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Land cover-based ecosystem service assessment of irrigated rice cropping systems in southeast Asia—An explorative study

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ABSTRACT

Continuing global population growth requires an increase in food production, but also new strategies to reduce negative effects of intensive land use on the environment. Rice as key staple food for a majority of the human population is of crucial importance for global and particularly Southeast Asian food supply. As food provision is one key ecosystem service (ES), it is important to know which ESs are provided at which places. Therefore, an ES scoring exercise harnessing local experts' knowledge in a 'rapid assessment' was conducted in seven rice cropping regions in Vietnam and the Philippines. The expert-based scoring values were linked in an 'ES-matrix' to the different land use/land cover (LULC) classes abundant in the study areas. The LULC classifications were based on SPOT satellite image interpretation. The matrices were used to compile ES supply maps that give first indications about ES in regions with different intensive agriculture. The outcomes provide a first 'screening' of ES supply related to different LULC types in rice-dominated regions enabling the communication of the relevance of specific ecosystems for local communities and decision makers. Uncertainties inherent in expert- and land cover-based ES assessments are discussed and recommendations for improvements of future studies are given.

1. Introduction

Facing a projected world population of more than 10 billion by the end of this century (UN, 2013), but having 868 million people suffering severe food scarcity in the year 2012 (FAO, 2013), explains why intensive research is conducted to enhance food security (Ericksen et al., 2009). Rice (*Oryza sativa* L.) is the major staple food for 2.5 billion people worldwide, whereof 557 million people live in Southeast Asia (Manzanilla et al., 2011). Southeast Asia provides ideal production conditions for rice regarding climate and water supply (Willenbrink, 2003) and therefore the crop has been traditionally cultivated for centuries. However, the face of rice cultivation has changed extremely in most Southeast Asian rice cropping regions since the 'green revolution' in the 1960ies (Greenland 2006).

Achievements like the implementation of new varieties, synthetic fertilisers and the intensive use of pesticides contributed to a significant rise in yields per hectare (Bottrell and Schoenly, 2012). Today, yield increases are slowing down (Laborte et al., 2012; Dobermann et al., 2002), which brings up questions about future food security. Moreover, in many cases ecosystem structures

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(including biodiversity) and functions have suffered from a food production approach that is only focused on maximising yields (Gagic et al., 2012; Olhan and Alaseven, 2010). Exemplary effects are chronic pest infestations and epidemic outbreaks (Hossain, 2007; Heong and Hardy, 2009), unsteady water supplies, biodiversity loss and constantly rising costs of additionally inputs needed to safeguard the agro-ecosystems' functionalities (Singh, 2013). Approaches that enable a sustainable management of rice cropping systems and the surrounding landscapes are urgently needed. It is obvious that instead of technical approaches, more nature-based solutions are required to optimise food production (Ericksen et al., 2009) and to mitigate risks of lacking food supply.

Ecosystem services (ES) offer promising ways to communicate the relevance of biodiversity and functioning ecosystems to decision makers (de Groot et al., 2010). Spatially explicit ES mapping can visualise the consequences of land use/land cover (LULC) changes like conversion of forest to agricultural land (Crossman et al., 2012). Related case studies are an important step towards the further development, acceptance and policy implementation of the ES concept (Maes et al., 2012; Burkhard et al., 2012a, 2013; Daily and Matson, 2008). Expert surveys have become a recognized tool for acquiring and screening complex ES-related information which otherwise would be too resource-consuming to be obtained (Jacobs et al., 2015; Palomo et al., 2013). The combination of expert scores with LULC-data are common within ES mapping studies (Kienast et al., 2009; Maes et al., 2011; Burkhard et al., 2012b). The rather rapid creation of results, especially on the landscape scale, is one main advantage of LULC-based studies (Jacobs et al., 2014). Based on the assessed information, their analysis and the subsequent compilation of ES supply maps, differently managed rice-dominated landscapes in the Philippines and Vietnam were compared referring to their capacities to supply ES.

Such ES-based information can help providing alternative management options for decision-making in agricultural systems (Swinton et al., 2007). Assessing the supply of ES and illustrating it in a way that is easily understandable in order to reach a broad audience also outside the field of ecological sciences, is considered an auspicious approach, to which this work wants to contribute. Therefore, this study aims to identify service providing units (SPUs) for different ESs relevant in the study regions and to detect differences in ES supply between different cropping systems. ES trade-offs between maximised capacities to supply food (rice) ES and areas with multiple ES supply were expected in regions where rice cultivation is practiced more intensively or more traditionally.

The following research questions were used to guide the study:

- Which ES are relevant in the study areas and in which LULC types are they supplied to what extent?
- Are there differences in ES supply between different cropping systems and related production intensities?

2. Materials and methods

The study has been part of the research project LEGATO[1] with partners from Europe and Southeast Asia (Settele et al., 2013). The project's core objective is to investigate the interactions between irrigated rice cropping systems, the landscapes in which they are embedded and the human perception and valuation of relevant ESs. The project aims to quantify in what degree ecosystem functions and services relevant in rice cropping systems depend on local and regional land use practices, biodiversity, climate as well as socio-economic and cultural drivers and constraints. Seven research regions of 15 × 15 km² in Vietnam and in the Philippines have been defined (Fig. 1).

2.1. Research regions

The research regions (Fig. 1) were selected to enable a comparison of rice cultivation systems in tropic/subtropical climatic conditions with partly different agricultural intensities, structural patterns and socio-cultural settings. Vietnamese as well as Philippine rice cropping is in large parts characterized by intensive cultivation techniques and use of herbicide and fertiliser inputs, especially in lowlands and river deltas (see Klotzbücher et al. (2014)). This development is increasingly affecting the landscapes' natural capacities to maintain biodiversity, ecosystem functions and to supply ES (Spangenberg et al., 2015). In contrast to the majority of sites, the chemical inputs in Philippine rice terraces are extremely low. Also, the yields obtained in such systems are smaller, while simultaneously the landscape is well diversified and high quality local rice varieties are grown (Settele et al., 2013; Settele, 1998).

2.1.1. Research regions in Vietnam

The first region (VN_1) is located in the Red River Delta in the Hai Duong province about 20 km east of Hanoi. In this area, most rice varieties used are highly productive hybrids with two harvests per year. Fast industrialisation in the Hai Duong province has recently led to LULC changes from agricultural land to settlements and industrial areas. The second region (VN_2) is also situated in the Red River Delta about 50 km north of Hanoi in the Vinh Phuc province. In contrast to the Hai Duong province, the area suffers from a general lack of water, mainly caused by sandy soils and a decrease in forest cover (Jadin et al., 2013). Agriculture has a smaller relevance in this region compared to Hai Duong. On most of the rice fields, traditional varieties with higher genetic diversity are planted. Rice is harvested 1-2 times each year, and instead of chemical, mostly organic fertilisers and less pesticides are used.

The third region (VN_3) is located in the mountainous Lao Cai province around 1200 m a.s.l. 300 km northwest of Hanoi, bordering China. The relief is engraved by terraces and the climate is more temperate than in the first two regions. The area faces high population density and growth, leading to periods of food deficiency (Jadin et al., 2013). The growing tourism targeting for the rice terraces is the main source of income here. Rice is grown only in the form of subsistence farming and no market exists within the grasp of local people. Rice is normally planted once a year, due to climatic constraints and water scarcity (Lò Dieu Phu, pers. comm. 2012). New terraces are constantly created, while others have been abandoned. Landslides are visible at numerous slopes.

The fourth region (VN_4) is situated in the Tien Giang province, about 60 km southwest of Ho-Chi-Minh City in the Mekong River Delta in southern Vietnam. Thanks to its plain relief and favourable climatic conditions, this region is presumed to be the most productive rice cropping area of the whole country. The rainy season here lasts from May to November, enabling three major cropping seasons (Bambaradeniya and Amerasinghe, 2004). Insecticides, pesticides and fungicides are commonly used several times per cropping season. The cultivation intensity has been increased considerably in the region with the introduction of the high-yield variety IR8 in 1966 (Tran and Kajisa, 2006). The ancient forests that covered the area of the Mekong Delta prior to the American war have completely disappeared. At some places, small spots of secondary forest have developed and the trees growing there are intensely used for construction.

[1] Land-use intensity and ecological EnGineering-Assessment Tools for risks and Opportunities in irrigated rice based production systems: http://www.legato-project.net