RICE – TEEBAGFOOD

[EXECUTIVE SUMMARY]

Valuation of rice agro-systems

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Suggested citation for the final report:

Bogdanski, A., R. van Dis, Attwood, S., Baldock, C., DeClerck, F., DeClerck, R., Garibaldi, L., Lord, R., Hadi, B., Horgan, F., Obst, C., Rutsaert, P., Turmel, M.-S., Gemmill-Herren, B. Forthcoming. *Valuation of rice agro-ecosystems.* TEEB Rice. Final report. UNEP/FAO, unpublished project report for The Economics of Ecosystems and Biodiversity (TEEB) global initiative for Agriculture and Food

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EXECUTIVE SUMMARY

Background

The **UNEP TEEB Office** has recently begun to undertake a study on '***TEEB for Agriculture and Food***'. This study is designed to provide a comprehensive economic evaluation of the 'eco-agri-food systems' complex, and to demonstrate that the economic environment in which farmers operate is distorted by **significant externalities**, both negative and positive, and a lack of market, policy and societal awareness and appreciation of human **dependency on natural capital**.

The Food and Agriculture Organization of the United Nations (FAO) together with its partners, **the International Rice Research Institute (IRRI)** and **Bioversity International** as well as **Trucost** has applied the TEEB approach to the rice farming sector. Rice (*Oryza sativa* from Asia *or Oryza glaberrima* from Africa) production is essential to the food security and livelihoods of around 140 million rice farming households and provides a range of ecosystem services 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 GHG emissions, air and water pollution as well as an increase in water consumption. Policy makers need to make 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.

Study objectives

As these challenges are not independent, but rather interlinked, reaching them is likely to require **trade-offs**. The question of interest is therefore of how to reduce trade-offs between these different goals. Where possible, one should identify **synergies** that allow for a maximization of benefits, while minimizing costs to society and the environment, (i.e. negative externalities), and the wellbeing of the farmer him or herself through the degradation of natural capital from rice production.

It is therefore crucial to know which types of farm management practices or systems offer the best options to reach these synergies, and reduce trade-offs.
The specific objectives of this study were three-fold:

1. To identify visible and invisible costs and benefits of rice agro-ecosystems; i.e. externalities

2. To identify and assess those rice management practises and systems which reduce trade-offs and increase synergies

3. To make these trade-offs and synergies visible by assigning biophysical or monetary values to the different options

The approach

1. Scope and framework setting

In a first step, five case study countries were selected which cover rice farming globally and which represent a gradient from low intensified to high intensified production systems. Countries selected were: **the Philippines** and **Cambodia** in Asia, **Senegal** in Africa, **Costa Rica** in Latin America and **California/The United States** in North America. According to FAOstat (2013), Cambodia was, on average, the lowest yielding country with 3.3 tons/ha and the USA had the highest yielding production with 9.5 tons/ha.

In a second step, a rice production system typology was developed. On a first level, rice systems were distinguished by rice growing environments. The three main categories were Irrigated Lowlands, Rainfed Lowlands and Rainfed Uplands.

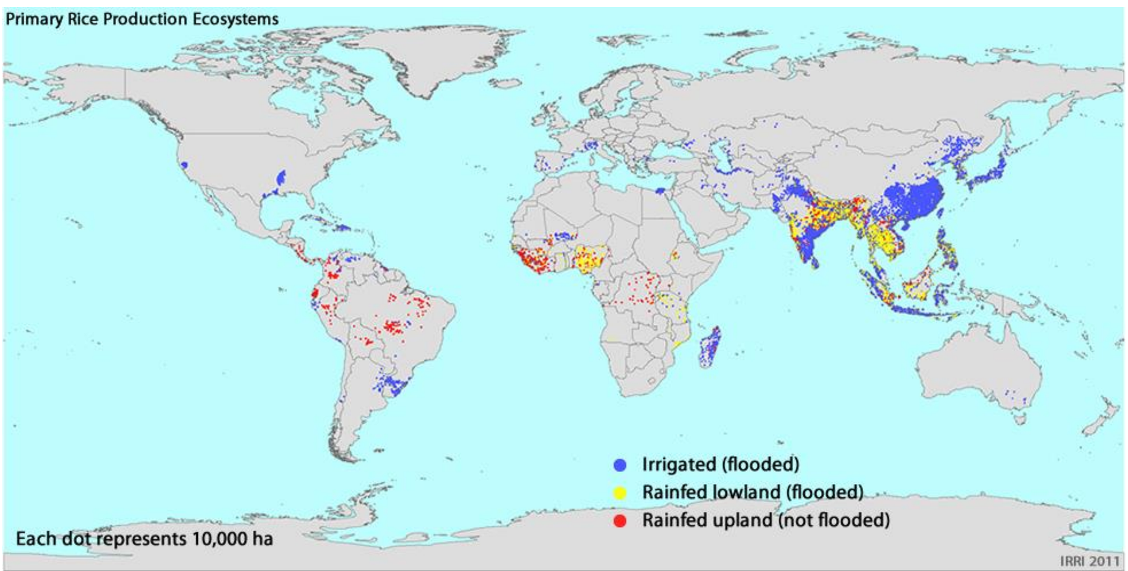

Figure 0.1. Map of different rice production systems globally, showing the considerable extent of irrigated rice (blue). Source: IRRI, 2009

On a second level, the rice production systems were further categorized by rice management systems and practices. 28 different system and practice category comparisons were identified, starting with land preparation and finishing at harvest.

The study has set out to identify those **farm management practices** that offer the best options to reach synergies, and reduce trade-offs between different management objectives. Several scenarios, i.e. pairwise comparisons (table 1), 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, instead of herbicide use, hand weeding or biological control could be practiced.

Table 0.1. Practice and system comparisons included in the study.

Management practices (Scenarios)		
1. Preplanting	Land preparation	Dry tillage – puddling
		Land levelling – no levelling
		Minimum soil disturbance – conventional tillage
		No tillage – conventional tillage
2. Growth	Planting	Direct seeding – transplanting Dry seeding – wet seeding
	Water management	Low irrigation frequency - high irrigation frequency
		Improved water management - continuous flooding
	Soil fertility management	Reduced mineral fertilizer use - high mineral fertilizer application
		No fertilizer use – mineral fertilizer application
		Organic fertilizer application - mineral fertilizer application
		Organic fertilizer application - no fertilizer application
		Mineral + organic fertilizer application – mineral fertilizer application only
	Weed management	No weed control - herbicide use
		Biological weed control + hand weeding - herbicide use
		Hand weeding – herbicide use
		Reduced herbicide use – higher herbicide input
	Pest and disease management	No pesticide use - pesticide use
		Reduced pesticide use – higher pesticide input
3. Postproduction	Residue management	Winter flooding – no winter flooding
		Straw incorporation – straw burning
		Straw baling and removal – straw burning Straw rolling – straw burning
Management systems		
		System of Rice Intesification – Conventional agriculture
		Organic agriculture - Conventional agriculture

In a third step, the project team identified pertinent policy and management issues related to the selected rice management systems and practices. These constituted the basis for the development of the analytical framework, which was built around a set of relevant costs and benefits related to rice production (see **Table 0.2**).

Table 0.2. Benefits and costs related to rice cultivation.
Those with an * could not be covered due to data limitations

Benefits	Costs
Rice grain (Revenue)	Water pollution
Rice straw (Nutrient value)	Air pollution
Rice husk (Energy value)	Land pollution
Pest control	Water consumption
Nutrient cycling and soil fertility	GHG emissions
Carbon storage*	Labor
Ecological resilience (pests)	Fertilizer
Recreational and tourism opportunities	Pesticides
Flood prevention*	Fuel*
Water recharge*	Capital costs (e.g. machinery)*
Habitat provisioning	Irrigation water*
Dietary diversity	Seeds*

2. Biophysical quantification and monetary valuation

TEEBAgFood has unique challenges in developing a means of analysis of the positive and negative externalities of agriculture; negative externalities align well with standard valuations of environmental pollination, but positive externalities – such as ecological resilience, or dietary diversity – are not well captured by standard monetary valuations methods. In this first phase, so that the gaps and needs can be better understood, a conventional process was followed to attribute monetary values to the costs and benefits above (many of which then could not be analysed or compared). Thus this section presents the conventional process, with gaps described at a later point.

Placing monetary values on the costs or benefits that arise due to different management practices takes place in three distinct steps. This process is guided at all times by an overarching research question, which outlines the aim of the monetary valuation, why the valuation is needed, and who the target audience is.

The first step, which measures the changes in physical conditions, has been performed in the academic literature used for this study. This includes the identification of the drivers for change, such as fertiliser or pesticide inputs. Additional to extracting this data in a standardized way across all five case study countries, a vote counting analysis was done to synthesize these results.

The second step requires the biophysical modelling of the impact, or impacts, that are caused by changing physical conditions. This includes identifying factors such as the endpoint of nutrient run-off, which may be adjacent freshwater ecosystems for example, and quantifying the change in the biophysical indicator that is to be valued, such as the change in the quality of human health, measured in disability adjusted life years (DALYs) (see below for more details).

The final step involves 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.

In this study, the biophysical modelling assigns the costs and benefits of the impacts to either human health, or ecosystems, arising from different management practices. Human health is measured in terms of disability adjusted life years, or DALYs. This metric quantifies the burden of disease on human populations, and can be thought of as one year of healthy life lost. The measure includes both the years of life lost due to illness (mortality), and the years of healthy life lost due to disability (morbidity). The valuation approach uses a willingness-to-pay (WTP) survey, which elicits values from society based on changes in factors like reduced income due to ill health, the pain and discomfort caused, as well as decreased life expectancy.

The costs or benefits of the impacts on ecosystems are quantified in terms of the change in ecosystem functioning, and then valued in terms of the change in the monetary value of the ecosystem services provided. Ecosystem functioning is measured as the change in net primary production (NPP) within ecosystems outside of the farm gate. Currently, impacts on the farm have not been considered. The monetary valuation approach involves conducting a meta-analysis of primary valuation studies of provisioning, regulating, and cultural ecosystem services. The approach allows the quantification and valuation of ecosystem services that are impacted due to changes in environmental quality. This can be due to the emission of air land and water pollutants, or to changes in water availability. Provisioning ecosystem services, such as rice and rice husk production, coming from within the farm gate have been valued using direct market pricing.

3. Scenario analysis

In the last step, we upscale management practices from field to country level. All results – costs and benefits – are given on a per hectare basis. Knowing the rice farming area in each country and the percentage of irrigated lowlands, rainfed lowlands and rainfed upland systems, one can calculate the production area in each rice growing environment. Multiplying this area by the difference in impact between two management practices, one can calculate the gains, losses or savings related to an environmental impact or ecosystem service when changing from one scenario to the other.

RESULTS AND DISCUSSION

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 it carries a number of trade-offs as this study has shown.

This study sought 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, alternate wetting and drying (AWD), during aerobic soils production and the system of rice intensification (SRI). The study further compared dry tillage to puddling, and direct seeding to the transplanting of seedlings. **Figure 0.2** shows the effects of SRI and conventional management on irrigated (IL) and rainfed lowland (RL) system 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).

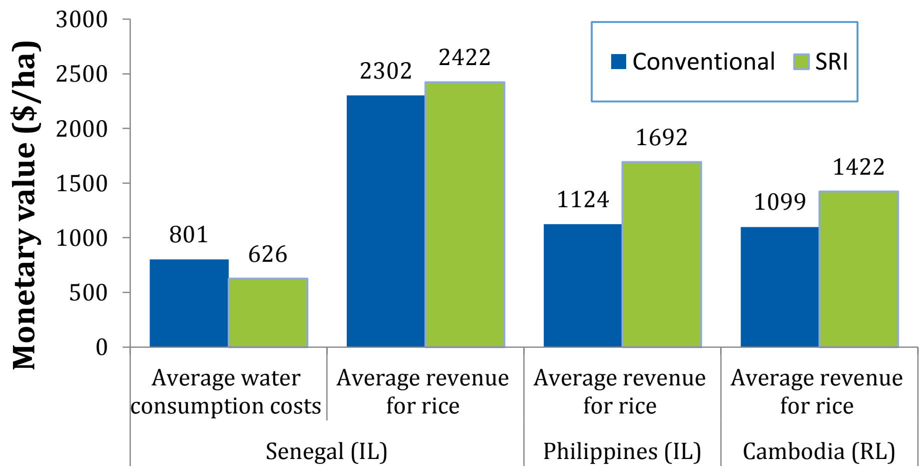

Figure 0.2.

Comparison of the effects of conventional management and SRI on the revenue and environmental and health costs of water consumption per hectare in irrigated lowland systems (IL) and rainfed lowland systems (RL).

Scenario analysis: SRI versus conventional management

The System of Rice Intensification (SRI) includes intermittent flooding as part of the production package. The system advises 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 SRI, 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 SRI, 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 SRI are highly variable and mainly occur in highly weathered soils, whereas in ideal rice soils yields tend to be the same or less with SRI (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 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.

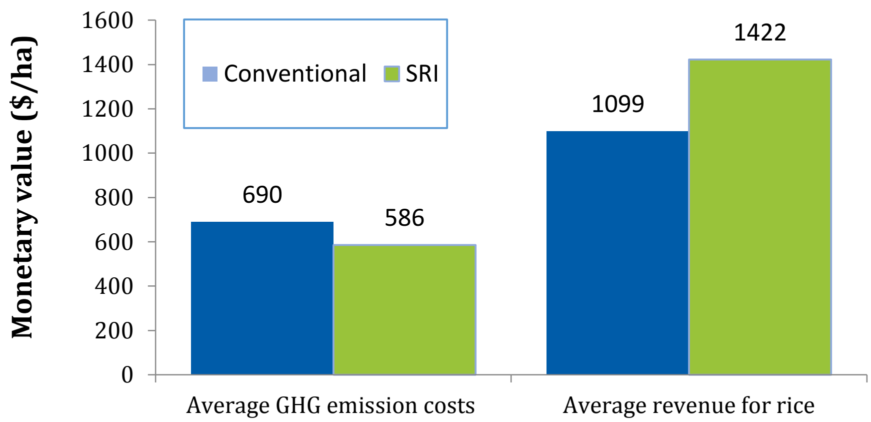

Figure 0.3 shows the effects of SRI and conventional management on the revenue for rice grain of rice and GHG emission costs in RL systems in Cambodia.

Scenario analysis:
SRI versus conventional management

While the concept of SRI 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, SRI fields 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 SRI – a reduction in costs of 15%.

If all rice farmers in RL systems in Cambodia would change to SRI, 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.

CONCLUSIONS

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. Farming is very diverse, and so are the environmental impacts and ecosystem services that are linked to each type of production. Typologies therefore need to zoom in on management practices and systems as much as possible to reflect the reality of (rice) farming and the diversity of its values. It would be illusionary to think that there is ONE type of producton that leads to ONE specific set of positive and negative externalities.

The study results further confirm that a trade-off analysis is mandatory if the study is to inform policy. Focusing on environmental impacts or ecosystem services alone without considering the impacts on food production, for example, would fail to provide a sound basis for decision making. One therefore needs to value all potential benefits and costs at the same time, providing a holistic assessment of a farming system that is truly multifunctional.

This 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. Furthermore, there is a need to enhance models that can mimic agro-ecological processes where specific data points are missing, and where field studies are not feasible.

Alternatively, farmers themselves are carrying out just such experiments, varying their practices to attain multiple benefits. Instead of relying on the scientific data alone, where experimental protocols generally require that most aspects are held constant while one or a few variable are manipulated, there may be large scope for applying a TEEB-type analysis to specific farms, and making greater use of on-farm, farmer-led research.

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, as noted above. 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.

Recognising that national assets extend well beyond GDP, or gross domestic product, there is an initiative underway to bring in methods to account for other forms of capital including natural capital, to national statistical accounts, through the UN initiative on Systems. Of Environmental-Economic Accounting. TEEB-AF, in addressing the current challenges to develop multi-dimensional valuation, also may provide and share important insights with the System of Environmental-Economic Accounting for Agriculture (SEEA-AGRI). 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.