RICE – TEEBAGRIFOOD

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Valuation of rice agro-systems

Prepared by: UN Environment TEEB Office

Table of Contents

Synthesis

This note provides a brief outline of the rice study conducted by The Food and Agriculture Organization of the United Nations (FAO) together with its partners, the International Rice Research Institute and Bioversity International as well as Trucost, commissioned by the UN Environment TEEB Office. It contextualizes the study within the larger mandate of TEEBAgriFood (http://www.teebweb.org/agriculture-and-food/). Specifically, it summarizes the objectives, approach, scope and results of the study in the context of the comprehensive and universal evaluation framework of TEEBAgriFood. It comments on methodologies used and highlights future work that may be commissioned to meet the goals of the TEEBAgriFood project.

Introduction to the study

Rice is central to the food security of half of the world, and the production of rice is essential to the food security and livelihoods of around 140 million rice-farming households. This way, rice production provides a range of ecosystem services (benefits) beyond food production (i.e. cereal grain) alone.

At the same time, rice production has been linked to a range of different environmental impacts such as high greenhouse gas (GHG) emissions, air and water pollution, as well as an increase in water consumption. Therefore, information provided in this study can inform decisions on how to manage and mitigate these impacts while providing affordable, nutritious, equitably accessible and safe food for a growing global population with changing patterns of consumption.

As these challenges are not independent, but rather interlinked, reaching them is likely to require trade-offs. It is therefore crucial to analyse how to reduce trade-offs between these different goals. Where possible, synergies that allow for a maximization of benefits, while minimizing costs to society, the environment and the wellbeing of the farmer through the degradation of natural capital from rice production should be identified.

Objectives and scope of this study

This study aims to highlight which types of farm management practices or rice production systems potentiate synergies and reduce trade-offs between different management objectives. The specific objectives are to identify visible and invisible costs and benefits of rice agro-ecosystems (i.e. externalities); to identify and assess different rice management practices and systems which reduce trade-offs and increase synergies; and to make these trade-offs and synergies visible by assigning biophysical or monetary values to the different alternatives.

Several scenarios, i.e. pairwise comparisons, were applied to show the effect of the various farm management practices on different environmental and/or agronomic variables:

1. The baseline scenario describes a conventional management approach. For instance, herbicide use to combat weeds.
2. The alternative scenario describes a farm management practice that is expected to decrease an environmental impact or to increase an ecosystem service. For instance, hand weeding or biological control, instead of herbicide use.

The TEEB rice study set out to describe a variety of trade-offs and synergies that occur in rice agro-ecosystems in five case study countries around the globe: the Philippines and Cambodia in Asia, Senegal in Africa, Costa Rica in Latin America and California/The United States in North America. The analysis makes a distinction between the three most common rice growing environments: irrigated lowland, rainfed lowland, and rainfed upland systems. The different typologies are based on altitude (upland vs. lowland) and water source (irrigated or rainfed).

Approach and Methodologies

Rice production systems were categorized by rice management systems and practices. Thus, 28 different system and practice category comparisons were identified, starting with land preparation and finishing at harvest. The study consists of two parts, a biophysical quantification and an economic valuation. The biophysical framework for analysis details what should be included in the eventual monetary and non-monetary analysis.

Main ecosystem services analysed by the study where water quality, water use, air pollution, energy production, reduction of GHG emissions, habitat provisioning, improving nutrient cycling and soil fertility, and preventing pest and disease outbreaks. Other invisible benefits related to rice production, such as contributions to dietary diversity, genetic variability, water purification, groundwater recharge, moderation of extreme events and cultural heritage conservation were briefly discussed.

The team extracted data from peer reviewed literature from all five case study countries and synthesized them in a vote-counting analysis. The final outcome was a statistical review of primary research, i.e. peer reviewed literature, on the effects of different agricultural management practices on different environmental, agronomic and ecosystem variables.

Next, impacts that are caused by changing physical conditions were modelled biophysically. This includes identifying baseline factors and quantifying the change in the biophysical indicator that is to be valued.

The final step involved the economic modelling component of the valuation. This includes the identification of the final recipient of the impact, such as the local populations who experience the negative effects of eutrophication, and then selecting an appropriate valuation technique to monetize the change in biophysical conditions.

Results

As this study has been designed to be a trade-off analysis, the results have been structured according to the effect of different management practices on two contrasting or synergistic ecosystem benefits or costs. The assumptions that underpin the analysis refer to rice production, on the one hand, and a range of different externalities (i.e. an environmental impact or ecosystem service) on the other, to show potential trade-offs or synergies between the two. Two examples are given below:

1. **Increasing rice yields versus reducing water consumption**

Worldwide, about 80 million hectares of irrigated lowland rice provide 75% of the world’s rice production. This predominant type of rice system receives about 40% of the world’s total irrigation water and 30% of the world’s developed freshwater resources. The dependence on water of the rice farming sector is a huge challenge as freshwater resources are becoming increasingly depleted due to competing water uses from the residential and industrial sector, and as rainfall is increasingly erratic due to climate change and variability. More efficient water use is therefore a must, yet given the importance of rice to food security around the globe, any trade-offs need to be carefully assessed.

Thus, this study sought undertook to assess and valuate trade-offs resulting from irrigation management, soil preparation and crop establishment on rice yields, on the one hand, and water consumption, on the other. The study analyzed the change in yield and water consumption under continuous flooding under conventional rice cultivation and water-saving practices such as alternate wetting and drying (AWD) and the system of rice intensification (SRI). The study further compared dry tillage to puddling, and direct seeding to the transplanting of seedlings; two other practices used in water-saving rice production systems. Figure 1 shows the effects of water-saving rice production systems and conventional management on irrigated lowland (IL) and rainfed lowland (RL) systems in Senegal, Cambodia and the Philippines based on data from Krupnik et al (2010), Krupnik et al (2012a), Krupnik et al (2012b), Miyazato et al (2010) Dumas-Johansen (2009), Koma (2002), Ly et al (2012), Ly et al (2013) and Satyanarayana et al (2007).

Scenario analysis: water-saving rice production systems versus conventional management

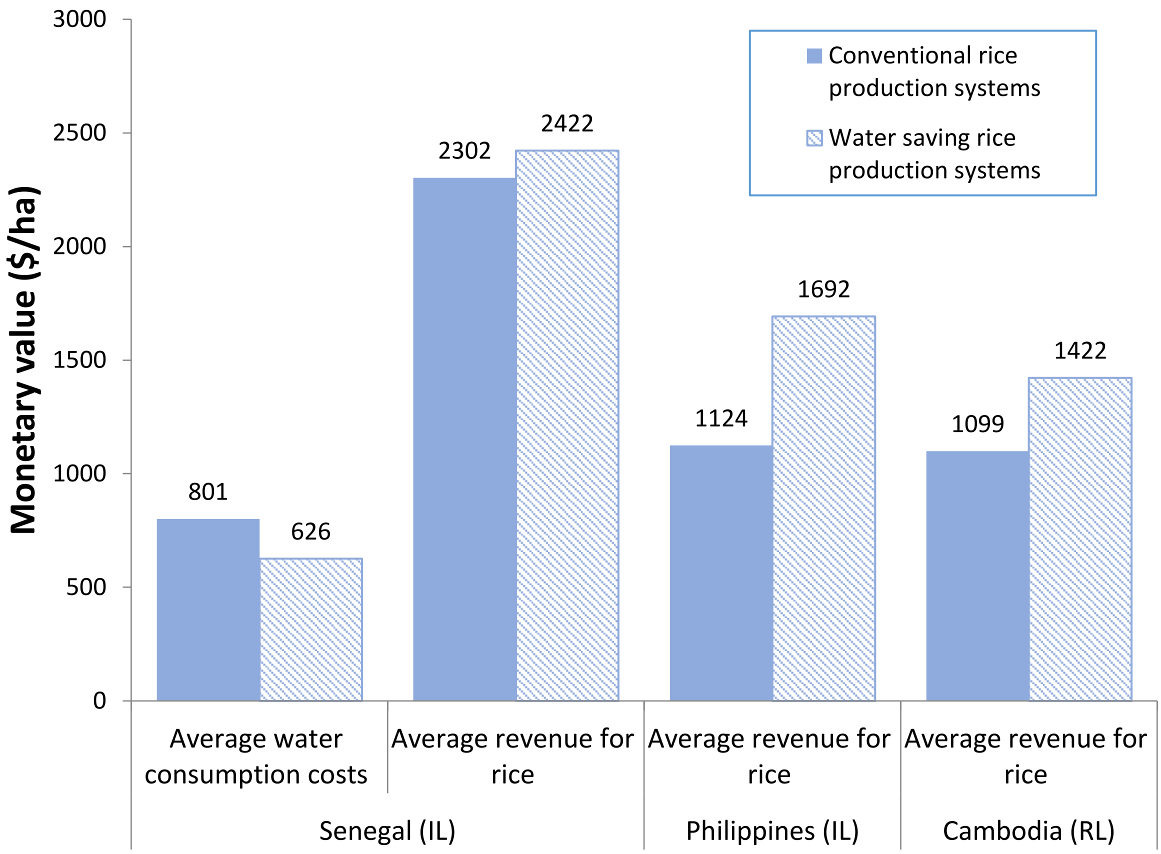

Figure 1. The comparison of conventional rice production systems and water-saving rice production systems for Senegal, Philippines and Cambodia in terms of average revenue for rice and environmental and health costs of water consumption.

Management systems to ensure water savings include intermittent flooding as part of the production package. Such systems advise transplanting of young (eight to ten days old) single rice seedlings, with care and spacing, and applying intermittent irrigation and drainage to maintain soil aeration. In addition, the use of a mechanical rotary hoe or weeder to aerate the soil and control weeds is encouraged.

If Senegal was to change all its irrigated lowland systems from conventional management to water-saving rice production systems, the society would save about US$ 11 million in water consumption related health and environmental costs. At the same time, the rice producer community would gain a total of US$17 million through yield increases – a clear synergy.

If the Philippines were to change all their rainfed lowland systems from conventional management to water-saving rice production systems, the rice producer community would gain a total of US$750 million through yield increases. Data on water consumption was not recorded.

If Cambodia was to change all its rainfed lowland systems from conventional management to SRI, the rice producer community would gain a total of US$801 million through yield increases. No irrigation water consumption costs result from this farming system as it is dependent on rainfall only.

While extrapolating the results from a few studies only for an entire country may show some general trends, one needs to be cautious about the context of each study. Yield increases with water-saving rice production systems are highly variable and mainly occur in highly weathered soils, whereas in ideal rice soils yields tend to be the same or less with such systems (Turmel et al. 2010).

2. Increasing rice yields versus reducing GHG emissions

Global estimates attribute about 89 percent of rice global warming potential to CH_4 emissions which are due to flooding practices in irrigated and rainfed lowland systems (RL) (Linquist et al, 2006). To a much smaller degree, the production and application of N-fertilizers contributes to the rice global warming potential. And also emissions from rice straw burning impact global climate change. In addition to rice production being a major emitter of GHGs, rice systems may also sequester carbon via soil organic carbon. Yet overall, rice production is a net producer of greenhouse gas emissions.

This study sought to assess and monetize the trade-offs resulting from irrigation water management, residue management, fertilizer application and the choice of rice varieties on rice yields, on the one hand, and GHG emissions, on the other. The value of rice production was estimated on the basis of the country specific revenue for rice grain received per ton of paddy rice. Primary data on GHG emissions as reported in the peer reviewed studies was used to model the GHG emission costs. The cost of GHG emissions were valued following the Trucost Greenhouse Gas methodology which provides a valuation coefficient for CO_2 equivalent emissions based on the social cost of carbon emissions.

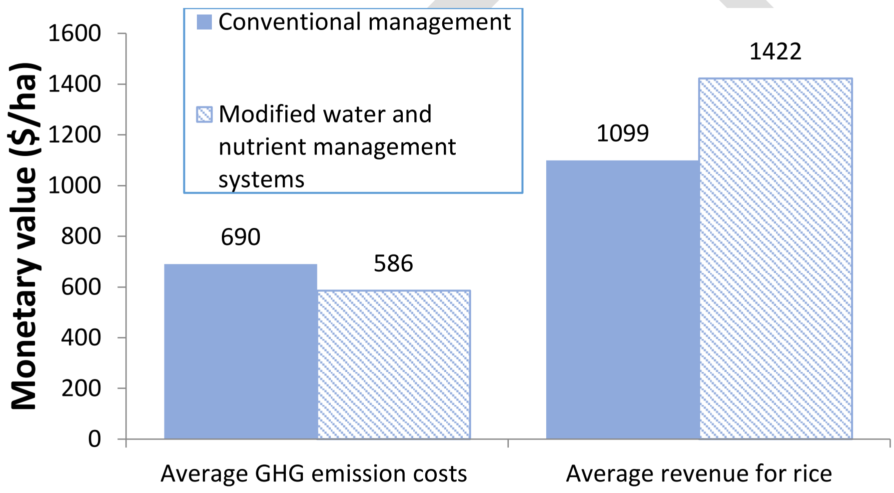

Figure 2. Valuation results comparing conventional management to modified water and nutrient management systems in terms of GHG emission costs and rice grain revenues in rainfed lowland systems in Cambodia. Monetary valuation for GHG emissions is based on primary research data.

Scenario analysis: modified water and nutrient management systems versus conventional management in rainfed lowland rice production in Cambodia

While the concept of SRI with its modification of water and nutrient management was originally developed under irrigated conditions, these systems have also been adapted to rainfed lowland (RL) paddies. The SRI in RL systems differ from the conventional management system in several parameters, but the focus of included research studies is on modified water and nutrient management. In these studies, fields under modified water and nutrient management are moist during transplanting and drained several times during the growing season. Trade-offs are likely to occur between CH_4 emissions when the fields are flooded and N_2O emissions when fields are drained.

Data from Dumas-Johansen (2009), Koma (2002), Ly et al (2012), Ly et al (2013) and Satyanarayana et al (2007) collected in RL systems in Cambodia led to a value of rice production of US$1099 per hectare when conventional management was practiced and US$1422 when SRI was implemented.

The monetary valuation for GHG emissions in Cambodia’s RL paddies resulted in an average cost of US$690 per hectare of rice production for conventionally managed systems and US$586 for systems with modified water and nutrient management – a reduction in costs of 15%.

If all rice farmers in RL systems in Cambodia would adopt modified water and nutrient management, they would increase the revenue of rice by US$ 801 million. At the same time, society would have to spend US$ 258 million less in GHG emission costs.

3. Impacts of pest control management practices on regulating services

The reality of biological systems, that TEEB seeks to capture, is that there are many intermediate factors and products in agricultural production systems, generated by biodiversity and ecosystem services. For example, ecological alternatives to pest control are not simply a matter of not applying pesticides, and thus avoiding such costs; it is an intricate process (on the part of nature, when not impeded by humans) of building a natural enemy community, through a management that encourages such ecological processes. This form of management has some value in an initial year and place, but adds value as it is allowed to flourish over time and space,; thus not reflected adequately in a simple calculation of pesticide costs avoided.

As has been well documented in a landmark study on the ecology of Asian rice production systems (Settle et al. 1996) rice ecosystems under careful management are capable of sustaining important regulating services. Under such management, there may be no need of external inputs of pesticides, and there are important synergies related to nutrient management. In fact, invertebrates can contribute to soil fertility in irrigated paddy fields by decomposing rice straw, an ecosystem service that is degraded by the application of pesticides (LEGATO 2017).

However, over the last few decades in many parts of the world, rice agriculture has become (or is perceived to be) heavily dependent on agricultural inputs. Synthetic fertilizers are used to boost yields, while pesticides and herbicides are applied to address pest outbreaks and weed manifestation. Weeds are a major challenge in rice production worldwide.

With respect to insect outbreaks, it is still unclear whether pesticides (particularly insecticides) actually increase rice yields (Heong et al 2015). Agricultural expansion and intensification can often lead to a change in the ratio of predatory invertebrates to herbivorous invertebrates. One of the main reasons is the misuse of pesticides. Not only is rice production itself affected but also the adjoining waterways, their wildlife such as fish and birds and the supply of drinking water. Finding alternative ways to address pests is therefore very important.
Another reason is the increased use of fertilizer. Increasing fertilizer use often leads to higher disease incidence and a greater abundance of herbivorous insects and mites. This, in turn, often leads farmers to apply higher levels of pesticides and thereby reduce ecosystem efficiency and reduce water quality (Horgan and Crisol 2013; Spangenberg et al 2015).

Coverage of the TEEB Agrifood Framework in this study

Value chain stages / Visible and invisible flows	Production (and associated waste)			Processing and Distribution (and associated waste)			Consumption (and associated waste)
Flows generated at the level of	**Landscape**	**Infrastructure and Manufacturing**	**Farm**	**Wholesale**	**Food and Beverage**	**Retail**	**Industry/ Household/ Hospitality**
Value Captured by System of National Accounts (SNA)			Income from yield				
Provisioning Services (Materials, Energy, etc.)			Food production (grain yield) Habitat provisioning Production of energy from rice husk				
Regulation and Maintenance Services (Soil, Water, Habitat for biodiversity, etc.)	Watershed management		Freshwater saving Nutrient cycling Soil fertility enhancement Pest control Groundwater recharge Genetic diversity				
Cultural Services (Heritage, Recreation, etc.)	Cultural Heritage Maintenance of rice terraces Tourism Traditional rituals and spiritual experiences related to rice system		Traditional knowledge on rice cultivation				Access to and consumption of traditional rice varieties

Health Impacts (Nutrition, Lifestyle diseases, Antibiotic resistance, etc.)			In disability adjusted life years (DALYs) Health costs related to pesticide use				Dietary variability
Pollution Impacts (Nitrates, Pesticides, Heavy metals, etc.)			Water pollution from pesticides Water pollution from fertilizer Eutrophication				
GHG Emissions (CO2, CH4, etc.)			GHG emissions Air pollution				
Social values (Food security, Gender equality, etc.)							
Risks and uncertainties (Resilience, Health, etc.)			Moderation of extreme events				

Key
Monetary estimates
Quantitative estimates
Qualitative discussion

Study Recommendations

The results show that the development of a solid typology that is further disaggregated into specific farming systems and practices is key to valuing externalities from the agriculture and food sector. The study results confirm that a trade-off analysis is mandatory if the study is to inform policy. The study can bring the opportunities for synergies to the attention of decision makers and point out where trade-offs can be minimized, synergies can be maximised, and yields can be maintained while ecosystem services are being generated and enhanced.

The results have confirmed the need for practice and location specific typologies to show the full range of externality benefits and costs. As the results clearly show, environmental impacts and ecosystem services linked to rice farming strongly respond to the type of agricultural management practised. Rice farming or agriculture in general, is too often categorized as one homogenous activity, when in reality farming is extremely diverse. This study has therefore made an attempt to go beyond production systems and rice growing environments, zooming in on the different ways in which rice is produced.

Further research

In order to provide a holistic assessment of a farming system it requires that experimental studies provide a comprehensive data set that goes beyond food production alone as is typically done in agronomic studies. Likewise, ecological and environmental studies need to record agronomic values, including yields, and widen their often restricted focus on natural resources and biodiversity alone. In addition, environmental and socio-economic benefits and costs are often studied in isolation from each other, despite them being closely interconnected.

Instead of relying on the scientific data alone, there may be large scope for applying the TEEB approach to analyse specific farms, and making greater use of on-farm, farmer-led research. Follow up studies must focus on integrating the available evidence into models that –using data where available, and expert knowledge where not- can provide insightful comparisons of conventional practices versus alternative, more ecologically-based production systems.

There is also a need to improve current valuation methodologies, as there is a clear lack of those that can value agroecosystem benefits as opposed to costs. There is a need to link economic valuations to market costs, and avoided costs for the farmer. Methods are urgently needed to be able to assess and compare multi-dimensional values, as monetary analysis is not appropriate for all positive and negative externalities of agriculture. Furthermore, one needs to better adapt current models for valuation to the realities of developing countries. While ecosystem valuations usually focus on the local level, ecosystem accounting methods aim to aggregate information to produce statistical results at the national level. Since both areas of expertise are still in its infancy, it is timely to join forces now in order to follow a coherent approach in the future.

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» Executive Summary

» Final Report

» Rice Study Slideshow Presentation

Additional documents

» **Narrative Report TEEBAgriFood Rice**

» **Trucost Methodology Report**

» **Counting the impacts of rice farming**

» **Case Study Data**