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Integrated evaluation of Ecosystem Services in Prawn-Rice rotational crops, Vietnam

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ABSTRACT

The hydrologic condition in Kien Giang province on the west coast of Vietnam's Mekong Delta is unique in the sense that it has extensive saline water intrusion during the dry season every year. Instead of a triple crop scheme like other areas in the Delta, a prawn and rice rotational cultivation scheme was initiated to facilitate agricultural production in Kien Giang. In this paper, the ecosystem services (ES) generated from the agriculture ecosystem under the prawn and rice rotational crops (PRRC) were assessed using an integrated approach. The specific ES identified here include water and nutrition regulation in the soil together with climate regulation in favor of the cultivated crops. A multi-disciplinary approach including remote sensing, GIS, social surveys and statistical analysis was adopted to comprehensively evaluate the geographical, biophysical, economic and social aspects of the ES. Firstly, Landsat 8 images were processed with Normalized Difference Vegetation Index (NVDI) and Modified Normalized Difference Water Index (MNDWI) to identify the areas cultivating PRRC. The accuracy of image classification was assessed by ground truthing and we found an 80% coincidence between the simulated results and the field observations. Then, the social survey was conducted using face to face interviews at 50 local households to collect data related to farming practices. Economic values of ecosystem services were obtained using the revised market methods by annual crop yields per unit area. The mean estimated value of ES provided through the PRRC was 1300 USD/ha/year (standard deviation of 600 USD/ha/year) which accounted for 38.1% and 59.4% of the averaged economic revenue and net benefit, respectively. The analysis of social survey data revealed the factors having the greatest effects on ecosystem services values were selling prices of prawn and farming experiences. Finally, results were synthesized with GIS to describe how ES values vary across the research area which facilitates effective communication of the importance of ES concepts to policy makers regarding land use planning and natural resources management decisions.

1. Introduction

A number of definitions for ES can be found in the literature (Hayha et al., 2015) of which three are commonly cited:

- the conditions and processes through which natural ecosystems and the species that make them up, sustain and fulfill human life (Daily, 1997),
- the benefits human populations derive, directly or indirectly, from ecosystem functions (Costanza et al., 1997),
- Or more concisely, the benefits people obtain from ecosystems (MA, 2005).

In spite of different terms and notions, these definitions share a common ground: human well-being depends on the continued provision of ES in many ways. Therefore, these services should bear some economic value. It is the emphasis on welfare and human well-being that sets the need for economic valuation which must be coupled with biophysical analysis (Boyd and Banzhaf, 2007). The ultimate goals of valuation practices must not entirely be putting price tags on goods and services provided by nature. Rather, such efforts also must be done to realize pathways to bring the pedagogical concept of ES from the academic arena to reach the government policy agenda. More explicitly, Liu et al., (2010)

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pointed out at least three specific objectives of ES valuation are to (1) assess and ensure the ecological sustainability of human activities within the biosphere, (2) distribute resources fairly taking into consideration the links between generations, between humankind, and the environment; and (3) efficiently allocate natural resources.

Guided by such goals, a number of valuation frameworks have been developed of which TEEB's *Total Economic Value* (TEV) one of the most is commonly applied. Using standard accounting units (such as money), TEV can facilitate the comparison between ES and conventional services. There are three clearly differentiated valuation approaches in this framework: (1) revealed preference; (2) cost-based; and (3) stated preference. These different economic techniques are adopted to handle ES with contrasting characteristics. For instance, the *market price method*, which is an example of the revealed preference approach, is widely used for those services with real markets such as crops, livestock or forestry products. Conversely, for others without well established markets such as cultural or spiritual values of landscapes, stated preference methods such as contingent valuation methods are more appropriate. These two techniques as well as related methods have strengths, weaknesses as well as their specific validity. Nevertheless, yet another methodological review is not the intent of this paper because such reviews are readily available (*e.g.* Farber et al., 2002; Freeman et al., 2003; Hadley et al., 2011; Atkinson et al., 2012). Rather, this paper looks at how to overcome some of the challenges faced in applying ES through the use of an integrated socio-economic/biophysical visualization and statistical approach.

Along with the dramatic increase in the number of ecosystem valuation publications such as Environment Valuation Reference Inventory (Liu et al., 2010), mapping of ES values also constitutes a fast growing body of literature, especially with the advancement of GIS and other earth observation techniques. How natural benefits vary across a geographical area has become one of the most active topics in the environmental research agenda (Troy and Wilson, 2006). Attempts have been made to map the use values of timber production, carbon sequestration and natural hazard protection (Seidl et al., 2007; Teich and Bebi, 2009) as well as non-use values such as cultural, educational or spiritual services (Fagerholm and Kayhko, 2009; Fagerholm et al., 2012; van Berkel and Verburg, 2014). The additional geographical dimension of *where* has the potential of improving the comprehensibility of ES values in supporting land use decisions (Nahuelhual et al., 2015).

The objectives of this article are to analyze how economic values of ES can be calculated and mapped at the district scale, focusing on the PRRC areas of the An Minh district, Vietnam and to examine how applying ES valuation framework can improve land use planning decisions. The PRRC scheme includes rice and prawn crops periodically cultivated within the course of a year in accordance with the specific hydrologic conditions, in particular saline concentration. The research was initiated with the acquisition and processing of Landsat 8 data to identify the PRRC areas in An Minh District. The validation of land cover classification was controlled by ground truth points. Secondly, within the framed ecosystem of PRRC we consider all the ES contributing to crop yield. The services include, but are not limited to, water and nutrition supply, nutrient cycling, hydrologic regulation, and pest control. Each of these, individually, does not appear in any well-established markets for purchase or exchange. But as a bundle, they contribute to the generation of rice and prawn crops which are marketable. Therefore, a common value for all the associated ES is assigned and reflected partially in the total crop revenues. This is the prerequisite to apply the direct market price methods. Ubiquitously 100% of the crop revenues have been used as the proxy to evaluate agriculture related ES (Sumarga and Hein, 2014; Hayha et al., 2015). However, this assumption is prone to overestimation because it neglects the human participation through capital and labor. Furthermore, in the context of agricultural ecosystem, anthropogenic contributions do not only bear economic significance but social values as well, such as family and communal tillage experience. Clearly, direct market price methods are not originally designed to handle these values. This shortcoming raises questions about the validity of the market approach in valuing ES.

To overcome the challenge, we first subtract the total crop revenues by associated costs to account for the human contributions which, in turn, makes the economic values of ES better estimated (TEEB, 2010; EC, 2013). Information about these costs were collected through face to face interviews. Secondly, these costs were further analyzed to uncover the underlying socio-economic relationships associated with the local context. This analytical framework constitutes a *modified market approach,* in which we strive to integrate new ways to understand and appropriately evaluate ES and thereby make it a more comprehensive, yet practical decision-making tool, particularly for planning practitioners. Our analytical framework highlights both the biophysical performance and social integrity of ES and in this way addresses the nature-social dualism that often is a barrier to effective environment management. Our results were synthesized in thematic maps for better visualization and communication with stakeholders to re-evaluate the current land use planning and to shed useful light on challenges in both natural suitability and social integrity.

2. Material and methods

2.1. The research area

Kien Giang is a province of Vietnam, located on the southwestern side of the Mekong Delta, with the provincial capital being Rach Gia city. The total area is about 6299 km^2 of which 66% of the natural area is agricultural. The population is about 1,634,043, of which 22% live in the urban area. The research area is An Minh district, located on the west coast of the province. The district is bordered by An Bien district in the North, U Minh Thuong district in the East and the West Sea in the west, with 37 km of coast line. The district consists of 11 communes (smaller administration units under districts) with the total area of 59,000 ha. Fig. 1 shows the location of the research area with the identification of Kien Giang within Vietnam's Mekong Delta.

An Minh district was chosen for this research due to its large cultivated area as well as its high productivity of PRRC (BCS, 2015). Historically, rice is the predominant crop of Kien Giang province. However, due to its unique hydrologic conditions with periodic salinity intrusion during dry seasons, the productivity and values of rice crops are heavily affected, especially for coastal areas such as the An Minh district. The situation has become even worse in recent years due to climate change impacts which were mainly storm surges and salinity intrusion (Vietnam National Mekong River Commission, 2011). Recently, the provincial government has initiated several measures to cope with this situation, one of which is the shifting from a rice intense tillage scheme to PRRC.[1] The concept behind this rotation is to combine crops with different water requirements and salinity adaptability to cut down on land idle time and to increase crop yields in the course of a year.

[1] PRRC was discovered by chance in Ca Mau Province when farmers found brackish water prawns in their fields after harvesting the rice crops. The prawns are believed to have followed the irrigation stream to enter the fields.