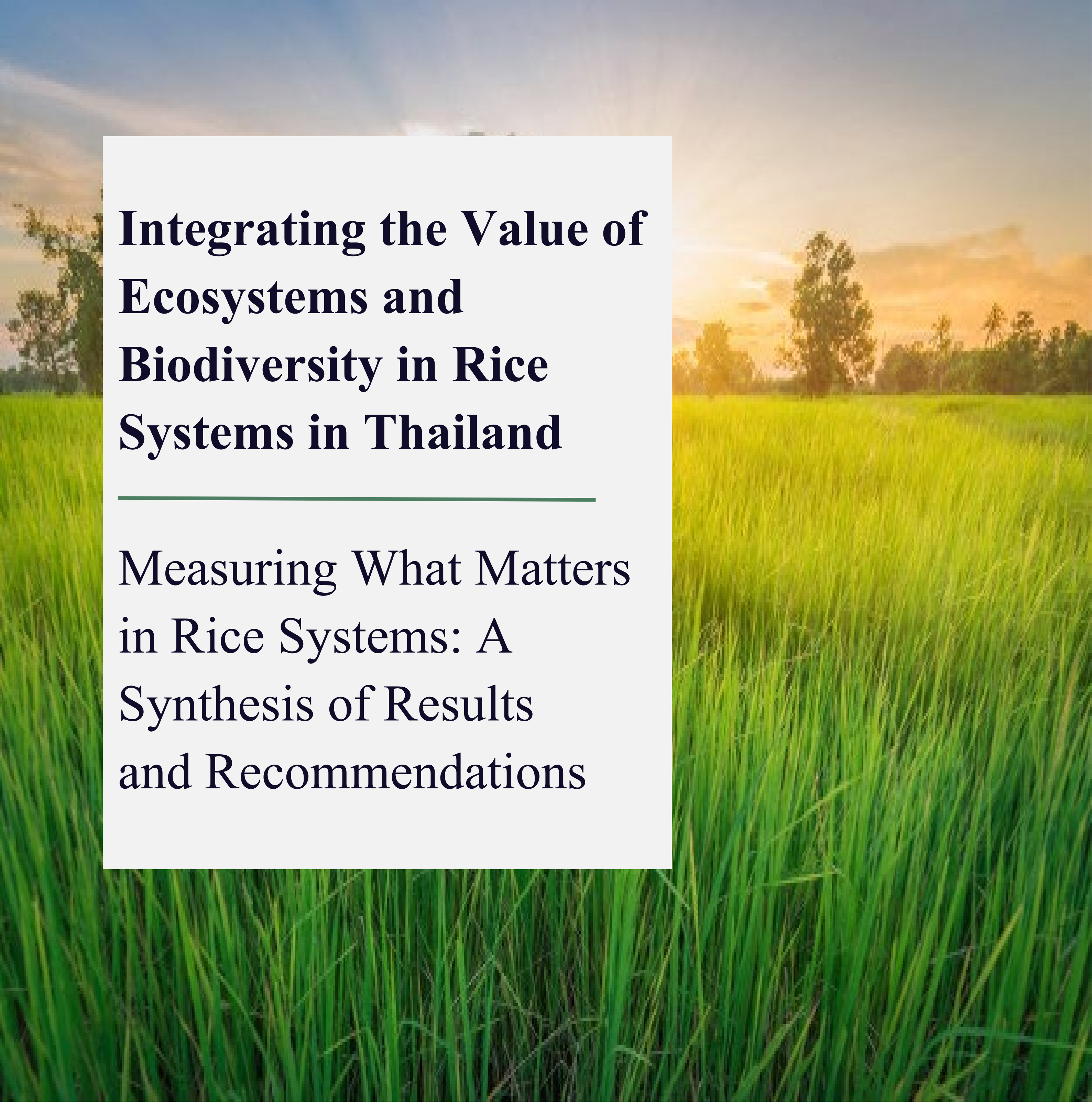

Integrating the Value of Ecosystems and Biodiversity in Rice Systems in Thailand

Measuring What Matters in Rice Systems: A Synthesis of Results and Recommendations

August 2022 – Final

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The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) supports this initiative on the basis of a decision adopted by the German Bundestag

TEEB The Economics of Ecosystems & Biodiversity

econ คณะเศรษฐศาสตร์ มหาวิทยาลัยขอนแก่น FACULTY OF ECONOMICS, KHON KAEN UNIVERSITY

Supported by: Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

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Foreword

For Thailand, agriculture is a backbone sector of socioeconomic development and delivering food security. Among several agricultural products, rice is the most significant product in the country. However, the food production system depends on natural resources, and in the meantime, it affects biodiversity and the environment. The food production system may be faced with the risk of uncertainty if we are not paying attention to maintain a wealth and resilience ecosystem. Therefore, moving forward to transformative change in food systems is urgently required. Promoting organic rice cultivation is one of the sustainable rice production that benefits biodiversity and the ecosystem. However, the limitation of the regulations on organic rice production challenges the farmer to transform conventional to organic practices. The results of this project are evidence-based to reveal the net benefits, in terms of visible and invisible added values, that value of organic rice production over conventional in the North-East of Thailand. The policy recommendations on marketing mechanisms, incentive measures, and technology transfer from this project not only encourage concrete action and sufficient support from the government but also introduce more options for the farmers to make better decisions on their rice cultivation. The integration of ecosystem and biodiversity values in rice systems in Thailand could promote long-term sustainability, support global targets such as the SDGs, and the implementation of the Convention on Biological Diversity (CBD) and the UN Framework Convention on Climate Change (UNFCCC).

Dr. Phirun Saiyasitpanich
Secretary - General
Office of Natural Resources and Environmental Policy and Planning

คำนำ (Foreword)

การเกษตรมีความสำคัญต่อการสร้างความมั่นคงทางอาหารและการขับเคลื่อนเศรษฐกิจของประเทศไทย โดยเฉพาะข้าวซึ่งเป็นหนึ่งในผลิตภัณฑ์การเกษตรที่สำคัญของประเทศ ทั้งนี้ ระบบการผลิตอาหารเป็นกิจกรรมที่ต้องพึ่งพาทรัพยากรธรรมชาติโดยสามารถส่งผลกระทบต่อสิ่งแวดล้อมและความหลากหลายทางชีวภาพได้ ดังนั้น การเกษตรที่คำนึงถึงการอนุรักษ์ความหลากหลายทางชีวภาพและระบบนิเวศจะช่วยลดความเสี่ยงที่อาจเกิดขึ้นต่อระบบการผลิตอาหารในอนาคตได้ ดังนั้นจำเป็นต้องให้ความสำคัญกับการเปลี่ยนแปลงไปสู่ระบบการผลิตอาหารที่ยั่งยืน การปลูกข้าวอินทรีย์เป็นรูปแบบหนึ่งของการผลิตข้าวยั่งยืนที่สนับสนุนการคุ้มครองความหลากหลายทางชีวภาพและระบบนิเวศ อย่างไรก็ตาม ข้อจำกัดและกฎเกณฑ์ต่าง ๆ ในการผลิตข้าวอินทรีย์เป็นความท้าทายที่ทำให้เกษตรกรตั้งคำถามถึงความคุ้มค่าของการปรับเปลี่ยนรูปแบบจากการปลูกข้าวทั่วไปเป็นการปลูกข้าวอินทรีย์ ผลการศึกษาโครงการนี้เป็นหลักฐานเชิงประจักษ์ซึ่งนำเสนอการบูรณาการมูลค่าของระบบนิเวศและความหลากหลายทางชีวภาพในระบบผลิตข้าวของประเทศไทยที่ชี้ให้เห็นถึงต้นทุนและผลประโยชน์ต่าง ๆ ของการผลิตข้าวอินทรีย์และข้อเสนอแนะเชิงนโยบายในการจัดการพื้นที่ปลูกข้าวอย่างยั่งยืนในระยะยาวเพื่อผลักดันไปสู่การปฏิบัติอย่างเป็นรูปธรรมผ่านการสนับสนุนของรัฐทั้งกลไกการตลาด การสร้างแรงจูงใจและการสนับสนุนเทคโนโลยีต่าง ๆ และยังนำเสนอข้อมูลเพื่อเป็นทางเลือกในการประกอบการตัดสินใจให้กับเกษตรกรผู้ปลูกข้าวอีกด้วย การผลิตข้าวและการเกษตรที่ยั่งยืนจะเป็นหนึ่งในหัวใจสำคัญในการบรรลุเป้าหมายการพัฒนาที่ยั่งยืน ตลอดจนสนับสนุนการดำเนินงานของอนุสัญญาว่าด้วยความหลากหลายทางชีวภาพและกรอบอนุสัญญาสหประชาชาติว่าด้วยการเปลี่ยนแปลงสภาพภูมิอากาศ

ดร. พิรุณ สัยยะสิทธิ์พานิช

เลขาธิการสำนักงานนโยบายและแผนทรัพยากรธรรมชาติและสิ่งแวดล้อม

Foreword

Across cultures, geographies, land and seascapes, the future and health of almost everyone on earth today, and everyone yet to be born, depends on the health of our food system. As we overexploit natural resources beyond sustainable limits and degrade the health of ecosystems, we put our food systems at further risk – in a world where hunger and malnutrition continue to grow.

Globally, agri-food systems are major drivers of our triple planetary crisis of pollution, biodiversity loss and climate change. The more we douse the fuel, the pesticides, and the chemical fertilizers into farming, the more we knock out the biodiversity that makes our food systems work – with deleterious knock-on effects to health, livelihoods, our economy and the attainment of our 2030 Agenda. We know how to change this. A greater investment in nature is essential for sustainable food systems.

Nature provides a range of benefits that contribute to our economies and well-being, such as pollination and the provision of water that are the basis of food production. More and more evidence suggests that adopting nature-positive agricultural systems not only improves the ability of nature to provide these benefits but also provides long-term socio-economic benefits. Yet, too often these benefits are ignored in decisions taken on how we grow, transport, and manage food. Most of these benefits are not priced in the market or included in financial analyses, ultimately skewing decisions and choices towards the degradation and destruction of nature. Since 2008, UNEP has worked to make sure that these benefits are valued and fully included in policymaking through the Economics of Ecosystems and Biodiversity (TEEB) Initiative.

This report is the result of an IKI-funded TEEB policy assessment in Thailand. Together, partners sought to answer the question: What is the economic case for expanding the adoption of organic rice in North-East Thailand? As such, the report provides the economic evidence for this real-world policy question, selected by the project Steering Committee, chaired by the Office of Natural Resources and Environmental Policy and Planning. UNEP commissioned and provided technical steer to a consortium of researchers from multiple Thai universities, under the leadership of the Economics Faculty of Khon Kaen University.

One of the critical dimensions explored was to compare yield levels over time of conventional rice production versus switching from conventional to organic production. This is particularly important today, considering the increasing levels of global food price inflation and the alarming trends in food insecurity. The research consortium modelling found that, contrary to common perception, switching to organic from conventional rice production only reduces yields by around 1%.

The report finds that these relatively small projected losses are massively outweighed by the potential benefits of a switch to organic production. Converting 90 % of rice fields to organic could generate benefits of $3.8 billion by 2035. There are also substantial benefits which are not valued in monetary terms. For instance, there is a more than three-fold increase in the biodiversity index (which measures the variety and quantity of insects) by switching to organic farming.

UNEP and partners have shown that shifting from conventional rice production to organic rice production in North-East Thailand makes both economic and ecological sense. By measuring and putting economic values on the often ‘invisible’ benefits of nature, this report makes the economic case for nature-positive food production in one of the largest food staple sectors in the world.

The UN Food Systems Summit in 2021 opened a collective discussion on national pathways for a radical change to the way we govern our food systems. Drawing from the findings of this report, UNEP looks forward to continuing to collaborate with the Thai authorities to promote the application of nature-positive farming practices for the sustainable transformation of our food systems – for people and planet.

Susan Gardner

Director, Ecosystems Division

UN Environment Programme

Box 1: TEEBAgriFood Thailand:
Integrating the value of ecosystems and biodiversity in rice systems

TEEBAgriFood is an initiative of the United Nations Environment Programme (UNEP) which seeks to make visible the impacts and dependencies of the agri-food value chain on nature. These critical contributions and concerns are often not counted in economic transactions and are often overlooked in decision-making. Thailand joins China, India, Indonesia and Malaysia in the Asia Pacific region as well as other countries (Brazil, Colombia, Georgia, Kenya, Mexico, Rwanda, Tanzania, and Uganda) in piloting the TEEB for Agriculture and Food initiative around the world.

Objectives TEEBAgriFood is aimed at informing the agriculture and food planning process in Thailand by providing comprehensive, scientific evidence to support agriculture and food system policies, with direct links to policy priorities of the Ministry of Environment and Natural Resources, and Ministry of Agriculture and Cooperatives.

Partners TEEBAgriFood Thailand is an initiative under the political lead of the Office of Natural Resources and Environmental Policy and Planning, ONEP, in the Ministry of Natural Resources and Environment. Khon Kaen University is the host research institution, leading a team of researchers in three local universities and government agencies to carry out a multidisciplinary analysis of rice agroecosystems. The project is supported with funding from the German government and the European Union. The assessment reported here was supported through the International Climate Initiative (IKI).

Focus and location The initial analysis is focused on the impacts of different intervention options for the promotion of organic rice in Thai rice landscapes in the Northeastern region of Thailand, where rice is the main crop.

Methods The TEEBAgriFood analysis in Thailand uses a scenario modelling approach to examine the potential future impacts of land-use changes as a result of current organic rice expansion and sustainable agriculture policies. Impacts are assessed at the landscape level in terms of changes in rice-field biodiversity, the emission of greenhouse gases, air pollution, and the health impacts of chemical pesticides. Various biophysical and ecosystem services models are used in the analysis, applying locally available and field data, to project changes in natural capital, produced, human and social capital over the medium term. Economic valuation methods are applied to quantify the true costs and benefits of different agricultural approaches in rice agroecosystems. Research is also being conducted with farmers to assess the factors that could encourage farmers to switch from conventional practices to organic practice.

Expected outcomes: Policy makers will be equipped to recognize, measure, and capture the values of biodiversity and ecosystem services into their policy decision-making and strategies for sustainability of the rice production system. The true value of nature-positive production systems can be more fairly assessed alongside conventional agricultural production systems. Analysis of policy-linked scenarios projected over a long-term timeframe can be a powerful tool to assess the future environmental and economic impacts of the actions taken in the present. A holistic economic assessment will support the development of a policy roadmap to better support the integration of environmental, health, social and production goals.

For more information: http://teebweb.org/our-work/agrifood/

1. Introduction: The TEEBAgriFood Evaluation Framework

A transformative change in food systems is needed in order to meet the internationally agreed Sustainable Development Goals. The TEEBAgriFood initiative was developed by the UN Environment Programme in response to this need and seeks to achieve positive human livelihood outcomes and biodiversity improvements. The overall programme goals are to measure and mainstream the values of nature in decision-making and policy, to highlight the hidden, and often invisible, contributions of nature to agricultural production, and trade-offs made in land-use decisions, to highlight links of agricultural systems with human health, culture, and other ecosystems at the landscape level, and based on this scientific research, to work with partners and key stakeholders on pathways to implementing reform of national policies and measures for meeting the Sustainable Development Goals by 2030.

The TEEBAgriFood Evaluation Framework and approach was developed through a collaboration of scientists from many different countries and disciplines. This approach is synthesized in the report "Measuring What Matters in Agriculture and Food System" (UNEP, 2018) and described in more detail in the "TEEB for Agriculture & Food Scientific and Economic Foundations" report (UNEP, 2018). The components of the framework were adapted for this study to apply to the Thai rice sector. Figure 1 below illustrates the approach, highlighting the dependencies of the rice system upon stocks of natural, produced, social and human capitals and the value additions and impacts that the rice production system generates.

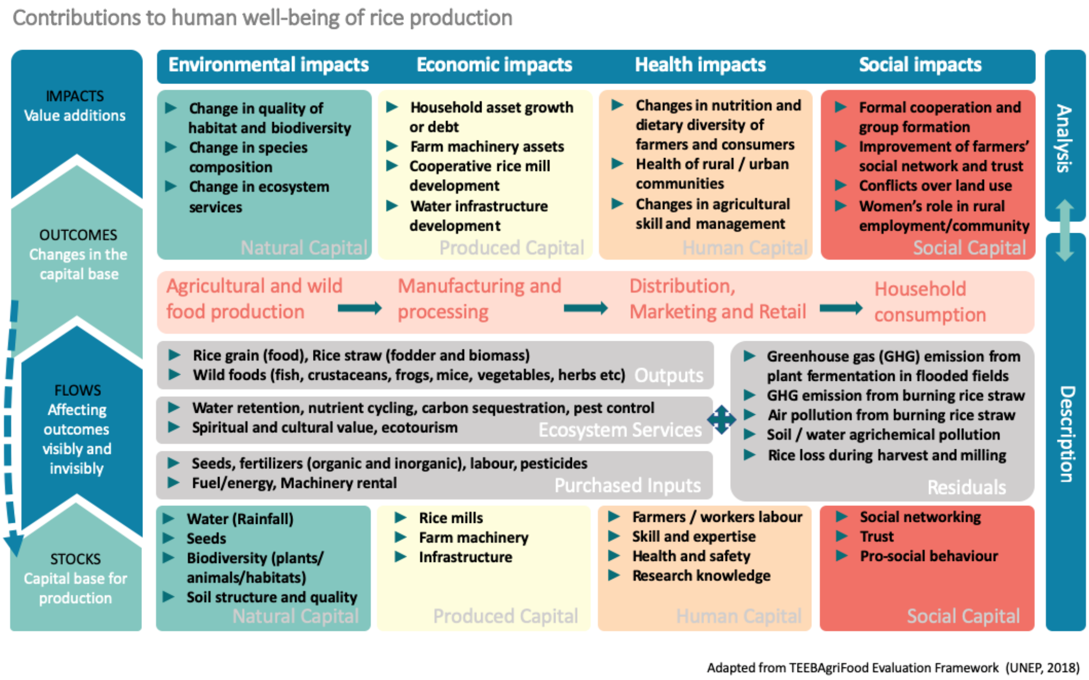


Figure 1: TEEBAgriFood Evaluation Framework adapted to the rice sector: capturing 'invisible' costs of rice systems in conventional economic analysis

2. Applying the TEEBAgriFood Evaluation Framework to the Thai Rice Context

Rice is the most important cereal crop in Thailand, and the main staple food of Thai households. It is a significant source of livelihood for 4.30 million rice farming households, comprising approximately 20 million people, or around 28 percent of the Thai population (National Statistical Office, 2019). Rice occupies around 50 percent of total agricultural area in Thailand (Office of Agricultural Economics, 2020). Most of this, or about 62 percent of the rice cultivation area, is in the Northeast region (Office of Agricultural Economics, 2020). Unlike the central plains of Thailand, the Northeast mostly does not have access to irrigation supply, such that most farmers in this region produce only one crop of rice each year, with cultivation starting in the annual rainy season.

Rice farming in Thailand is carried out by both men and women. Most rice farmers in Thailand are small-scale farmers, holding on average of 2.08 hectares of land per household (OAE, 2018) - 43% of rice farming households hold less than 10 rai (1.6 ha) of land. With low annual returns from rice, many rice farmers are risk-averse and are motivated not only to generate income, but also to spread risks, and maintain food security (see box 2 below).

Rice fields are a unique type of agricultural ecosystem - within a single crop rotation, the ecosystem of the rice field encompasses a diversity of habitat states that are ephemeral, providing a variety of niches for diverse flora and fauna species (Edirisinghe and Bambaradeniya 2010; Bambaradeniya et al. 2004). Besides being a source of food and livelihood, rice agroecosystems generate multiple ecosystem services for local communities and the public (see box 3 below).

The different practices for managing monoculture rice crop, from land preparation, cultivation to post-harvesting, can result in different impacts on ecosystem services in the rice fields and beyond. The main focus of policy makers on rice production in Thailand has been to increase productivity to ensure food security and competitiveness in the world market. Chemical fertilizers and pesticides have been promoted and are regularly applied in conventionally cultivated rice fields to ensure this goal and achieve maximum yields. Around 21% of rice residues are burned after harvest to eliminate rice straw and control pests, which significantly helps farmers to reduce time to management for the next crop. However, such practices are harmful to biodiversity and functioning of ecosystem services, for example soil fertility, root system development, crop resilience in the rice fields, and have a range of environmental and health impacts at the farm level and beyond include eutrophication and pollution of water bodies, affecting aquatic fauna in downstream river systems and ultimately the ocean, as well as acute and chronic sickness of local communities through exposure to farm chemicals and airborne particulate matter.

Box 2: Economic context of rice farming in Northeast of Thailand

Over recent decades, Thai farmers have been facing increased production costs along with increasing fluctuations in revenue. According to Attavanich et al 2019, this is partly explained by the structure of Thai input and output markets, which tend to be less competitive and have a long supply chain. Statistics provided by the Office of Agricultural Economics for a series of crops showed that in general, net farm profits have been squeezed over time. The analysis shows that rice farmers on average have received negative net farm income since 2013, indicating widespread fragility of farmers in this sector.

Many rice farming households have chronic debt. Even before the Covid-19 pandemic, the median outstanding debt amongst rice farmers in the Northeast was 163,798 Baht and 54% of these households have accessed payment holiday or restructuring programs according to 2018 data from the Bank for Agriculture and Agricultural Cooperatives (BAAC) (Chantarat et al 2020). Many also obtain loans from other sources.

Like the majority of Thai agricultural households, many rice farmers are dependent on income outside the agricultural sector, particularly daily wage labour income, which has been adversely affected during the Covid pandemic. A survey of farm households, found high income inequality, with rice farming households receiving an average annual income of 60,276 Baht, while 27% of households earned less than the poverty line (Chantarat et al 2020). On average, the survey found that non-farming income accounted for 80% of total household income. Over 40% of households are reliant on transfers from relatives working in other provinces.

Data from the register of Thai farmers, Department of Agricultural Extension 2018 show that rice farmers have access to a number of government different instruments, including compensation for rice harvesting costs (95% of farmers), crop insurance for main season rice (44% of farmers), debt repayment holidays (33% of farmers), relief provided in cases where fields are completely damaged by natural disasters (11% of farmers), loans for farmers after natural disasters (3% of farmers), promotion of growing crops after the rice crop (6.5% of farmers), organic rice promotion policy (0.3% of farmers), and other policies (17% of farmers). Farmers receive an average of around 17,000 Baht per household per year from these government instruments (Attavanich et al, 2019).

In 2017, government started the One million Rai Program to increase organic rice area. Support for organic rice farmers under the One Million Rai rice programme includes: a funding subsidy of 2,000, 3,000 then 4,000 Baht per rai for each qualified farmer who adopts organic rice cultivation practices, for the first three years respectively. Qualifying farmers are also eligible to receive organic rice seed for planting, to a maximum of up to 15 rai (roughly 2.4 ha) per farmer, for a total of three years. In the fourth year, the rice product is eligible to apply for certification by the Organic Thailand scheme run by the National Bureau of Agricultural Commodities and Food Standards (ACFS). The expenses associated with farm inspection and certification are covered for the next two years.

Access to water is expected to be an increasingly limiting factor in agricultural production as temperatures rise, and rainfall patterns change and become more erratic. At present, only 26% of agricultural households have access to irrigation in Thailand. The majority of the areas in the Northeast are not supplied by irrigation and rely on annual rains to produce one crop of rice per year.

Note 1,000 Baht = approximately 33 USD

The cultivation of organic rice has been gaining more attention amongst Thai farmers, there was on average an increase about 18,000 hectares of organic rice area each year between 2019-2021. Organic rice practice prohibits the use of synthetic fertilizers and pesticides, and focuses on building up soil quality through animal and green manures, managing pests through biological control taking advantage of natural ecosystem services, and enhancing functional biodiversity (Wachter and Reganold, 2014). Organic practice would be able to enhance biodiversity, ecosystem services, minimize GHG emissions, and adverse human health impacts from rice production when compared to conventional practice. However, many farmers expect that organic rice practices would provide lower rice yield than conventional rice cultivation systems especially during the transition period, which would result in a higher risk of farmers' income instability.

The disparate goals of food and income security, improving environmental and health impacts are important and interdependent, and reaching them is likely to require trade-offs. The question of interest is therefore of how to reduce trade-offs between these different goals, and to identify synergies that allow for maximizing benefits and the better well-being of farmers, while minimizing costs to environment and society. This study aims to answer this question through a scenario analysis to reveal and demonstrate the potential trade-offs generated should organic rice production practices in Thailand be extended to cover an increasingly larger area of the rice zone of the Northeast region over the next ten to fifteen years.

Adopting the TEEBAgriFood Evaluation Framework, the study sought to measure quantitative changes occurring in produced, natural and human capital under three alternative future scenarios versus "business as usual" (BAU). In terms of production capital, changes in rice output and production costs were modelled, including the initial cost of preparing the land for organic production. In terms of natural capital, potential impacts on green-house gas emissions, and biodiversity were assessed. In terms of human capital, health impacts of agrichemical and air pollution were quantified. These results were monetized to demonstrate the relative trade-offs and assist policy makers to identify the best scenario compared to BAU. In addition, social capital was also studied qualitatively to provide insightful information that should be seriously considered with the results from scenario analysis for policy design.

In the summary report below, Section 3 presents an outline of the projected scenarios, including maps of projected land use changes, which represent the variations in cultivation area of conventional and organic rice under each scenario. The changes which are measured through this study are explained in Section 4. Section 5 notes how these changes were valued in monetary terms for more direct comparison, and presents the results of the analysis revealing the changes in outcomes as a result of the expansion of organic rice under the four scenarios. Conclusions and key messages are summarised in Section 6. The relevance of these results to current Thai environmental and agricultural policy discussions and specific recommendations are summarised in Section 7. Key messages from the research are also presented in an accompanying document, available on the TEEB website.

The full findings and discussion of the scenario analysis are presented in a separate TEEBAgriFood Thailand report available on the TEEB website.

Box 3: Rice agro-ecosystems: ecosystem services and biodiversity and human well-being

Ecosystem services refer to nature's contributions to people. In addition to rice crops, many fauna and other flora of the rice fields have direct value for the farmers and other members of farming communities. Studies in the Northeast of Thailand have identified a high diversity of wild plants in and around the rice fields that are considered to provide important dietary and health benefits for farmers (Cruz-Garcia and Price, 2011). Fish, frogs, crabs, mice, crickets for example are harvested and cooked or preserved to supplement local diets, providing proteins, calcium and other useful nutrients.

The fauna of the rice fields also has indirect agricultural value, for example providing feed to ducks and chickens. Post-harvest, rice straw may provide fodder for cattle or buffalo. The household survey conducted for this assessment survey found that about 25 percent of farmers harvested the rice straw for cattle feed. About 6 percent of farmers produced straw bales for sale. About 65 percent of the farmers surveyed left the straw in the field as organic fertilizer.

The rice field is managed to maximise agricultural production and convenience of farmers. Many farm decisions involve trade-offs. Farmers are sometimes encouraged to keep rice bunds clear to avoid pests, but encouraging flowering plants on rice bunds can contribute to biological control of rice pests and encourage the maintenance of pollinator colonies important for other farm crops. Farmers consider the choice and location of trees at rice field borders to limit shading or soil nutrient competition to the rice crop. However, often the costs and benefits being traded-off are not easy to visualise or only become apparent over a long-term period.

Rice fields host a high degree of agrobiodiversity, much of which benefits rice production. Spiders, and predator insects, such as damselflies and dragonflies, as well as parasitoid insect populations control rice pests such as plant- and leafhoppers. Such natural checks and balances have been adversely affected by the increase in broad spectrum pesticide applications (Heong et al. 2015; Spangenberg et al. 2015) that do not distinguish between pests and beneficial insects. Insecticide use has ironically in the past caused an increase in pest abundance (Horgan et al. 2018; Gurr et al. 2016), as short-term success in pest elimination, over time increases system sensitivity to subsequent pest infestations. Trees in border areas provide resting sites for wild birds which help to control other types of rice plant pests, such as golden apple snails.

The food webs sustained by this biodiversity span many trophic levels in the rice field ecosystem. Near the bottom of many food chains, macro- and meso- invertebrates help to decompose organic matter ultimately feeding the microorganisms in soil which contribute to other ecosystem services such as soil nutrient exchange, soil moisture retention, carbon emission and sequestration, and crop resilience, each of which have key relevance to sustainable rice production.

At the larger scale, rice production is dependent on many other ecosystem services and natural processes, such as stable temperatures, adequate and timely rainfall and the nutrient deposition that this brings. Climate change threatens to alter weather patterns, increasing unpredictability and risk as global temperatures rise.

3. Scenario Analysis

Scenario analysis allows us to compare outcomes of different plausible policy futures. The research team has analyzed the benefits and costs of different rice production systems through a comparison between three different plausible future policy scenarios. The scenarios were defined on the basis of key government policies and targets for sustainable development of the rice sector. A focus group of local stakeholders in study sites, including local agricultural officers, farmers, millers, merchants, agricultural banks, and farmer organization heads, were invited to reflect on significant concerns related to the development of the organic agriculture sector. As part of the process of their development, the scenarios outlined below were approved by the TEEBAgriFood Steering Committee, which is chaired by the Office of Natural Resources and Environmental Policy and Planning (ONEP) and comprised of agencies from Ministry of Natural Resources and Environment and Ministry of Agriculture and Cooperatives, as well as the National Economic and Social Development Council.

3.1 Scenario development

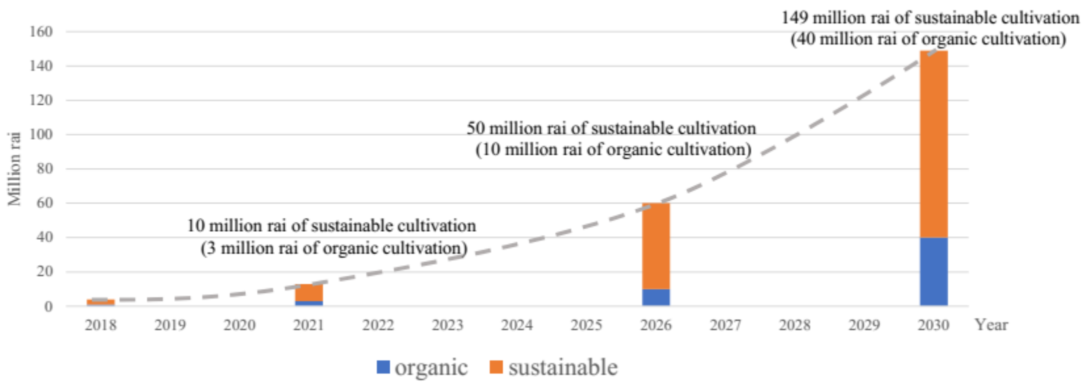
The plans and policies taken into account in the development of the scenarios for assessment include the current One Million Rai Organic Rice Farming pilot project, (2017-2021), and Thailand's long term 20-year Strategic Plan (2017-2036), and the related Master Plan for Agriculture, that promotes the expansion of Thailand's organic products for both domestic and international markets. The timeframe for scenario analysis is 17 years, starting in 2019 and ending in 2035. These timeframes are defined as the period from **2019-2025** (short term costs and benefits), **2019-2030** (medium-term costs and benefits), **2019-2035** (longer term costs and benefits).

The current organic rice production program target of the Rice Department of the Ministry of Agriculture and Cooperatives (MoAC), to be implemented in all provinces across the country, is to promote the conversion of one million rai of rice fields to organic production practices by 2019. Looking forward, the policy targets of the Committee on Agriculture and Cooperatives of Thai Parliament include the achievement of 100 percent of agricultural land nationwide (149 million rai or 23 million hectares) to be cultivated using either organic or sustainable agricultural practices by 2030[1]. Translating these targets into areas for spatial analysis, two percent of agricultural land is expected to be under organic agriculture by 2021 (about 3 million rai or 0.48 million hectares). By 2026, seven percent of agricultural land (about 10 million rai or 1.6 million hectares) should be under organic agriculture. After 2030, 30 percent of agricultural land (about 40 million rai or 6.4 million hectares) should be under

[1] Committee on Agriculture and Cooperatives https://bit.ly/2QOj46D

organic agriculture. The assumption underlying the scenarios adopted in this study is that up to 80 percent of the area targeted for organic agriculture development will be dedicated to the production of rice (as discussed below). According to the MoAC, the promotion of organic rice cultivation is mainly targeted in the Northeastern region. It should be noted that in each of the scenarios described below, the overall rice cultivation area is not changed. The scenarios assume that other existing land uses remain the same, such that the only changes are a differing proportion of conventional and organic rice farming.

Figure 2. MoAC target adopted in 2017 for sustainable and organic agriculture land in Thailand

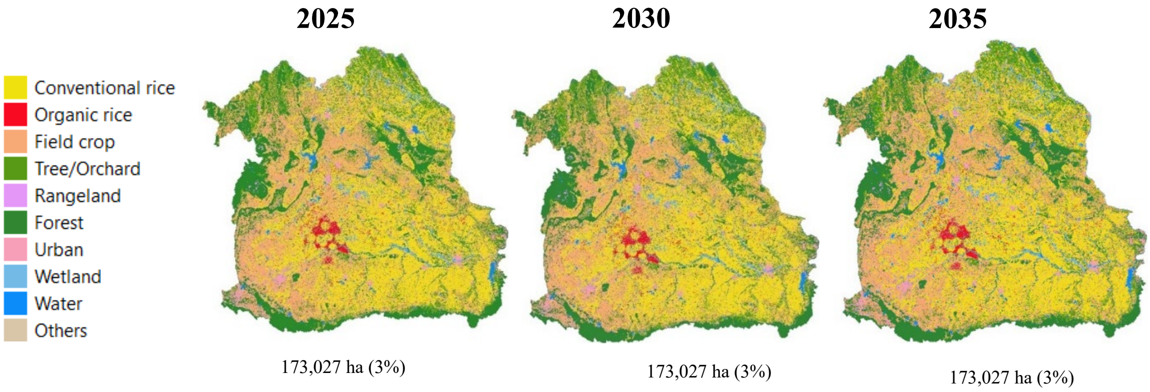


Source: Committee on Agriculture and Cooperatives https://bit.ly/2QOj46D.

Scenario 1: Business as usual (BAU)

The BAU scenario assumes the successful implementation to 2021 of the government's One Million Rai Organic rice program according to published targets. Participants targeted through this programme are assumed to successfully adopt organic practice in their rice fields and achieve certification under the "Organic Thailand" scheme. It takes at least three years for an organic farmer to qualify for certification. On this basis, it is assumed that the area of certified organic rice will reach just over one million rai (173,027 hectares) by 2025, or 3 percent of the current rice area of the Northeast region. Projecting forward, farmers are assumed to continue to produce organic rice in this area throughout the subsequent period to at least 2035. This scenario assumes that no new policy initiatives are implemented for further promotion of the organic sector. Figure 3 presents the areas of the Northeast region of Thailand which are projected through the BAU scenario to produce conventional and organic rice from 2025 to 2035.

Figure 3. Projected organic rice area expansion in the NE of Thailand under the Business As Usual scenario (Scenario1 or BAU)

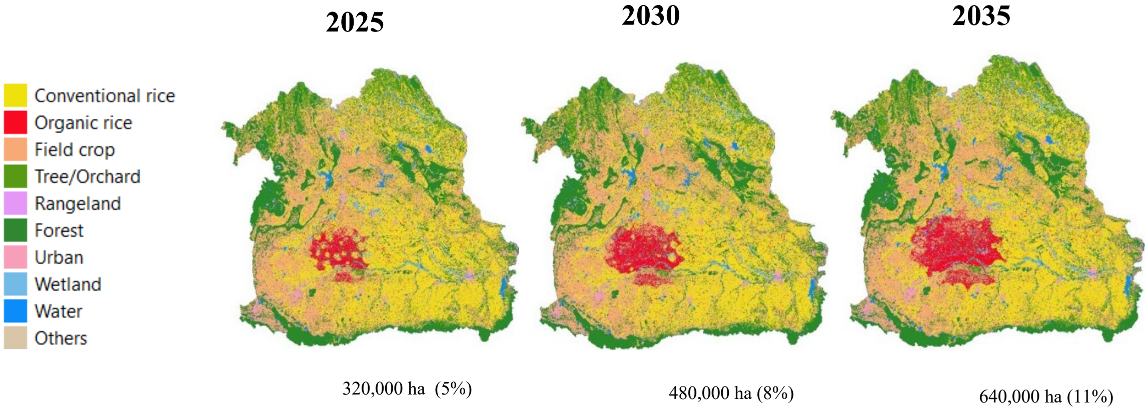


Note: The number under each picture indicates the projected organic rice area in hectares, and the number in parenthesis indicates the proportion of organic to total rice area in the Northeast region.

Scenario 2: One Million Rai Organic Rice promotion continued

This scenario assumes that the support provided by the One Million Rai Organic Rice programme is continuously renewed after the current programme expires in 2021 to continue to increase the adoption of organic agriculture by Thai rice farmers. Thus, the area under organic production is expanded by a further million rai nationwide, every five years to 2035. Figure 4 presents the areas projected to be dedicated to conventional and organic rice from 2025 to 2035 based on scenario 2.

Figure 4. Projected organic rice area expansion in the NE of Thailand under Scenario 2: One Million Rai Organic Rice promotion continued

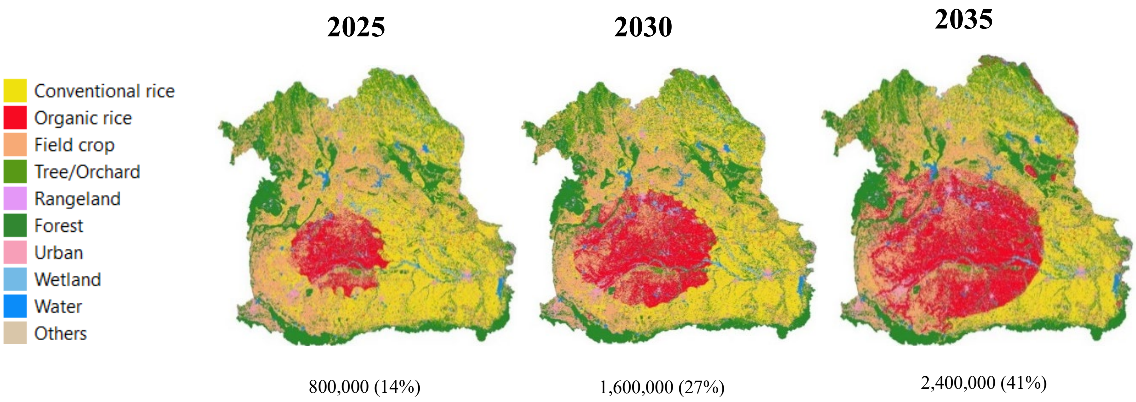


Note: The number under each picture indicates the projected organic rice area in hectares, and the number in parenthesis indicates the proportion of organic to total rice area in the Northeast region.

Scenario 3: Enhanced organic rice promotion

This scenario assumes that not only that the One Million Rai Organic rice promotion programme is continued as projected in Scenario 2, but also additional intervention programs are introduced after 2020 to accelerate the adoption of organic agriculture by Thai rice farmers over a wider area. The additional policy initiatives are not elaborated but are expected to be introduced through a collaboration of the Ministry of Natural Resources and Environment, the Ministry of Agriculture and Cooperatives and other ministries, including the Ministry of Public Health, the Ministry of Commerce between 2020 and 2035. Thus, the organic rice expansion in this scenario is target-seeking. This scenario assumes that the organic rice area in the northeast will expand to 800,000 ha, 1,600,000 ha, and 2,400,000 ha in 2025, 2030, and 2035 respectively. Figure 5 presents the areas projected to be dedicated to conventional and organic rice from 2025 to 2035 based on scenario 3.

Figure 5. Projected organic rice area expansion in the NE of Thailand under Scenario 3: Enhanced organic rice promotion

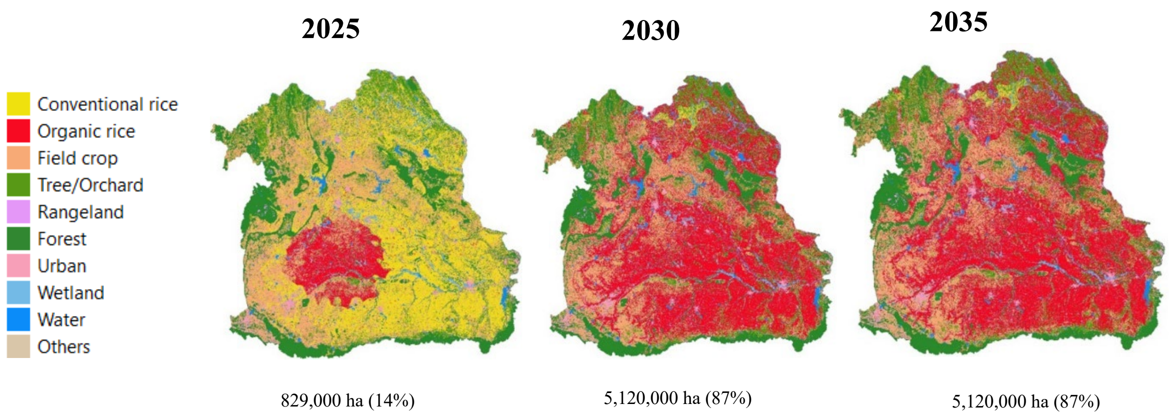


Note: Number under each picture indicates the projected organic rice area in hectares, and the number in parenthesis indicates the proportion of organic to total rice area in the Northeast region.

Scenario 4: Transformational change towards sustainability

This scenario assumes that demand for organic rice production has dramatically increased and that powerful stimulus programmes are introduced to reach the government target, organic and sustainable agriculture by 2030. It means that 100 percent of agricultural land in the northeast area (149 million rai or 23 million hectares) will be cultivated using either organic or sustainable practices. According to the government target, organic farming practices should be applied nationwide over 40 million rai or 6.4 million hectares by 2030, and it is assumed that 80 percent of that area would be dedicated to produce organic rice in the northeast region. Figure 6 presents the areas of conventional and organic rice from 2025 to 2035 based on scenario 4.

Figure 6. Projected organic rice area expansion in the NE of Thailand under Scenario 4: Transformational change towards sustainability



Note: Number under each picture indicates the projected organic rice area in hectares, and the number in parenthesis indicates the proportion of organic to total rice area in the Northeast region.

The projected policy-induced land-use change from conventional to organic rice described above will take place in the context of changes in the climate, which are expected to significantly affect Thai agriculture over the course of at least the next twenty to thirty years. Global warming is expected to generate changes in the amount and timing of rainfall. Some studies warn that extreme climate events, such as prolonged early season droughts and heavy downpours during the harvest season, may threaten rainfed lowland rice cultivation in some provinces in the Northeast (see Sujariya et al 2020). At higher temperatures, rice is expected to produce less grain in tropical areas (Nguyen, 2005; Peng, et al, 2004). Jintrawet et al, (2017) applied five climate models to assess emission scenarios RCP 4.5 and 8.5 in various sites around Thailand, with most projecting that rice yields in Thailand will decrease during 2006-2040, as a result of changes in rainfall patterns and increasing temperatures.

Thailand's population is expected to grow gradually during the scenario period under assessment until approximately 2030, when it will begin to drop. Population projections for 2025, 2030, and 2040 are 67.09 million, 67.14 million, and 65.37 million, respectively[2].

4. Summary of Changes Measured and Modelled

The land use area changes under each scenario are linked to measurable changes not only to produced capital including rice output and revenue flows, but also changes in natural capital, and human capital. As described in the TEEBAgriFood framework, the outcomes of agricultural production, processing, distribution, and consumption can be understood as changes in natural, human, social, and produced capital. Outcomes related to natural capital stocks that are covered in this study include changes to biodiversity, GHG emissions, and air pollution. Outcomes in terms of changes in human capital relate to changes in health of both farmers and the general public.

TEEBAgriFood analysis in Thailand uses a scenario modelling approach to examine the potential future impacts of land-use changes as a result of current organic rice expansion and sustainable agriculture policies. Impacts are assessed at the landscape level in terms of changes in rice-field biodiversity, the emission of greenhouse gases, air pollution, and the health impacts of chemical pesticides. Various biophysical and ecosystem services models, such as the Denitrification-Decomposition (DNDC) model and the Shannon-Wiener diversity index, are used in the analysis, applying locally available and field data, to project changes in natural capital, produced, human and social capital over the medium term. Economic valuation methods are applied to quantify the true costs and benefits of different agricultural approaches in rice agroecosystems. A full outline of the methods and their details applied for each component of the analysis are included in the full findings report.

The research team conducted farming household surveys to identify relevant variables that differed between conventional and organic rice farmers. The main variables captured through this household survey included the processes of rice cultivation, the cost structure of rice cultivation, income from rice production, measures of social capital, demographic and socioeconomic data from each household. The rice farming households surveyed were statistically representative of farming households in the northeast region. All the areas studied

[2] https://unfccc.int/sites/default/files/resource/Thailand_LTS1.pdf

were rainfed areas, without access to irrigation. This is why the impacts of alternative wetting and drying (AWD) techniques, particularly with respect to the potential benefits for reduction of greenhouse gas emissions, were not examined in the study.

4.1 Changes in rice production and income

One of the most visible and directly important impacts from organic rice cultivation on farmers and Thai economy are rice yields, revenues, and costs. Rice farmers, referred to as the backbone of the Thai economy and key actors in the food security of the nation, face considerable economic constraints in Thailand, particularly in non-irrigated areas (see box 3).

The TEEBAgriFood study generated modelling results using the Denitrification-Decomposition (DNDC) model to predict rice yields under conventional and organic practices over 2019-2035. This took into account the climate conditions projected by medium climate stabilisation scenario (RCP4.5), including maximum, minimum and mean temperature, as well as average daily precipitation, for assessing changes to ecosystem services according to the four study scenarios outlined above. Annually predicted climate forecasts in the Northeast of Thailand from 2019 to 2035 and current data on relevant climate ecological zones and soil series data from the Land Development Department were included in the parameters. Land and water management, rice residue management, and maximum rice production were taken into account. Changes in the urbanization area, related to population changes, were included in the land use modelling, measured by distance to the urban area and road network. Key economic indicators of rice yield, farm income, and production costs were assessed and modelled.

Often, when considering whether a switch to organic from conventional is viable and desirable, it is assumed that rice yield under organic production will be diminished in the short to medium term. The possibility of yield reduction following adoption of organic methods was the issue that the conventional farmers surveyed were the most concerned about. They expressed fears that in the first 1 or 2 years of transition to organic methods, they would get no output whatsoever. However, results from studies in Thailand indicate that this is not always the case. A study from the Rice Department shows that in the initial period of transition, the yields are indeed very low in comparison to the yields achieved before the transition. However, the same study found that, if farmers improve the fertility of the soil, after around 5 years, yields recover to a level similar to that of conventional production. In the study areas, particularly in Surin province, organic farmers have been using organic methods to grow rice for over 10 years. Their yields do not differ on average from those who grow rice using conventional methods.

Rice fields also generate usable secondary products, such as rice straw, wild foods and herbs (see Box2). Rice straw can be valuable for cattle feed, soil amendments, and processed for industrial uses which might be explored further. However, this study did not measure or value the outputs from rice fields other than the rice crop.

The cultivation costs of conventional and organic rice practices were analyzed by field data collected from both types of farmers. The data reveals that the cost structure of both practices is similar. The survey data indicated that organic farmers used machinery more often than conventional farmers, for planting rice seedlings especially. However, conventional rice practice requires higher overall costs than organic rice practice, mostly in expenditure on chemical fertilizer and pesticide costs. Organic practice prohibits the use of chemical pesticides, leading to a significant cost reduction compared with conventional rice. In fields that are not treated with pesticides, a diverse set of predator insects keeps herbivore insects in check, providing natural biological pest control in rice fields (Heong et al, 2017). As there is no expenditure on chemical fertilizer and pesticide, the cost of organic rice cultivation is on average lower than that of conventional practice by about 20.83 USD per hectare.

The information from the survey also allowed to analyze the amount of fertilizer (NPK nutrients) used in the organic rice fields, based on the addition of manure and other biological inputs into the field. The total amount of macronutrients (NPK) supplied to organic rice fields was found to be lower compared with conventional rice fields, which is associated with lower output for organic rice vs conventional methods. However, other factors were found to provide a boost in yields for organic rice farmers. The field survey revealed that organic rice farmers often used seedling planting machines (i.e. for transplanting rice seedlings into the field (*na dam*)), which contrasted with conventional rice farmers. The majority of the conventional rice farmers used the method of broadcasting seeds (*na wan*). The model showed that the use of machinery had the effect of upping the yields for the organic farms back to the same levels as the conventional farms. As a result, our study did not find any statistically significant difference between the yields from the organic and conventional fields taking all factors into account.

In addition, transferring from conventional rice cultivation to organic rice cultivation requires land management in the first year of transition. The land management mainly includes the establishment of physical buffers to prevent residual or external chemical contamination to the organic field. This activity imposes additional cost to organic farming by 114.58 USD per hectare in the first year of switching from conventional to organic practice.

All of these measures were analyzed at landscape level in scenario analysis to identify the effect of organic rice area expansion on these measures, which are presented in section 5 below.

4.2 Environmental Externalities – changes in natural capital stocks

For natural capital, this study focused on changes in biodiversity and greenhouse gas emissions from the transition from conventional to organic rice practices.

Insect Biodiversity

Rice fields are habitats for a high degree of biodiversity. This study focused on rice field arthropods, such as insects and spiders, due to the fact that they have a discernible, strong impact on rice production process. Their ability and function in controlling crop pests can be directly linked to production yields. This was not the case for the other animals, vertebrates such as fish, frogs etc, which could not be clearly linked as a variable in rice production output between conventional and organic.

As noted above, rice fields provide a habitat for many insects including herbivores, predators, pollinators, parasitoids, and others. The rice plants themselves are vulnerable to many herbivorous insects. Invertebrate predators, such as spiders and hornets, as well as birds, use the rice ecosystem as a hunting ground, keeping the herbivorous insects in check, with the benefit of limiting the damage to the rice crop. The functioning of ecosystem services and biodiversity are directly affected by pesticide use. Applying pesticides terminates not only herbivores but also predator insects that keep herbivores in check. Hence, organic and conventional practices of rice farming, generate changes in physical, biological and chemical composition of ecosystems. Such changes result in different services from ecological systems, which affect the benefit and cost of rice farming.

The TEEBAgriFood assessment analysed field data of insects combined with data from existing studies to compare the diversity of insects in organic and conventional rice systems. Modelling was applied in this study to project changes to the Shannon-Wiener diversity index as a result of adopting different rice practices. Random forest model was employed to predict the Shannon-Wiener diversity index at landscape level to assess the responses of biodiversity in rice fields based on projection of rainfall and temperature as well as different rice practices.

The biodiversity index of conventional rice practice is around -0.2, while the biodiversity index of organic rice practice is around 0.2. These results suggest that conventional rice landscape has less biodiversity than organic rice landscape in terms of plentiful and diverse insects. The scenario analysis links the variability of insects to changes in rice production cost as reported in section 5 below.

Greenhouse gas emissions

Rice production is both an important sink for the sequestration of carbon dioxide and an important source of emissions. The two main sources of GHG emissions in the rice field during cultivation, are mainly methane (CH4) from the fermentation of vegetative matter in the flooded fields and nitrous oxide (N20) from fertiliser application, and post-harvest (various emissions), mainly as a result of rice stubble combustion.

This study estimated the long-term change in GHG emissions (CH4 and N2O) and soil organic carbon stocks (SOC) from two standardised rice cultivation practices (organic and conventional) using the Denitrification-Decomposition (DNDC) model with parameters as described above. Given that the area studied is not served by irrigation[3], methods for potential mitigation of methane emissions such as alternative wetting and drying (AWD), which rely on irrigation supply, were not examined in the study. The DNDC model does not cover GHG emissions that would be released through post-harvest burning, so these additional emissions were estimated using the method proposed by Junpen, et al. (2018).

The average GHG emissions from rice straw burning in conventional rice production were calculated at 0.19 tons of CO2 equivalent per hectare per year[4]. It should be noted that, based on previous study (Junpen, et al, 2018), only around 21 percent of rice residues in the northeast of Thailand is subject to post-harvest burning. There is no GHG emission from rice straw burning for organic rice production, as burning is prohibited.

In respect to the emissions from the cultivation stages of production, organic rice practice releases slightly higher GHG than conventional rice practice. Namely, we found that conventional rice practice released on average 14.59 ton of CO2 equivalent per hectare per year, while organic rice practice released on average 15.54 ton of CO2 equivalent per hectare

[3] Most rice fields in the Northeast region cannot access irrigation system. Most of rice fields in this region are therefore rainfed. Rice fields are commonly continuously flooded during cultivation. Therefore, our DNDC model assumed that 100 percent of rice fields were under continuous flooding.

[4] The GHG emissions from rice stubble burning are calculated based on chapter 2 of 2006 IPCC guidelines for national greenhouse gas inventories, which exclude CO2 in the calculation ((Eggleston, H. S., et al., 2006).

per year[5]. In terms of carbon sequestration, this study found that organic rice practice improved soil organic carbon stock in comparison with conventional counterpart. The average soil organic carbon stock generated by organic rice practice is 42.46 tons of carbon per hectare per year, while that of conventional rice practice is 38 tons of carbon per hectare per year.

Adding together the three sources of GHG emission and sequestration, organic rice practice would release lower GHG than conventional rice practice. All of these measures are analyzed at landscape level in scenario analysis to identify the effect of expanding the organic rice area on GHG emissions, which are presented in section 5 below.

4.3 Health Externalities – changes in stocks of human capital

With respect to human capital, impacts on human health from pesticide poisoning and air pollution from conventional and organic rice cultivations were explored.

While pesticides are prohibited from use in organic rice practice, they are commonly used in conventional rice practice. The TEEBAgriFood assessment analysed data from field survey. Results confirmed that the risk of becoming sick as a result of pesticide poisoning faced by conventional farmers is significantly higher than that of organic rice farmers. The average treatment cost per individual amongst conventional rice farmers due to pesticide poisoning from the survey is 13 USD per crop season. The cost of these observable expenses for medical treatment for pesticide poisoning was approximately 1.17 million USD annually for conventional rice farmers.

The health impact elicited from survey data is considered the minimum health impact that could reliably be observed and reported based on visible cost of treatment. However, the long run effects of pesticides that may cause chronic diseases affecting internal organs such as liver and neurological system, which result in serious illnesses or death, cannot be captured through minor medical treatment cost information. To cover the invisible and long run effects of pesticides, the research team conducted a choice experiment method to elicit value of fatality risk reduction caused by pesticide poisoning directly from farmers' preferences. The responses

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[5] The findings on GHG emissions from rice fields in this study are similar to other field observation data reported in Thailand (Pengthamkeerati et al., 2011). However, applied to a national scale, these would imply that emissions from rice are higher than the total reported in Thailand's third Biennial Update Report (BUR3). The evaluation methodology and the GWP factors for methane and nitrous oxide were different. In the BUR3 report, the calculation of emissions followed the 2006 IPCC Guidelines, and the methane emission and GWP factors were based on default values from the IPCC Fourth Assessment Report (AR4). The emissions in this report were generated by the model which simulated the situation of emissions using daily climate data.

of farmers on choice experiment survey were assessed, using a value of statistical life (VSL) concept, to identify the marginal cost of enhancing safety or reducing fatality risk from pesticide poisoning placed by farmers. The estimated value of fatality risk reduction from pesticide poisoning accordingly was assessed at 251.67 USD per ha. The baseline result is used for the scenario assessment reported in Section 5 below.

Secondly, the health impacts of exposure to fine particulate matter (airborne particles with a diameter of less than 2.5 mm, or PM2.5) was quantified applying the association between the aerosol component and risk of mortality due to cardiovascular, respiratory, lung cancer, and all-cause mortality. The method proposed by Junpen et al (2018) allowed the research team to predict changes in health impacts from exposure to particulate emissions as a result of land use changes. Information on population growth was also included in modelling health impacts from exposure to PM2.5. Valuation is based on the Amended Human Capital approach (AHC), which estimates the cost in terms of loss to society of productivity. It reflects individual absence from work, adjusted with the gross domestic product per capita, depending on the health impacts under analysis. The AHC approach is commonly used to evaluate the human capital loss caused by air pollution assuming that human capital is the capital contributed for the entire society. The economic value of the loss of human capital is assessed by estimating the health impacts of those exposed to all ambient pollutants. In this study, the health impacts of PM2.5 from the rice straw burning were calculated to assess the negative externality to society. The health cost from risk of exposure to PM2.5 generated from rice straw burning in 2019 was calculated at 17.3 USD per hectare. The external cost of health impacts must be taken as a minimum assessment of the social cost of conventional rice production, and can be realized as the benefit from health impact reduction of switching from conventional to the organic rice system.

4.4 Social Externalities – changes in social capital

This study also assessed differences in social capital between conventional and organic rice farmers. Changes in social capital were explored through a qualitative analysis of the results of the household survey described above. This sought to understand the impact that the two rice cultivation practices may promote in terms of farmers' cooperation and collaboration and how this may affect differences in the level of trust, knowledge sharing, and prosocial behaviour among farmers and their community.

The results from the household survey suggest better social capital of organic rice farmers than conventional counterpart. Organic rice farmers reported more social participation than conventional rice farmers especially in the volunteering dimension. Prosocial behaviour toward others in their community may be explained by the higher rate of participation in group activities compared with conventional rice farmers for both male and female respondents.

The study also assessed whether or not conventional and organic rice practices generate any differences in gender roles in the community. It was found that female organic rice farmers worked side by side with male farmers for community and farmer group activities, while we could not clearly find this pattern for female conventional rice farmers from our survey data and observation in the field. Since our study design generated qualitative analysis results in relation to social capital, such changes could not be accounted for in terms of land use area changes for the scenario analysis.

4.5 Other - Government expenditures

Thailand has implemented initiatives and rice policies to induce farmers to adopt to more sustainable agricultural practice since 2017 under Thailand 4.0 agenda. The Million Rai Organic Rice Farming is one of the main initiatives to persuade conventional rice farmers to switch to organic practice. The primary objectives of this program are to promote organic rice production based on the organic rice standard of the Rice Department and to increase the area suitable for organic rice production that qualifies for the Organic Thailand certificate. Qualified farmers who adopted organic rice practice have received funding support of between 2,000 – 4,000 Baht per Rai per year for three years. In addition, the government invests in the agricultural extension services to enhance rice productivity, lead rice research and development, and support programme for organic rice transformation. To promote organic rice conversion, the government also creates the opportunity to support the investment and operation costs for this group of farmers. The Bank for Agriculture and Agricultural Cooperatives (BAAC), founded under the Ministry of Finance, offers a low-interest-rate loan for certified organic rice farmers.

5. Valuation and Scenario Analysis

The measures that could be quantified, which include rice yield / income, cost of rice cultivation, biodiversity, greenhouse gases emissions, and health impacts, were monetized to calculate relative benefits and costs generated under each scenario to identify the direct and indirect impacts of conventional and organic rice areas changes.

To evaluate all impacts together in terms of monetary value, different financial proxies are used as shown in Table 1 below. For the value of rice production, the average price of white rice from 1992 to 2020, $328 per ton, is used as proxy (Bank of Thailand, 2020). The cost differential between conventional and organic rice is developed on the basis of the household survey results showing that the cultivating cost of conventional rice is higher than cost of organic rice by about 20.83 USD per hectare per year. This is due to the cost of chemical fertilizer and pesticide, which are prohibited for organic rice. Conventional farmers on average spend about 16.67 USD per hectare and 4.16 USD per hectare for purchasing pesticides and chemical fertilizers, respectively. The pesticide cost saving is considered to represent the value of beneficial insects, or the benefit of biodiversity that results from organic practice.

The above analysis does not take into account the costs of converting from conventional to organic rice production, which requires the establishment of physical buffers and halting the use of chemicals for a period of at least three years to ensure there is no residual or external chemical contamination to the organic field. From our household survey, the average transition costs for such land preparation are around 114.58 USD per hectare for the first year of switching from conventional to organic practice.

The proxy value of GHG emissions is computed on the basis of the average price of a carbon credit from 2016-2020 reported by Thailand Greenhouse Gas Management Organization (2020) of 1.67 USD per ton of CO2 equivalent. It should be noted that this is a conservative financial measurement based on the current Thai market price[6], while the international average carbon price is around 3-5 USD per ton of CO2 equivalent (Zhongming, Zhu, et al., 2021).

The health impact caused by exposure to PM2.5 is estimated based on the AHC approach which measures the loss of human productivity adjusted to gross provincial product per capita. Finally, the value of statistical life (VSL) of fatality risk reduction from pesticide

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[6] There is no central market for buying and selling market carbon in Thailand. The Thai Greenhouse Gas Management Organization (TGO) has set up a Thailand Voluntary Emissions Reductions (T-VER) programme, which certifies and registers projects which are able to reduce carbon. T-VER certified carbon credits can be bought and sold "over the counter", e.g. between the registered owner of the reduced carbon emissions (company a) and someone who wants to buy/compensate them for this benefit (company b). Due to limited liquidity in this market, the price of carbon in Thailand is currently low compared with the price of carbon in the international market.

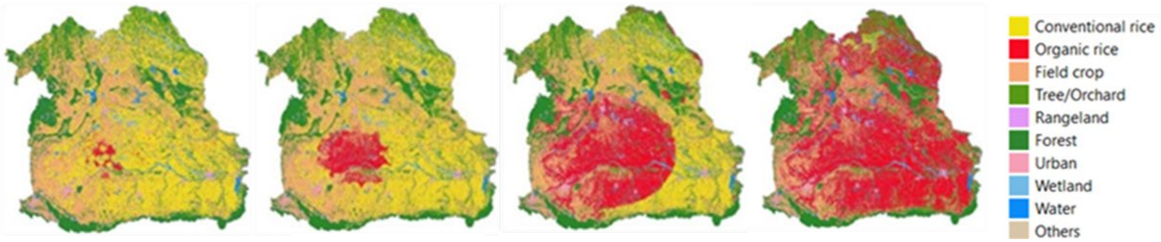
poisoning calculated from choice experiment method is applied for health benefit due to no pesticide applied in organic rice field. The VSL value is 251.67 USD per hectare of organic rice per year.

Table 1. Monetary proxies per unit of measure

Measure	Dimension	Monetary proxy	Unit	Value USD
Rice production	Financial	Price	$/ton	328
Benefit of cost saving	Financial	Chemical fertiliser cost	$/hectare	4.16
Beneficial insects	Financial	Pesticide cost	$/hectare	16.67
Land conversion cost	Financial	Cost	$/hectare	114.58
GHG emissions	Natural	Carbon price	$/ton CO2eq	1.67
Health cost from PM2.5	Health	Health cost from AHC approach	$/year	Calculated
Fatality risk reduction from pesticide poisoning	Health	Choice experiment method	$/hectare	251.67

These impacts are captured year by year based on the area change from conventional to organic in each scenario, BAU, S2, S3, and S4. These values are converted to net present values (NPV) applying a 5 percent discount rate for public project analysis, from year 2019 to 2035. The NPV presents the accumulated change in value that is projected to occur within 17 years as a result of land pattern changes of scenarios 2, 3, and 4 compared to BAU. The benefits and costs generated in the BAU scenario are used as reference to measure and compare the projected changes in scenario 2, scenario 3, and scenario 4. The results reveal an approximate minimum valuation of net benefits and costs generated after a transition from conventional to organic rice cultivation areas under scenario 2, 3, and 4 when compared to that of the BAU situation. Figure 7 illustrates the maximum extent of the expansion of organic rice area in each scenario by 2035 where the organic rice areas are 173,027 hectares, 640,000 hectares, 2,400,000 hectares, and 5,120,000 hectares under BAU, S2, S3, and S4, respectively.

Figure 7. Organic rice expansion in each scenario in 2035



BAU Scenario 2 (S2) Scenario 3 (S3) Scenario 4 (S4)

5.1 Results of scenario analysis

As described above, to identify the direct and indirect impacts of conventional and organic rice areas changes, the changes of outcomes of each scenario compared to BAU are explored in three dimensions applying the monetary proxies presented in table 1. Firstly, the direct revenue and cost of rice production dimension consists of value of rice production (yield), cost of cultivation, and transferring cost for land preparation. Secondly, human health externality dimension consists of health costs from exposure to PM2.5 and pesticides. Thirdly, environmental externality dimension consists of GHG emission.

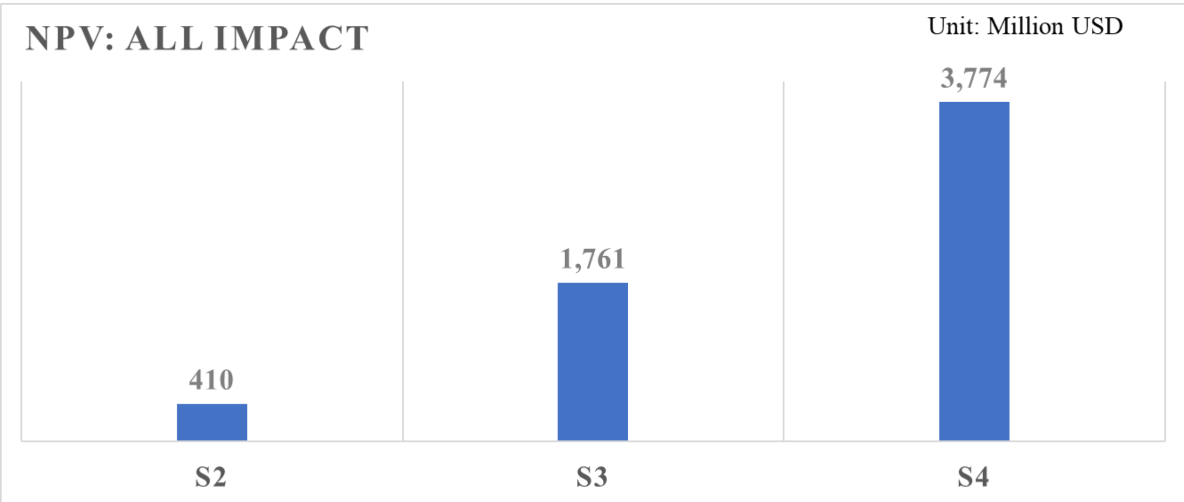
During 2019 to 2035, the BAU is projected to provide rice yield of 262 million tons, which is higher than that of S4, or 259 million tons. This is because the conventional rice practice provides slightly higher yield than organic rice, 2.33 tons per ha and 2.27 tons per ha on average respectively, or a difference of around 0.06 tons per hectare per year. Output varies according to climate factors as well as land use practice. In 2030, rice output is projected to be low in Scenario 4 both compared to other scenarios, and compared to other years, as a result of the heavy rainfall expected in that year. However, five years later, Scenario 4 is projected to produce a marginally higher rice output in 2035 than the Business as Usual scenario.

However, health concerns from the application of chemical pesticides and from exposure to PM 2.5 from stubble burning are major health negative externalities in conventional rice production. Moreover, the GHG emission in conventional practice could be higher than that in organic practice due to the lower capacity for soil carbon sequestration and continued GHG from post -harvest burning. These impacts are monetized and cumulatively calculated from 2019 to 2035 as present values in each scenario. The monetized impacts from organic rice expansion are shown below based on assessing the differences in net present values of costs and benefits generated by each scenario comparing to BAU.

Overall values: impact of expansion of organic rice production

Based on our assessment, taking into account all three dimensions, the overall result is that the greater the organic rice area, the higher the benefit. In relation to BAU, Scenario 4 (S4) projects the highest overall benefit of rice production, representing a total of an additional 3,774 million USD of accumulated value generated from 2019 to 2035, relative to BAU, as a result of the radical expansion of land use to organic rice production projected by this transformational scenario. This is followed by scenario 3 (S3) and scenario 2 (S2), generating 1,761 million USD, and 410 million USD respectively, relative to BAU as shown in figure 8. The benefits of these future value gains are presented here in a total sum, however the benefits are gained by different groups, including farmers (e.g. through risk reduction), and the public (e.g. through lower health costs), the international community (e.g. through lower GHG).

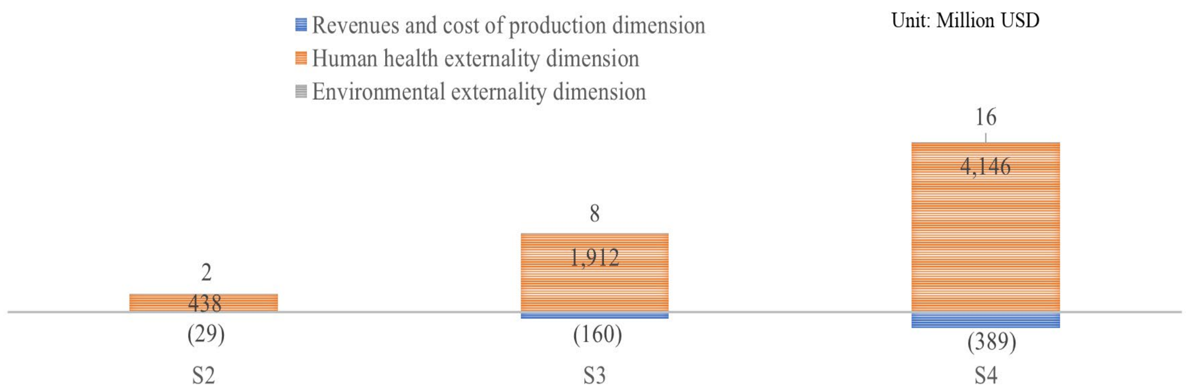
Figure 8. Net accumulated gains from organic area expansion from 2019 to 2035 in each scenario compared to BAU



Note: Changes in value are measured cumulatively over the period 2019-2035, and converted to net present value, at a discount rate of 5%.
Unit: Million US Dollars

Below, we also present the net present value of total accumulated benefits and costs by dimensions under expansion of organic rice areas of scenario 2, scenario 3, and scenario 4 compared to BAU. The dimensions covered are environmental externality, human health externality, and revenue and cost of rice production. These values are presented by figure 8a below. The figure clearly shows that expansion of organic rice area under these scenarios compared to BAU generates benefits for environment and human health dimensions. The human health net benefit is the largest benefit in every scenario ranging from 438 million USD in scenario 2 (S2) to 4,146 million USD in scenario 4 (S4). Expansion of organic rice area also induce net benefit to environment of between 2 million USD in scenario 2 (S2) to 16 million USD in scenario 4 (S4). On the other hand, expansion of organic rice area leads to net loss (or cost) of revenue and cost of rice production. Namely, expansion of organic rice area under scenario 2, scenario 3, and scenario 4 compared to BAU causes the net loss in this dimension from 29 million USD (S2) to 389 million USD (S4). The information provided by figures 8 and 8a present the overall picture of effects of different land use change under scenarios 2, scenario3, and scenario 4 compared to BAU on overall impact and by dimension, respectively. To better understand the situation and identify trade-offs under different land use changes, we next present more details of impacts of different land use changes under each scenario compared to BAU for each dimension.

Figure 8a. Total accumulated benefits and costs of organic rice area expansion by dimensions from 2019 to 2035 in each scenario compared to BAU.



Note: Changes in value are measured cumulatively over the period 2019-2035, and converted to net present value, at a discount rate of 5%.
Unit: Million US Dollars

Values in the production dimension: Revenues and cost of rice production

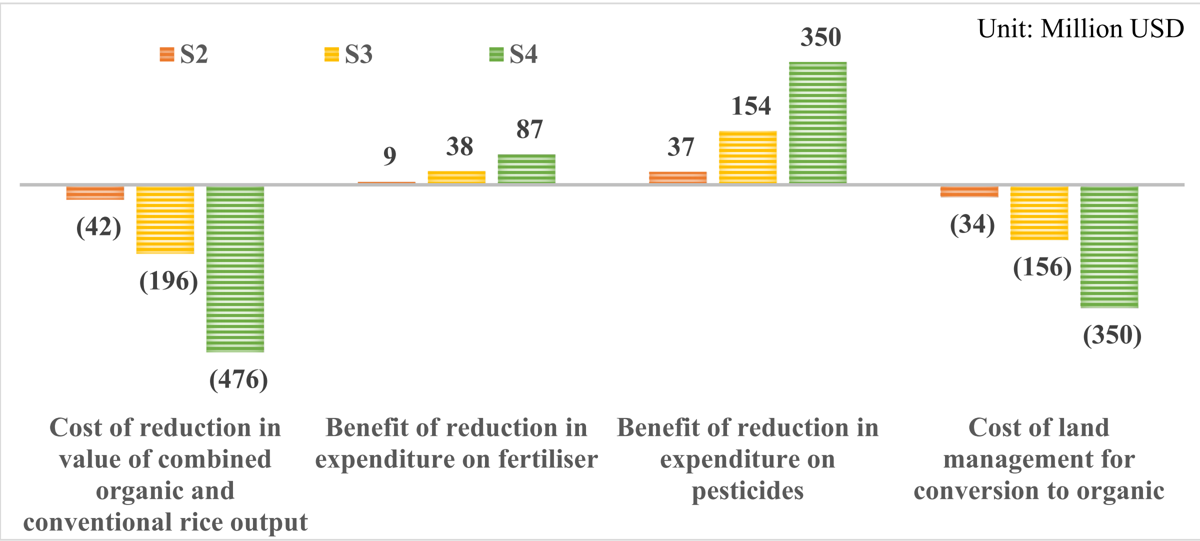
This dimension refers to changes in the value of combined organic and conventional rice output (benefit to livelihoods and food production), cost of cultivation, which is the change in expenditure on fertiliser and on pesticides, as well as land management costs of conversion from conventional rice to organic rice cultivation.

With respect to net farm revenues from rice, during 2019-2035, the BAU scenario is projected to generate about 57 billion USD in total, in net present value using a 5% discount rate. Figure 9 presents the details of revenue and cost of production of each scenario compared to BAU.

As noted in the previous section, this study projects minor losses over the 17 year period in terms of volume of rice output, as a result of adopting the alternative scenarios relative to BAU. Valued in dollar terms, the loss in output over this period amounts to a cumulative loss of about 476 million USD by 2035 in the fourth scenario (S4) relative to BAU. In addition, the cost of land conversion to organic is projected to be substantial. The greater the conventional rice area converted to organic area, the higher the cumulative cost. Scenario 4 which projects the most expansive conversion to organic, projects the highest cumulative land conversion cost, that is about 350 million USD for 2019-2035 in net present values.

However, the expansion of organic rice area also induces positive returns to farmers in terms of reducing the cost of cultivation, which is the reduction of expenditures on pesticides (350 million USD) and chemical fertilizer (87 million USD) in Scenario 4.

Figure 9. Production dimension: Total cumulative costs and benefits from 2019 to 2035, by measure, in each scenario, relative to BAU



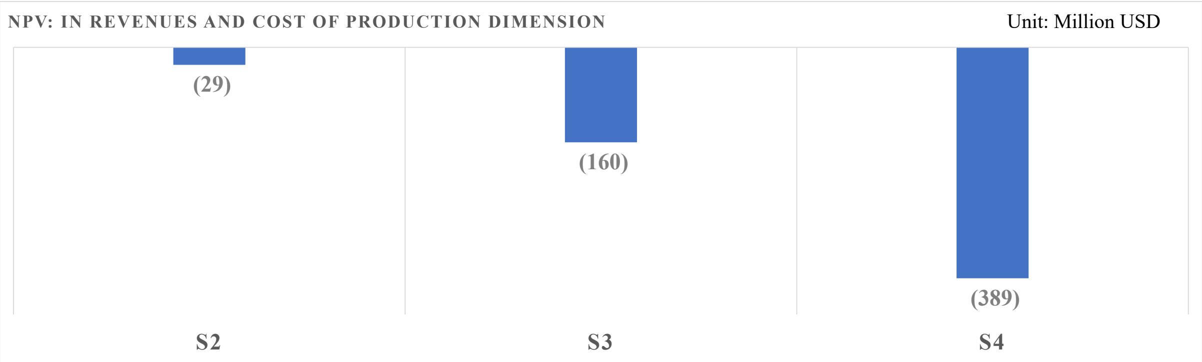
Note: Number in parenthesis represents negative number.

All figures are shown in net present value at discount rate of 5%

When the changes in value of rice yield and cost of cultivation are combined (presented in Figure 10), it is revealed that over the period assessed, the projected expansion of organic rice would generate a net loss in this dimension. The cost savings from organic rice cannot fully compensate the loss of rice yield / revenue. Thus, scenario 4 represents the highest cumulative net loss in this dimension relative to BAU, totalling 389 million USD during 2019-

2035. The same pattern also happens for scenarios 2 and 3 where the net losses are 29 million USD and 160 million USD, respectively, relative to BAU.

Figure 10. Total cumulative loss in revenues and cost of production dimension in each scenario from 2019 to 2035, relative to BAU



Note: Number in parenthesis represents negative number.
All figures are shown in net present value at discount rate of 5%

Values in the health dimension: Human health externalities

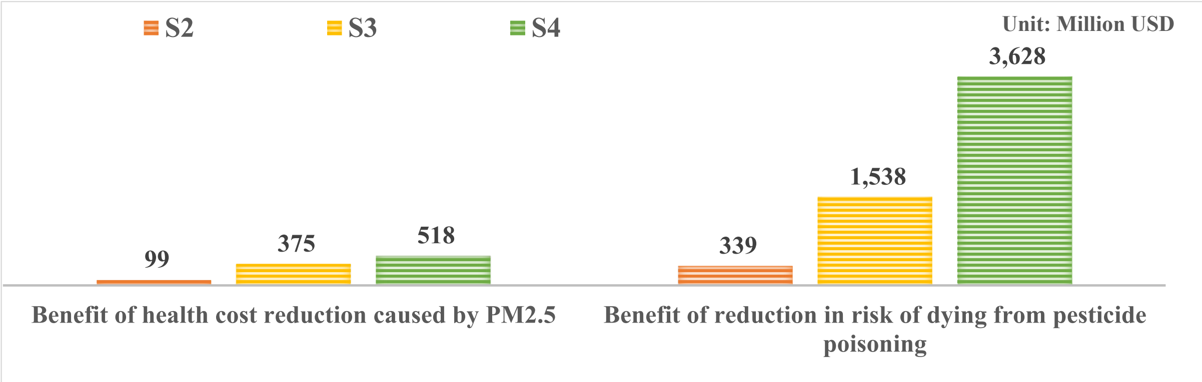
The health dimension covers two issues, which are health impact caused by PM2.5 and health impact caused by pesticide poisoning. The former directly affects not only local communities but also the general public more broadly, while the latter directly impacts farmers and the local communities.

The scenario analysis indicates that a large expansion of organic rice area would provide significant benefits in terms of reducing adverse health impacts, relative to BAU. An expansion of organic practice provides not only benefit to farmers in terms of reduction of health impact caused by pesticide, but also generates benefit to public through reduction of health impact caused by reduction of PM2.5.

The public positive externality on health from organic production from reduction of health cost of PM 2.5, about $518 million in S4, is shown in figure 11. The benefits increase as the organic area increases, because the stubble burning is prohibited in organic practice.

The highest contribution of health benefits is from the reduction of risk of pesticide poisoning. This represents a direct benefit to organic farmers. The higher the expansion of organic rice area, the higher the benefit of this risk reduction. The expansion of organic rice area under S4 generates a total of about 3,628 million USD between 2019-2035. This could be implied that farmers have a high concern of the effect of pesticide poisoning on their health.

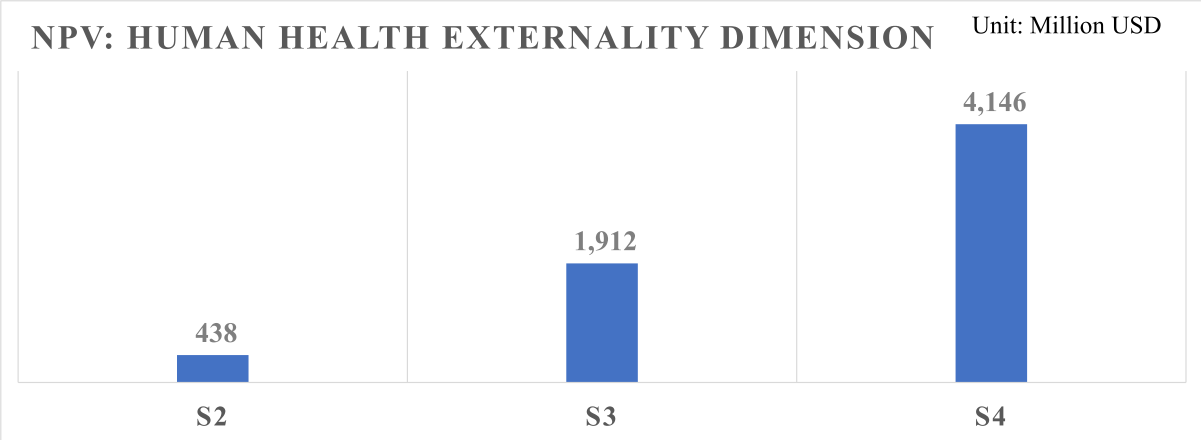
Figure 11. Total accumulated benefit of reduction in health costs from two sources from 2019 to 2035 in each scenario compared to BAU



Note: All figures are shown in net present value at discount rate of 5%

Due to positive effects of the reduction in health costs associated with exposure to PM2.5 and to pesticide poisoning modelled according to the scenarios for expansion of organic rice, the net benefit for health dimension generated from scenario 4 (S4) is the highest, followed by scenario 3 (S3) and scenario 2 (S2), respectively. Figure 12 presents the value of total health benefit from expansion of organic rice area under each scenario compared to BAU from 2019-2035. Scenario 4 (S4) brings the highest value of this benefit, about 4,146 million USD, followed by scenario 3 (S3) and scenario 2 (S2) that generate about 1,912 million USD and 438 million USD, respectively. These results make clearly visible the economic benefits of an expansion of organic rice area in terms of human health.

Figure 12. Total accumulated benefit from human health cost reduction from 2019 to 2035 in each scenario compared to BAU.



Note: All figures are shown in net present value at discount rate of 5%

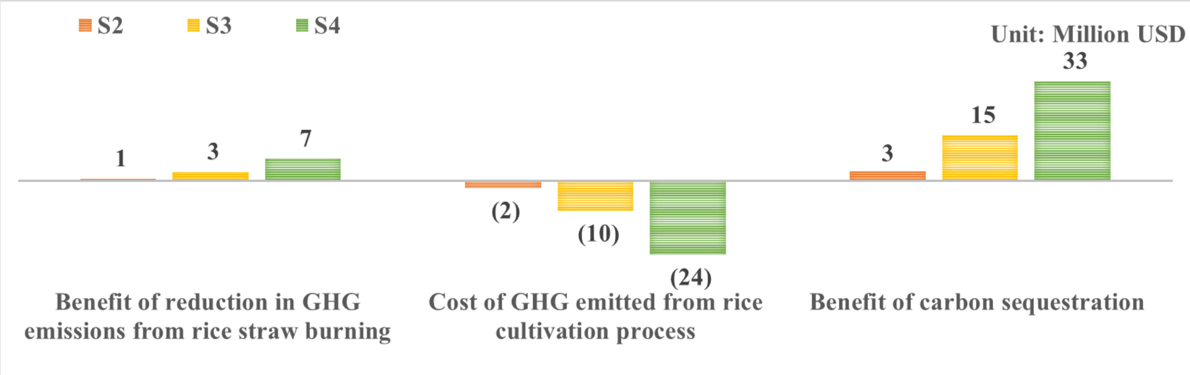
Values in the environmental dimension: Reducing greenhouse gas emissions

The last dimension covered for scenario analysis is the environmental externality dimension. This covers sources of GHG emission from cultivation, post-harvest activities, and the sequestration of carbon in the soil. Figure 13 presents the benefit / cost of the change in GHG emissions when the organic rice area is expanded in scenario 2, 3, and 4 compared to BAU from 2019-2035. The first set of bars in the figure show that the expansion of organic rice area reduces GHG emissions from rice straw burning. This is because burning rice field is prohibited for organic rice practice. Therefore, the greater the expansion of organic rice area, the lower the GHG emissions from rice straw burning. The benefit of GHG emissions reductions from rice straw burning is the highest in scenario 4 (S4), estimated at 7 million USD, where the organic rice area covers over 80 percent of total rice area. The similar pattern also occurs for scenario 2 (S2) and scenario 3 (S3), which generate benefits of about 1 million USD and 3 million USD, respectively.

However, for cultivation process, organic rice practice tends to generate more GHG emission than conventional rice. An expansion of organic rice area in each scenario compared to BAU is therefore projected to result in increasing in GHG emission from cultivation. This can be seen from the second set of bars presented in figure 13, showing the change in GHG emitted from rice cultivation process. The greater the organic area, the higher the GHG emission costs from cultivation, valued at 2 million USD, 10 million USD, and 24 million USD in S2, S3, and S4 compared to BAU, respectively.

The last measure in relation to GHG emission is soil carbon sequestration. In this case, an expansion of organic rice area induces more soil carbon stock than conventional rice counterpart. Hence, an expansion of organic rice area generates more benefit for this dimension. Scenario 4 (S4) that projects the greatest area of organic rice sees the highest benefit from the highest soil carbon stock, representing avoided GHG emissions. Scenario 2, 3 and 4 project higher organic rice areas than the BAU, and generate benefit for soil organic sequestration by 3 million USD, 15 million USD and 33 million USD, respectively[7].

Figure 13. Changes in GHG emissions, both benefits and costs, categorized by source from 2019 to 2035 in each scenario compared to BAU

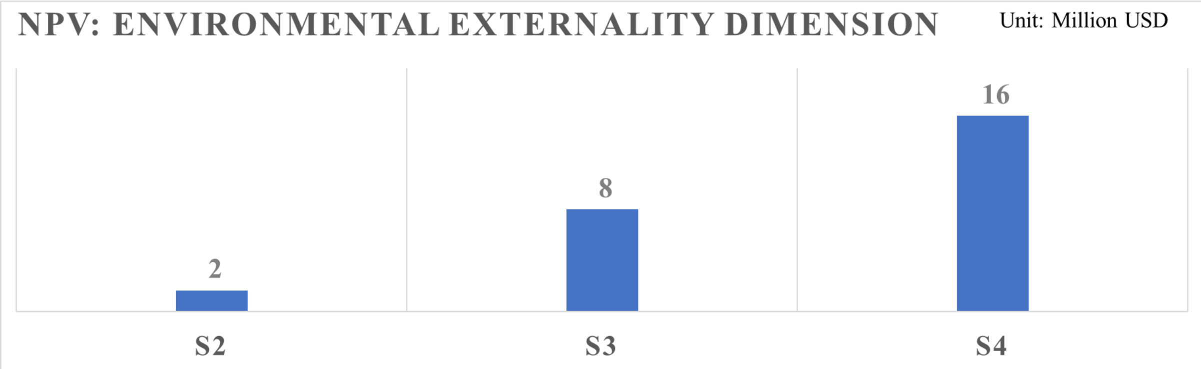


Note: Number in parenthesis represents negative number.
All figures are shown in net present value at discount rate of 5%

Overall, the impacts on environmental externality grow as the organic rice area expands. This due to the fact that the benefits gained from reduction of GHG emission from rice straw burning and increasing of soil carbon stock when organic rice area expanded can completely outweigh the cost from increasing of GHG emission during cultivation process. This pattern can be seen from figure 14 that represents the total accumulated net benefit in value of avoided GHG emissions from three sources presented in figure 13. Again, the total value of GHG emissions in each scenario is compared to BAU during 2019-2035. From figure 14, it is clear that S4, which contains the greatest area of organic rice, provides the highest net benefit of avoided GHG emissions (16 million USD) followed by S3 (8 million USD) and S2 (2 million USD), when compared to BAU.

[7] Note that with respect to net greenhouse gas emissions, a proxy value was calculated based on the prevailing market for carbon emission reductions in Thailand averaging $1.67 per ton CO2eq, as explained in section 4. Had the study adopted the prevailing international carbon prices, this would have result in higher assessed values for benefits to the public, accordingly.

Figure 14. Net avoided GHG emissions categorized by sources from 2019 to 2035 in each scenario compared to BAU (Unit: Million US Dollars)



Note: All figures are shown in net present value at discount rate of 5%

Note that another environmental benefit from an expansion of organic rice area is the benefit from biodiversity through natural pest control. Organic practice prohibits applying pesticide in rice fields resulting in an increase in beneficial insects, which function as natural pest control. From 2019 to 2035, the biodiversity index is projected to increase as the area of land practicing organic rice farming increases. The projected change in the biodiversity index in 2035 modelled according to scenario 4 compared to 2019 is 129 percent. Scenarios 3 and 4 have higher rates of biodiversity improvement than in BAU and scenario 2 throughout this period.

The presence of beneficial insects in the rice field provides natural pest control to substitute insecticides resulting, at the minimum, in the reduction of production cost for farmers. This environmental benefit has been already accounted for in the "Revenues and cost of production dimension" in "Change in expenditure on pesticide" presented above, reaching a benefit of 350 million USD in reduced costs in S4 relative to BAU.

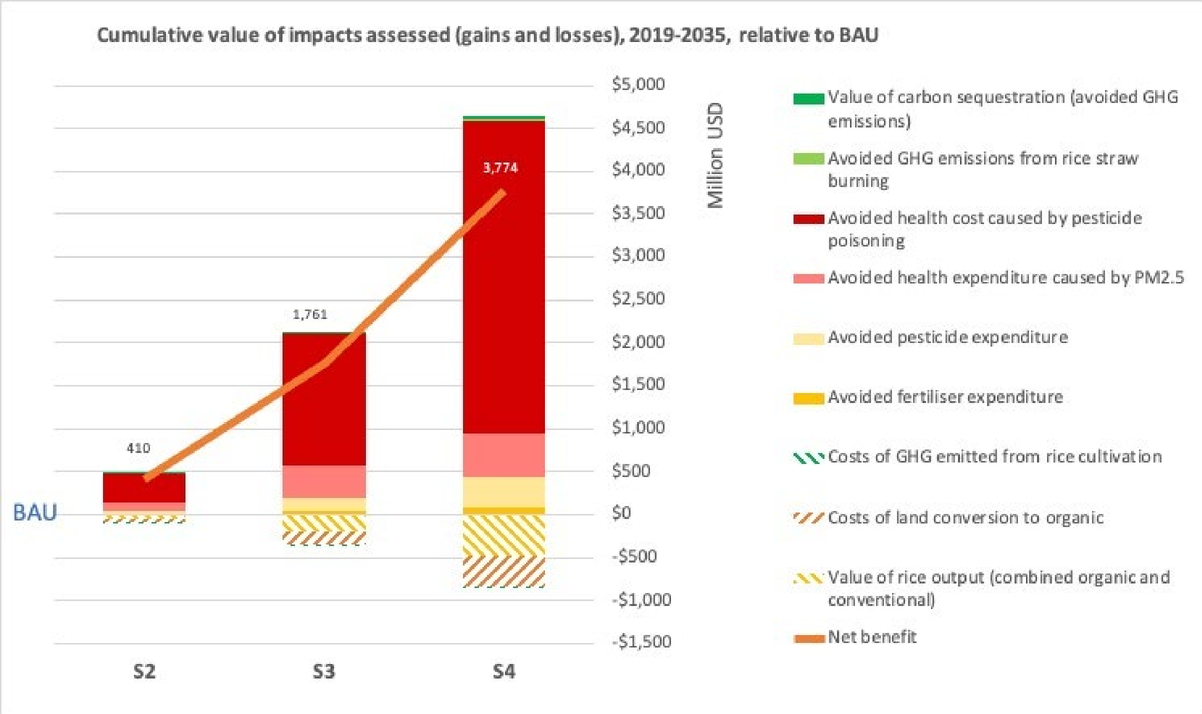
Synthesis

Combining the values from these three dimensions together as presented by figure 15, the highest benefit of the projected increase in organic rice area comes from the resulting reduction in human health impacts followed by the reduction of overall GHG emissions. As presented by figure 15, the benefits from health risk reduction caused by pesticide poisoning and PM2.5 are clearly visible when organic rice area expanded under scenario 2 (S2), scenario 3 (S3), and scenario 4 (S4) when compared to BAU. The reductions of GHG emission from rice straw burning and the increase in soil organic carbon stocks can be seen as benefits from organic rice area expansion. Even though an expansion of organic rice area induces more GHG emissions during cultivation, these are completely outweighed by the reduction of GHG emissions from avoiding rice straw burning and from the increase in soil carbon sequestration. Therefore, an expansion of organic rice area leads to reduction of overall GHG emissions.

For rice yield and cost of cultivation, an expansion of organic rice area leads to cultivation cost reduction as no chemical pesticides are used in organic farming. However, this benefit could not completely offset the loss of rice production. This therefore could provide negative impact on farmers' direct net revenue because loss of rice production can completely outweigh cost reduction. This results in loss in the net value of rice production. In this case, the higher the organic rice area, the greater the loss of the net value of rice production. Scenario 4, where organic rice area covers over 80 percent of the total rice area, projects the greatest loss of rice revenue relative to BAU. That is, the total accumulated rice output in present day values (at a 5% discount rate) is about 389 million USD lower than BAU during 2019 to 2035.

All in all, health and environment are normally not internalised in the economic calculus, but when measured, valued and presented in monetary terms, it can be seen that the expansion of organic rice production could provide great benefit on health and environment over the space of a decade and a half into the future. However, the farmers' direct net benefit from revenue and cost could be negative. Therefore, to encourage farmers to produce organic rice, the additional policies to internalise the value of these externalities should be considered.

Figure 15. The values of three dimensions from organic rice area expansion from 2019 to 2035 compared to BAU



Note: Changes in value are measured cumulatively over the period 2019-2035, and converted to net present value, at a discount rate of 5%.
Unit: Million US Dollars

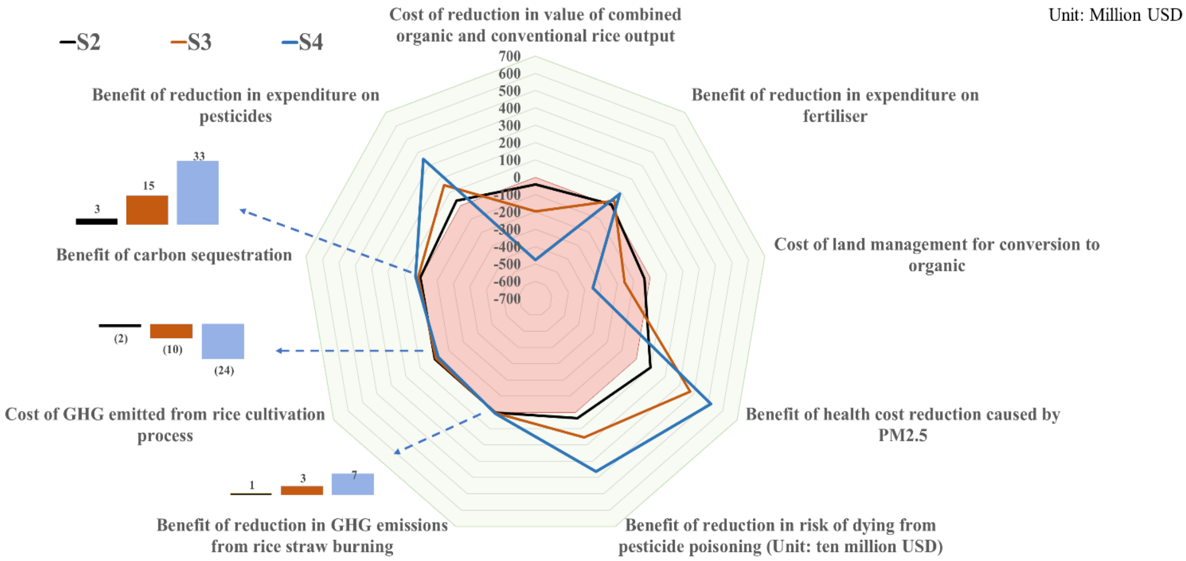
The analysis presented by previous sections provide insights on the impact of organic rice area expansion for nine measurements, grouped in three dimensions. To more clearly visualize the overall trade-offs and synergy points that would be important for policy design, we present the net changes projected to occur in each measurement under each scenario in figure 16 as a radar chart. The result shows that each scenario generates positive net benefits in almost all issues compared to BAU. Scenario 4 (S4) provides the highest total net benefit, although for direct revenue dimension, the result from Scenario 4 is negative compared to BAU. This result mainly comes from the loss of rice production and transferring cost under this scenario with vast increase of organic rice area, expanding to over 80 percent of total rice cultivation area in the Northeast region of Thailand. In figure 16, the blue line shows S4, orange line shows Scenario 3, and the black line shows Scenario 2 relative to BAU (shown as the shaded area in the centre). It can be seen in this diagramme that S4 projects lower values than BAU, Scenario 2 and 3 for both the total value of rice production and the total cost to the farmer of conversion of land from conventional to organic rice.

For the health dimension, scenario 4 (S4) clearly presents the highest benefit with no existing trade-off within the health dimension. This is because the organic rice practice clearly provides health benefits through reductions of exposure to both PM2.5 and pesticides. Hence, an increase in organic rice area would reduce the risks and economic costs of illness caused by them.

When considering GHG emissions, scenario 4 (S4), scenario 3 (S3), and scenario 2 (S2) project benefits compared to BAU in two out of the three values assessed. In respect to reductions in rice straw burning and increases in soil carbon sequestration, S4 generates benefits higher than those of S3 and S2, respectively (see small bar graphs adjacent to the radar chart for details of GHG emissions in the different scenarios). However, as presented in previous section, organic rice practice would induce more GHG emission during cultivation than conventional rice practice. This results in negative values of GHG emitted in the cultivation process in S4, S3, and S2 compared to BAU. However, taking together all emissions in this dimension, the organic rice practice is projected to release less GHG emission in total than conventional rice counterpart.

When considering the dimension-based scenario analysis (presented by figures 9-14) together, the highest overall benefit does not always generate all highest positive effects or benefits. This can be seen from figure 16 where scenario 4 (S4), which projects the expansion of organic rice area to over 80 percent of the rice area in the Northeast region of Thailand, generates the highest overall positive impact to society. However, it also contains the highest loss to farmers due to loss of rice production and higher land-transferring cost. This evidence suggests that if policy makers aim to encourage rice farmer to convert to organic rice practice, additional interventions and policies that could alleviate, subsidise or compensate for this loss are crucial.

Figure 16. The scenario analysis based on values of all issues in each scenario compared to BAU accumulated value from 2019-2035

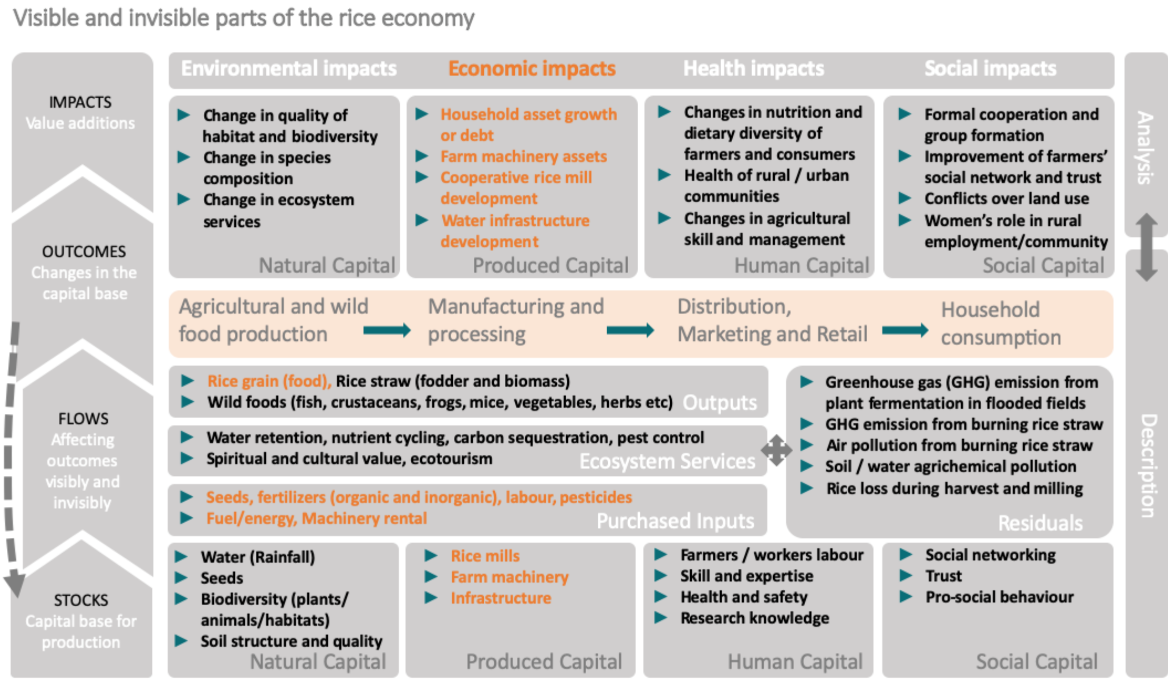


Note: Changes in value are measured cumulatively over the period 2019-2035, and converted to net present value, at a discount rate of 5%.
Unit for reduction in risk of dying from pesticide poisoning: Ten Million US Dollars
Unit for other measures: Million US Dollars

6. Conclusions / Key messages

This study reveals broader conclusions on some of the visible and invisible costs and benefits of conventional and organic rice production in the Northeast region of Thailand. Visible costs and benefits - those that involve monetary transactions and are regularly taken into account in economic policy decisions - include rice output quantity and value, production costs, farmer income, miller income, trading income, and GDP. However, as highlighted through this project, there are important additional economic costs and benefits within the rice system that are normally not directly calculated within the rice economy. Such invisible costs and benefits are referred to as "externalities". They need to be properly considered as they affect (deplete or increase) stocks of natural, produced, human and social capital on which future rice production and farm livelihoods will depend. A more complete picture of the rice economy can help to identify which trade-offs are currently being made, and which changes and interventions may be needed to increase the well-being of Thai farmers, the general public and even the global commons.

Figure 17: Visible and invisible parts of the rice economy



Adapted from TEEBAgriFood Evaluation Framework (UNEP, 2018)

As can be seen from figure 17, the externalised costs and benefits of rice production are many, particularly with respect to impacts on natural capital and human capital. As described above, the issues relating to natural capital included in this study consist of biodiversity and GHG emission. While, the human capital covers human health impact caused by air pollution and pesticides. TEEBAgriFood evaluation framework and scenario analysis are employed to identify trade-offs and synergies that could maximize benefits and minimize costs.

The results from our study have shown that there are some important trade-offs over the long term. Firstly, the projected expansion of organic rice area would generate less net overall GHG emissions than that of conventional counterpart, but it would reduce rice yield, resulting in reduction of farmers' income.

The second trade-off is between rice yield and the cost of cultivation. The expansion of organic rice areas would reduce the cost of rice cultivation for farmers due to more availability of beneficial insects, but there will be a decrease in rice production output. The reduction of cultivation could not outweigh the loss of rice production. If the price of organic rice were the same as that of conventional rice, due to significant increase of organic rice supply when the area of organic rice expanded as assumed in scenario 4 (S4), the profit of growing organic rice will be therefore lower than that of conventional counterpart.

By highlighting trade-offs in this way, the scenario analysis based on varying conventional and organic rice cultivation areas can shed light on opportunities for synergies to point out where trade-offs could be minimized, which would be of interest to the attention of decision-makers. The results of scenario analysis clearly show that the highest overall benefit may not generate positive effects in all dimensions, and trade-offs must be taken into consideration and discussed with key stakeholders.

Scenario 4 (S4), which has the highest overall impact, projects a negative effect for financial dimension due to the lower yields expected by the model when over 80 percent of rice area would be cultivated using organic practices. Even though the value of all positive externalities is substantially larger than the loss from rice production in this scenario, we need to keep in mind that the loss from rice production directly impacts farmers, and would reduce their well-being through income loss. To cope with this situation, the price of organic should be higher than that of conventional rice. Based on our calculations, a premium price for organic rice of at least about 3.5 percent higher than that of conventional rice per kilogram, would be enough to turn the negative return of rice production from yield loss to a positive return for farmers.

Further, it is important to identify who is affected by each issue assessed through this study. The expansion of organic rice areas would clearly induce more public benefits via reduction of health impact from PM2.5, improvement of biodiversity indexes, and reduction of overall GHG emission.

For farmers, switching to organic rice practice generates private benefits to rice farmers in two issues, reductions of cultivation cost and health impact from pesticides. However, it also imposes a private cost to farmers by yield reduction. The cost reduction can partially offset the loss of yield resulting in less profit per hectare given the price of organic rice the same as conventional rice. However, the total private benefit gained by farmers from switching to organic rice practice is still positive when considering the value farmers place on health benefit totally outweighs the loss of profit.

All in all, public and private benefits generated from an increase in organic rice areas are positive. However, we need to be careful to keep in mind that the decision to adopt the organic rice practice mainly depends on farmers. The loss of profit due to yield reduction would be very salient when compared to the farmers' health benefits, which would not be visible in the short run for farmers. In addition, due to uncertain economic condition as presented in Box

3, farmers would weigh their decision on economic factors more than on health benefit. To influence them to change from conventional practice to organic practice, policymakers therefore need to consider forms of interventions that could shoulder any risks during transition periods for farmers to new the practice, and cope with possible income loss caused by yield reduction. This will be further discussed in the next section.

To accompany this Synthesis a standalone document has been produced for policy makers focussing on the key messages from the assessment and providing key figures from the scenario analysis. This is available from the teebweb.org website. A brief summary is presented in Box 4 below.

Box 4: Summary of Key messages

1. To reach the aims of the Bio-, Circular, and Green Economy model in Thailand of more sustainable growth and more environmental responsibility, a transition is needed towards fully sustainable rice production and sustainable landscape management.
2. The impact of changes need to be assessed at the landscape level, as farm-level results give an incomplete picture because they fail to capture the full range of impacts, externalities and dependencies in the system.
3. It is important to make visible the connections between nature and rice food systems by quantifying the oft invisible flow of benefits from ecosystems to food systems and human well-being. This involves identifying where, how much and to whom nature provides benefits, showing the impacts of Business As Usual, and what would be the comparative impacts under alternative agri-environmental planning policy scenarios for the future.
4. Rice yields are affected by cultivation practices, seeds, and environmental conditions. Often, when considering whether a switch to organic from conventional is viable and desirable, it is assumed that rice yield under organic production will be diminished in the short to medium term. However, the findings of this study project relatively minor losses, both in terms of volume output and dollar value, as a result of adopting the alternative scenarios relative to BAU.
5. The emission of greenhouse gases (GHG) from rice fields is generated by cultivation practices (organic fermentation), post-harvest practices (stubble burning), and mitigated by soil carbon sequestration. The expansion of organic rice area as projected in the alternative scenarios 2, 3 and 4 would reduce overall GHG emissions, due to the stubble burning prohibition and high soil carbon accumulation in organic rice fields. Overall, organic rice practice generates lower overall GHG emissions per hectare than conventional rice practice.
6. Biodiversity is affected by cultivation practices. With expansion of organic rice, agro-biodiversity increases, especially insect varieties, at landscape level, which promotes natural pest control.

7. The impacts of conventional rice production have negative externalities on human health. The analysis found that policy pathways for organic rice expansion improve human health, through reduced exposure to pesticides and air pollution.
8. Organic rice production generates other benefits to human well-being for society, food, and culture.
9. Farmers' decision to adopt and/or continue to grow rice organically depends on policy support, particularly during the transitional period, and price incentives.

7. Policy Discussion and Recommendations

Thailand applies the Bio-Circular, and Green Economy model as a strategic framework to promote food security, economic opportunity, environmental sustainability, and social viability. To reach the aims of the Bio-, Circular, and Green Economy model in Thailand of more sustainable growth and more environmental responsibility, a transition is needed towards fully sustainable rice production and sustainable landscape management.

Rice production is dependent on ecosystem services such as biological pest control, and soil nutrient cycling. Future food production will be placed at risk if attention is not paid to maintaining healthy and resilient ecosystems that provide the ecosystem services that are critical for food systems. There are some anthropogenic changes that are more global in nature (such as climate change) but others that stem from the local in-country loss of biodiversity and ecosystem degradation. Rice production can and should be aligned with this model, and the results from the current study support that contention that the promotion of organic rice production fosters this alignment.

Without intervention, that is, under business as usual (BAU) conditions, over the period to 2035, the models developed in this study predict that current levels of use of chemical fertilizer and pesticide in conventional rice practice would maintain current levels of rice output, but also induce the loss of biodiversity in paddy fields, reduce ecosystem service provisioning, and impose significant risks on human health. By comparing the values of these losses to ecosystem services and human health with the equivalent values from the scenarios that promote organic production, a strong economic case can be made to support this shift to organic farming systems.

1. **Organic rice practice generates positive externalities through health and environmental improvements. However, when these positive externalities cannot be completely included or realized by market system, government should step in to minimize market distortion to ensure the public still benefits from positive externalities generated by organic rice farmers activities.**

As highlighted through this project, there are important additional economic costs and benefits within the rice system that are normally not directly associated with the rice economy. Such invisible costs and benefits are referred to as "externalities". The results from our study clearly suggest that an expansion of organic rice area induce more net overall positive externality to society. The positive externalities generated by organic rice practice cover environmental, human health, and social dimensions.

For farmers there are gains and losses from adopting organic rice practice. The gain is cultivation cost reduction due to eliminating the use of chemical fertilizer and pesticide. However, yield reduction compared to conventional practice imposes loss to farmers if they adopt organic practice. Our result suggests that if there were no premium price for organic rice, reduction of cost cannot outweigh the yield loss resulting in net loss to farmers.

Even though, the profit loss of farmers is very minimal compared to positive externality generated from an expansion of organic rice area, the challenge is how to get rid of the loss faced by farmers as this loss could significantly reduce well-being of farmers. In addition, it would also deviate farmers from adopting and continuing practicing organic rice. To answer to this challenge question and based on the evidence from this study, we propose potential interventions and policy guidelines aimed for increasing organic rice area with ensuring farmers' well-being.

2. **The main subsidy policies in agriculture have been focused on reducing farmers' financial hardship, but this does not encourage farmers to adopt more sustainable practices. To induce farmers to adopt organic practice, subsidies need to be reoriented, conditional on adopting sustainable agricultural practice, such as organic rice practice.**

The first issue is focus on how to induce more rice farmers to adopt organic practice. Adopting organic rice practice requires immediate additional investments such as labour, land preparing, and organic fertilizer. In addition, according to the household survey information, farmers may be concerned by the loss of yield especially during the early period of converting from conventional practice to organic practice. They may be therefore unwilling to bear these up-front costs for an uncertain future gain resulting in low rate of adopting organic rice practice even when long-term benefits of organic rice practice outperform conventional counterpart. One possible intervention to increase adoption would be to offer temporary incentives conditional on adopting organic rice practice. The result from this study clearly suggests that temporary subsidy during transition period (before getting organic certificate) either in form of cost subsidy or income subsidy does indeed induce more rice farmers to adopt organic practice compared to when there is no subsidy available. According to the One Million Rai Program, farmers receive three-year cost subsidy if they adopt organic practice. During the program, the total area of rice production has already been granted organic certification has dramatically increased, with an average of about 18,041 hectares per year. This compares with just 2,035 hectares per year before the implementation of the program. The combination of result from this study and the evidence from One Million Rai Program indicates that temporary subsidy during transition period is an important factor in increasing the rate of adoption of organic rice practice.

This study also found that another potential instrument that may provide better cost-effectiveness than subsidy regime. This instrument is to develop role model farmers as early organic adopter to promote organic practice in communities. The important point of developing role model farmers to promote organic rice practice is who should be promoted to be role model farmers that could make their advice more credible to others. The result from this study provides insight information that role model farmers whose economic and social conditions are the same or similar to most farmers in communities would induce more organic adoption than role model farmers with significant better economics and social status.

The subsidy and creating role model farmers aim to increase adoption of organic rice practice, which is the starting point of introducing rice farmers to organic practice.

3. **Exporting organic rice to international market requires different certifications depending on countries. To share cost of getting certification to ensure profitability for farmers, policies aimed to enhance more organic rice production should focus on promoting the grouping of farmers into discreet areas that can be certified as organic instead of at individual level.**

The next point that should be seriously considered is during the transition period where farmers already perform organic rice practice but not yet receive certificate. At this stage, receiving organic certificate is critical for farmers as the certificate could officially separate organic rice from conventional rice, and would ensure premium price for organic rice farmers. This study found that farmers who already adopt organic practice would likely to switch back to conventional practice during the transition period if they experience barriers of getting certification, which include high cost of certification and no information of how and where to apply for organic certification. To ensure rice farmers continue organic practice government and relevant organizations need to develop mechanism that could help farmers to effectively achieve organic certification. This should include not only domestic certification like the "Organic Thailand" Standard, but also certifications that allow farmers to export their organic rice product to global market.

In addition to certification, access to market with premium price is also crucial for farmers after adopting organic practice. According to the result from this study, rice farmers expect to get premium price if they adopt organic rice practice. Besides providing temporary subsidy to incentivize farmers to adopt organic practice, the government could support market development or to directly match demand for and supply of organic rice to ensure farmers that their organic rice product has secure market with premium price. Some groups of organic farmers have good leaders who can find markets for their produce. However, other groups of farmers can produce organic rice successfully, but do not know where they can sell it. That is, they cannot find a premium market for their organic produce. Such farmers have much higher costs in finding a market, compared with those who sell their rice to the conventional mills.

4. **On average, organic rice yields are lower than conventional rice yields, but not significantly so. The loss of income from the marginally lower yield for organic farmers would be directly offset as long as farmers can sell their organic rice at a price that is least 3.5 percent higher than that of conventional price.**

In regard to farmer support, price or income subsidy program could be promoted for organic rice production. In the long-term, when organic rice area is substantially increased as projected in scenario 3 (S3) and scenario 4 (S4), where the organic rice area covers almost 50 percent and 90 percent respectively of total rice area in the Northeast region, the supply of organic rice will be substantially increased. If the demand for organic rice from domestic market and global market also increases along with the supply, the prevailing high price of organic rice would not decrease. As a result, the farmers would still earn more profit from organic rice production, and the public will continue to receive positive externalities generated by organic rice farming.

However, in the case that demand for organic rice does not keep up with increasing organic rice supply, this would result in a sharp decline of the price for organic rice. Based on our results, organic rice farming output would be marginally lower than conventional rice farming in the Northeast region, if we assume that the price of organic rice is the same as the price of conventional rice, then farmers will receive lower profit from organic rice practice than conventional counterpart.

To cope with this situation, price or income subsidy program should be employed to incentivize organic rice farmers to continue organic practice. From cost and yield predictions of our study, the profit of organic rice will be higher than that of conventional rice if the price of organic rice is at least 3.5 percent higher than that of conventional rice. The main reason for proposing the subsidy in this situation is because our scenario analysis shows that organic rice practice generates tremendously positive externalities to society. When these positive externalities cannot be completely included or realized by market system, government should step in to minimize market distortion to ensure public still benefits from positive externalities generated by organic rice farmers activities. In addition, organic rice farmers also receive return from organic rice cultivation that considers not only cultivation cost but also positive externalities that they provide to society.

To build the rice organic market mechanism, many parties need to be involved. The government does not limit its focus to developing the farmers only, the supply side, the mills are also an important part of the chain for the development of rice for grain (*khaaw sarn*). To certify that rice is organic, not only does the farm produce have to be certified, but also the mill should be certified with the GAP standard.

Furthermore, the Ministry of Commerce considers the rice markets, both domestic and international. It may be possible to develop the domestic market in organic rice because, nowadays, Thai people are more aware of the need for environmental sustainability. Mechanisms to ensure genuine access to organic produce need to be developed, ensuring organic rice is available in the general market and easy to be recognized. As for the international market, the expanded production of organic rice needs to be linked to relatively clear demand within the international market, and a data center that could help farmers and exporters to identify potential market should be available.

Organic farming also has benefits which link to Thailand's goals in reducing GHG emissions, which could be more clearly highlighted. The alternate wetting and drying (AWD) technique could further reduce the low carbon benefits of organic rice. The Rice NAMA project is promoting the adoption of AWD and other low carbon techniques in rice production in the central region of Thailand, and is working to link with private sector groups within the Sustainable Rice Platform to stimulate interest in a low carbon rice market. Opportunities may be developed to set up a market for organic in tandem with the market for "low carbon" rice, in collaboration with the Rice Department.

The development of organic rice in Thailand is an important issue, a challenging issue, but it is a path that Thailand has to walk along, to generate premium quality products, with a premium price. Thailand should no longer compete by producing high quantity, with low margins, while there are impacts on the environment and on society, nationally and internationally.

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