [-] or stayed the same [=].

| Categories of change | + | – | = |
|---|---|---|---|
| Area cultivated | ❐ | ❐ | ❐ |
| Yield | ❐ | ❐ | ❐ |
| Input costs | ❐ | ❐ | ❐ |
| Seed rate | ❐ | ❐ | ❐ |

What was the size of your field BEFORE you used *selected practices*? __________ (ha)

How many kg/ha of fresh paddy were you producing BEFORE you adopted *selected practices*? _______ (kg/ha)

How many kilograms of seeds did you use BEFORE the adoption of best management practices? ______

Which of the following inputs did you have LESS COST since using *selected practices*? (Tick all that apply)

- ☐ Seeds
- ☐ Fertilizer
- ☐ Fungicide
- ☐ Irrigation
- ☐ Hauling and transportation
- ☐ Renting machine for land preparation

- ☐ Herbicide
- ☐ Insecticide
- ☐ Molluscicide
- ☐ Rodenticide
- ☐ Renting machine for planting
- ☐ Renting machine for harvesting
- ☐ Paid labor

With reference to your current input costs, please estimate by how much in percent (%) you SPENT LESS on the following items since you have been using *selected practices*.

- ☐ Seeds: __________
- ☐ Fertilizer: __________
- ☐ Fungicide: __________
- ☐ Herbicide: __________
- ☐ Insecticide: __________
- ☐ Molluscicide: __________
- ☐ Rodenticide: __________
- ☐ Irrigation: __________
- ☐ Hauling and transportation: __________
- ☐ Renting machine for land preparation: __________
- ☐ Renting machine for planting: __________
- ☐ Renting machine for harvesting: __________
- ☐ Paid labor: __________

### 4.1. General expenses (only for those with reported non-rice income)

Please indicate from which household income you generally source the money that you spend on the following household items. You may tick both or none at all if the item is not applicable to your household needs and expenses. How much in percent (%) from each income source do you generally use to spend for?

| Item | Non-rice | Rice | N/A | % from non-rice | % from rice |
|---|---|---|---|---|---|
| Food | ❒ | ❒ | ❒ | _____ | _____ |
| Meat and fish | ❒ | ❒ | ❒ | _____ | _____ |
| Fruits and vegetables | ❒ | ❒ | ❒ | _____ | _____ |
| Dairy | ❒ | ❒ | ❒ | _____ | _____ |
| Rice | ❒ | ❒ | ❒ | _____ | _____ |
| Special foods such as cola, chocolate, etc. | ❒ | ❒ | ❒ | _____ | _____ |
| Healthcare | ❒ | ❒ | ❒ | _____ | _____ |
| Clothing | ❒ | ❒ | ❒ | _____ | _____ |
| Mobile communication (cellphone, prepaid load, etc.) | ❒ | ❒ | ❒ | _____ | _____ |
| School fees and supplies | ❒ | ❒ | ❒ | _____ | _____ |
| University tuition | ❒ | ❒ | ❒ | _____ | _____ |
| Transportation (car, motorcycle, bicycle, etc.) | ❒ | ❒ | ❒ | _____ | _____ |
| Public transportation (bus ride, taxi, Grab, etc.) | ❒ | ❒ | ❒ | _____ | _____ |
| Input for rice cultivation (seeds, fertilizer, pesticide, etc.) | ❒ | ❒ | ❒ | _____ | _____ |
| Water bill | ❒ | ❒ | ❒ | _____ | _____ |
| Electricity bill | ❒ | ❒ | ❒ | _____ | _____ |
| Renting agricultural machinery | ❒ | ❒ | ❒ | _____ | _____ |
| Purchasing agricultural machinery | ❒ | ❒ | ❒ | _____ | _____ |
| Savings | ❒ | ❒ | ❒ | _____ | _____ |
| Home improvement | ❒ | ❒ | ❒ | _____ | _____ |
| Other: | | | | _____ | _____ |

### 4.2. Income allocation of increased income

Do you think you had an increase in income since you used *selected practices* on your rice farming?

☐ Yes ☐ No

By how much your rice income has increased since you adopted *selected practices*? Please indicate your estimated total income increase of your total land area in Dong per ha: ____________

Do you remember where you spent the additional increase in your rice income?

☐ Yes ☐ No

Please indicate whether you have allotted a portion of your increased income on the following items.

What percentage of your increased income did you allocate to the following selected items?

| Item | Yes | No | N/A | % |
|---|---|---|---|---|
| Food | ❒ | ❒ | ❒ | _____ |
| Meat and fish | ❒ | ❒ | ❒ | _____ |
| Fruits and vegetables | ❒ | ❒ | ❒ | _____ |
| Dairy | ❒ | ❒ | ❒ | _____ |
| Rice | ❒ | ❒ | ❒ | _____ |
| Special foods such as cola, chocolate, etc. | ❒ | ❒ | ❒ | _____ |
| Healthcare | ❒ | ❒ | ❒ | _____ |
| Clothing | ❒ | ❒ | ❒ | _____ |
| Mobile communication (cellphone, prepaid load, etc.) | ❒ | ❒ | ❒ | _____ |
| School fees and supplies | ❒ | ❒ | ❒ | _____ |
| University tuition | ❒ | ❒ | ❒ | _____ |
| Transportation (car, motorcycle, bicycle, etc.) | ❒ | ❒ | ❒ | _____ |
| Public transportation (bus ride, taxi, Grab, etc.) | ❒ | ❒ | ❒ | _____ |
| Input for rice cultivation (seeds, fertilizer, pesticide, etc.) | ❒ | ❒ | ❒ | _____ |
| Water bill | ❒ | ❒ | ❒ | _____ |
| Electricity bill | ❒ | ❒ | ❒ | _____ |
| Renting agricultural machinery | ❒ | ❒ | ❒ | _____ |
| Purchasing agricultural machinery | ❒ | ❒ | ❒ | _____ |
| Savings | ❒ | ❒ | ❒ | _____ |
| Home improvement | ❒ | ❒ | ❒ | _____ |
| Other: | | | | _____ |

## 4.3. Farmer's perception on their rice farming

Please rate the following statements from 1 to 6 based on your level of agreement; where 1 means completely disagree and 6 means fully agree: Since I've adopted *selected practices*

| item | Completely disagree | 2 | 3 | 4 | 5 | Fully agree |
|---|---|---|---|---|---|---|
| It was difficult for me to use less seeds | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| It was easy for me to change to certified seeds | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| It was easy for me to use less chemical fertilizer | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I have used more organic fertilizer | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| It was easy for me to use less herbicides | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| It was easy for me to use less insecticides | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| It was difficult for me to use less rodenticides | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| It was easy for me to use less molluscicides | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| It was difficult for me to use less fungicides | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| It was difficult for me to reduce my water use | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I have been doing less irrigation hours | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I have used more fuel for my agricultural machinery | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I have used less electricity for my agricultural practices | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| My soils have been more prone to erosion | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I leave my fields fallow during one rice season | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I have noticed less post-harvest losses | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| It has been difficult for me to reduce my post-harvest losses | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I have been collecting my rice straw | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I have used my rice straw for mulching, cattle fee, mushroom production biogas production or other | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I have planted trees and/or shrubs | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I have also planted other plants – not rice – between or along my fields | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |

Where do you receive information about new farming practices and technologies?

□ DARD □ MARD □ Village head □ Village farmer groups □ Farmer cooperative

□ Neighboring farmers □ Family members □ Internet □ Facebook □ WhatsApp

□ Television □ Radio □ Technical Change agents □ IRRI researcher

☐ Agrochemical sales representative ☐ Trader (rice buyer) ☐ NGOs ☐ Credit agency
☐ Miller ☐ Other: ________________________________________

### 4.4. Knowledge about best management practices

Please rate the following statements from 1 to 6 based on your level of agreement; where 1 means completely disagree and 6 means fully agree.

| Item | Completely disagree | 2 | 3 | 4 | 5 | Fully agree |
|---|---|---|---|---|---|---|
| I know pretty much about best management practices | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| I do not feel very knowledgeable about best management practices. | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| Among my circle of fellow farmers, I am one of the experts on best management practices | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| Compared to most other people, I know less about best management practices. | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| When it comes to best management practices, I really do not know a lot. | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| I know pretty much about how to use the best management practices. | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| I know pretty much about how the best management practices work. | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| I know pretty much about the importance of the best management practice for rice farming. | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |

### 4.5. Satisfaction with best management practices

Please rate the following statements from 1 to 6 based on your level of agreement; where 1 means completely disagree and 6 means fully agree.

| Item | Completely disagree | 2 | 3 | 4 | 5 | Fully agree |
|---|---|---|---|---|---|---|
| I expected that it would be easy for me to follow best management practices. | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| It has been easy for me to follow best management practices exactly. | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| I received a good explanation about best management practices. | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| I am not sure the best management practices were worth the trouble it took implement them. | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| The best management practices have been great for the environment. | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| The best management practices have been great for my financial development. | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| My fellow farmers are just as happy using the best management practices as me. | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| The best management practices have become standard practice for me. | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |

### 4.6. Expectations of best management practices

Please rate the following statements from 1 to 6 based on your level of agreement; where 1 means completely disagree and 6 means fully agree.

| Item | Completely disagree | 2 | 3 | 4 | 5 | Fully agree |
|---|---|---|---|---|---|---|
| The best management practices did not work out the way I expected them to. | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| My expectations on my financial development since using best management practices have been met. | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| The best management practices exceeded my expectations on productivity increase. | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |
| I expect to see more positive changes when I continue using best management practices. | ❐ | ❐ | ❐ | ❐ | ❐ | ❐ |

### 4.7. Dimensions of change

Please rate the following statements from 1 to 6 based on your level of agreement; where 1 means completely disagree and 6 means fully agree.

*1. Agricultural production:* Since I've adopted best management practices

| Item | Completely disagree | 2 | 3 | 4 | 5 | Fully agree |
|---|---|---|---|---|---|---|
| My yield has increased a lot | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I have produced higher quality rice | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| Rice farming has become more difficult | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I use recommended rice varieties | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I do not use certified seeds | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I have reduced my water use | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| Working on farm is not as hard anymore | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I have been able to save money due to avoided production costs | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| My seed rate has decreased | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I spent more money to pay on production costs | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| My fertilizer use has decreased | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I now apply more pesticides | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I have less post-harvest losses | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |

*2. Facilities and equipment:* Since I've adopted best management practices

| Item | Completely disagree | 2 | 3 | 4 | 5 | Fully agree |
|---|---|---|---|---|---|---|
| I have been able to buy new farming equipment. | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I have been able to upgrade or build new farm buildings (e.g. tractor shed) | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I can afford to buy pesticide safety equipment | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I rent more land for rice production | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I was able to have my house renovated and improved | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I have been able to build a new house | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |

*3. Employment:* Since I've adopted best management practices

| Item | Completely disagree | 2 | 3 | 4 | 5 | Fully agree |
|---|---|---|---|---|---|---|
| I was able to take on other paid work | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| my wife/husband was able to take on other paid work | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I was able to employ more farm workers. | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |

*4. Knowledge and knowledge sharing:* Since I've adopted best management practices

| Item | Completely disagree | 2 | 3 | 4 | 5 | Fully agree |
|---|---|---|---|---|---|---|
| I have gained a lot of knowledge | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I have been able to provide better workforce | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I have changed my farming habits | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I am now able to express concerns about my farming practices | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |

*5. Land tenure:* Since I've adopted best management practices

| Item | Completely disagree | 2 | 3 | 4 | 5 | Fully agree |
|---|---|---|---|---|---|---|
| I have been able to expand my rice production through renting other land | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I had to sell some of my land | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I have been able to buy more land for farming other crops, vegetables or fruit | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I have been able to buy land for building a house (or the land the rented where their house is on) | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |

*6. Social capital:* Since I've adopted best management practices

| Item | Completely disagree | 2 | 3 | 4 | 5 | Fully agree |
|---|---|---|---|---|---|---|
| I can now provide advice to fellow farmers on how to improve their farming practices | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I can now organize farmers into groups to work together to improve farming practices | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| The best management practices have been widely adopted by the rice farmers in my community | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I can now communicate with other farmers about my experience in using best management practices | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |

*7. Food security:* Since I've adopted best management practices

| Item | Completely disagree | 2 | 3 | 4 | 5 | Fully agree |
|---|---|---|---|---|---|---|
| My family's eating habits have not changed at all | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| My family can eat more meat | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| My family can eat more fruits | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| My family can eat more vegetables | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| My family eats more kinds of food | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| The portion sizes of our meals have increased | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |

*8. Wealth change:* Since I've adopted best management practices

| Item | Completely disagree | 2 | 3 | 4 | 5 | Fully agree |
|---|---|---|---|---|---|---|
| I can buy fashionable clothes for my children | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I was able to buy a mobile phone | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I was able to buy new furniture for the family home | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I have more money than before | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| My family has more money to spend | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I have lost a lot of money | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |

*9. Financial capital:* Since I've adopted best management practices

| Item | Completely disagree | 2 | 3 | 4 | 5 | Fully agree |
|---|---|---|---|---|---|---|
| I have been able to provide financial support to others | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I have been able to take out a loan | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I have been able to save money due to increase in income | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |

*10. Health change:* Since I've adopted best management practices

| Item | Completely disagree | 2 | 3 | 4 | 5 | Fully agree |
|---|---|---|---|---|---|---|
| My health has improved a lot | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I have more health issues | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I can immediately seek healthcare without waiting for government support | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I can afford private health insurance | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| My family members have become healthier | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |

*12. Cultural capital:* Since I've adopted best management practices

| Item | Completely disagree | 2 | 3 | 4 | 5 | Fully agree |
|---|---|---|---|---|---|---|
| I am able to participate in community activities | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I can now provide more donations/pledges for community activities | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I was able to participate in community activities | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I was able to participate in religious pilgrimages | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |

*11. Natural capital:* Since I've adopted best management practices

| Item | Completely disagree | 2 | 3 | 4 | 5 | Fully agree |
|---|---|---|---|---|---|---|
| I see more wasps in my fields | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I see fewer flies in my fields | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| There are more dragonflies in my fields | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I have seen fewer birds around my fields | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I have seen fewer frogs in my fields | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| There are more fish in my fields | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I have seen fewer rats in my fields | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| There are more crickets in my fields | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I have seen more bats in my fields | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I have seen more bugs in my fields | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| There are fewer beetles in my fields | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I have seen more butterflies in my fields | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I have seen fewer snakes in my fields | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| There are more stemborers in my fields | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I have seen fewer moths in my fields | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I have seen fewer spiders in my fields | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| I see more planthoppers in my fields | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| There are more trees and shrubs on my farm | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| There are more wildflowers around my fields | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| The environment has overall improved | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |

Are you a member of a farming cooperation? □ Yes □ No