Ecosystem services in agricultural landscapes

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Abstract

Ecosystem services (ES) are the benefits that humans derive from natural and modified ecosystems. Natural and modified ecosystems significantly impact the delivery of ES that contribute to human welfare. Agricultural landscapes are '*engineered*' ecosystems which have been extensively modified by humans explicitly to provide a narrow set of marketable ES such as food and fibre. But the expansion of these services has often been achieved at a high cost to other ES, such as regulation of climate, water and biodiversity, which are necessary to sustain human life. There are limited natural resources on farmland and to make rational choices among alternative uses of a given natural resource, it is important to know both what ES are provided by farmland and how much they are worth. As the economic value of the direct and indirect benefits of global ES are substantial, there is growing awareness of the utilisation of these services for the long-term sustainability of agroecosystems and their ability to generate economic and ecological wealth. This paper outlines the above context, provides conceptual model for evaluating ES in agroecosystems and evaluate economic value of ES on farmland with case studies from Danish CFE (Combined Food and Energy) system and New Zealand arable land (organic and conventional systems). It also discusses the prospects of ES approach in the Australian agricultural context.

Key Words

agroecosystems, economic valuation, ecosystem goods, marketed ES, non-marketed ES

Introduction

Goods and services (ES) provided by natural and modified ecosystems are essential for human survival (Daily 1997). Recent studies (Reid *et al*. 2005; FAO 2006; Comprehensive Assessment of Water Management in Agriculture 2007) state that there is decline in the abilities of productive ecosystems to provide essential ES. Modern agriculture has been very successful in providing food and other products to fulfill the needs of markets and growing population. However, the expansion of these services has often been achieved at a high cost to other essential ES, such as climate regulation, water, pest/disease regulation, soil erosion control and biodiversity.

There is thus an increasing interest in the services provided by nature to replace unsustainable inputs and to counter the external costs of high input production systems. As the economic value of the direct and indirect benefits of global ES (US $33 trillion annually, almost twice the global gross national product, Costanza *et al,* 1997) are substantial, there is growing awareness of the utilisation of these services for the long-term sustainability of agroecosystems and their ability to generate wealth. Although the actual value of ES is infinite as human existence depend on them. However, the incremental or marginal value of ES is estimated here in agroecosystems.

This paper provides a conceptual model of an ES approach that can be used to identify and evaluate economic value of ES operating on farmland. It also provides valuation of ES in Danish and New Zealand studies as an example based on this conceptual model. It is not the aim of this paper to compare ES between farming systems in different countries.

Methods

Conceptual model

Agroecosystems are highly '*engineered'* systems designed to produce food, fibre and raw products for industrial uses. Agroecosystems are consumers as well as producers of ES (Heal and Small 2002). Some of the ES are marketed but most of them are non-marketable as they carry no price tags. Management of agricultural landscapes can have negative or positive impact on the supply of ES under various farming systems. ES in agricultural landscapes have social, economic and ecological value associated with it (EFTEC, 2005). Value of ES supports decisions by landholders and policy makers to provide support in maintaining ecosystem structures and functions.

Agroecosystems provide many ES, delivering public (aesthetics, carbon sequestration, provision of cultural services) as well as private (soil erosion control, biological control of pests/diseases, soil health, water regulation) benefits (Sandhu *et al*. 2007). These benefits have economic worth and potential for trading them in a market. This concept is presented in Figure 1.

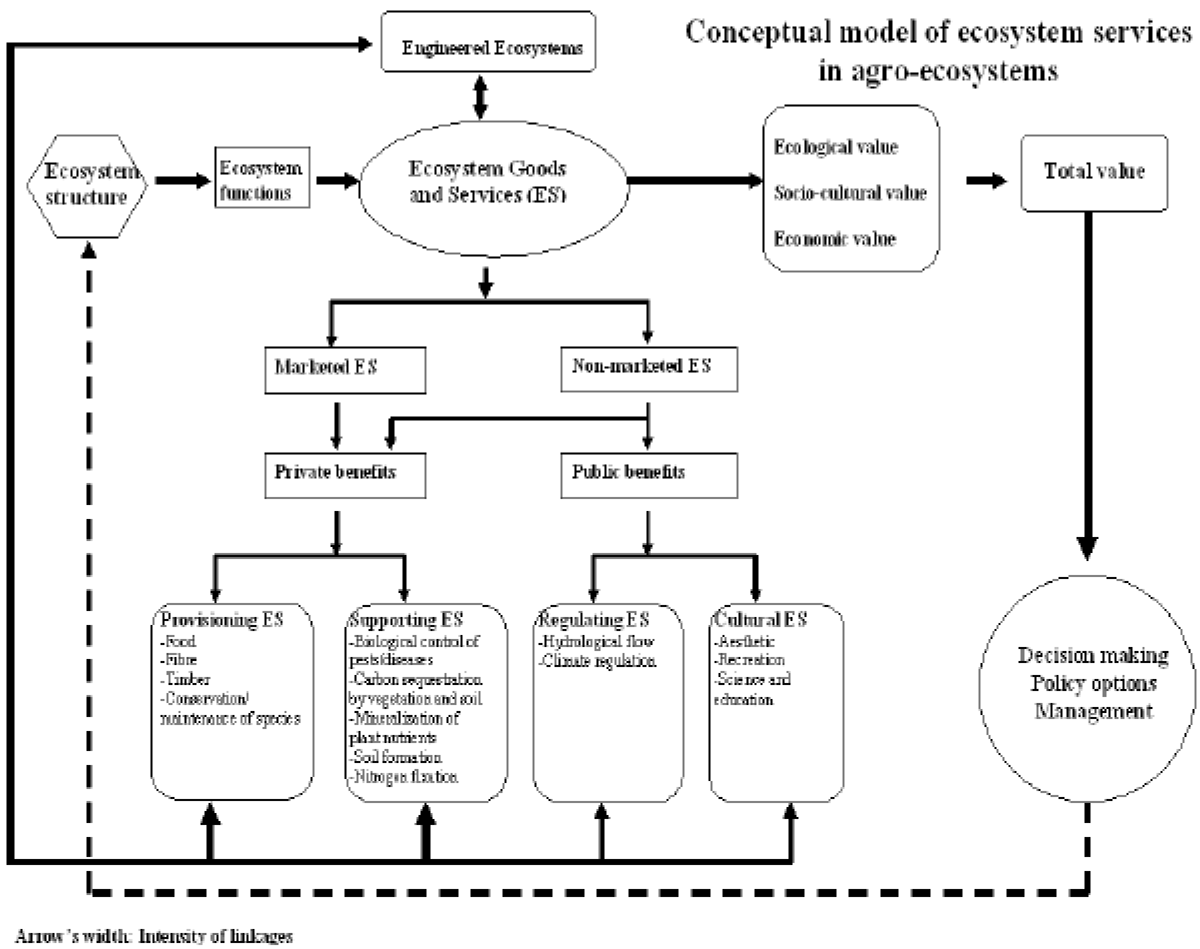

Figure 1 Conceptual model of ecosystem services in agroecosystems (adapted from de Groot *et al*., 2002 and Sandhu *et al*., 2007).

ES valuation

This conceptual model provides framework for the economic evaluation of ES in two different farming systems which are discussed in brief in this paper. The economic value of ES in these systems was estimated by using 'bottom-up' approach that assessed a range of ES experimentally. Field assessment of ES was done in Danish CFE (Porter *et al*. 2008) and also in New Zealand arable farmland (Sandhu *et al.* 2008). ES were identified and measured by field scale processes and translated into monetary terms

(US \$ ha^{-1} yr^{-1}) by using willingness-to-pay, value-transfer and avoided cost estimates (Wilson *et al*. 2004).

The CFE system

The combined food and energy (CFE) system study site was at the experimental farm of the Faculty of Life Sciences of the University of Copenhagen, Denmark. It consists of 10.1 ha of arable food (barley and wheat) and a pasture fodder crop (clover-grass) and ca. 1ha of biofuels that consists of four belts of fast-growing trees (willows, alder and hazel). This system is a net energy producer, with the system producing more energy in the form of renewable biomass than consumed in the planting, growing and harvesting of the food and fodder (Porter *et al*. 2008).

New Zealand arable farmland

The study sites included 29 arable fields, distributed over the Canterbury Plains and comprised 14 organic and 15 conventional fields. Codes O1-O14 were assigned to the organic fields and C1-C15 to the conventional ones (Sandhu *et al*. 2008).

Results

The mean economic value of ES in organic, conventional and CFE system (Sandhu *et al*. 2008; Porter *et al*. 2008) is given in Table 1. Suites of ES were identified in these agroecosystems. These ES fall under the category of provisioning services (food and raw materials), regulating services (hydrological flow), cultural services (aesthetics) and supporting services (biological control of pests, mineralization of plant nutrients, soil formation, carbon accumulation, nitrogen fixation, soil fertility, pollination and shelterbelts). Regulating and cultural services are mostly public benefits where as some public benefits falls under supporting services e.g., carbon accumulation; high carbon provides support for soil microbial activity and release of nutrients (private benefit) as well as carbon storage, reducing carbon from atmosphere (public benefit). Provisioning services are purely private benefits (Sandhu *et al*., 2007). Supporting services are mostly private benefits as they support food and fibre production.

Table 1. Summary of mean economic value of ecosystem services in organic and conventional fields in New

Zealand arable land and Danish CFE system.

		Economic value in US \$ $ha^{-1}yr^{-1}$		
	Ecosystem services	**Organic fields**	**Conventional fields**	CFE
1	Biological control of Pests	50	0	7
2	Mineralization of plant nutrients	260	142	294
3	Soil formation	6	5	13
4	Food	3990	3220	329
5	Raw materials	22	38	60

6	Carbon accumulation	22	20	34
7	Nitrogen fixation	40	43	0
8	Soil fertility	68	66	0
9	Hydrological flow	107	54	77
10	Aesthetic	21	21	213
11	Pollination	62	64	47
12	Shelterbelts	880	200	0
	Total economic value of ES	5528	3873	1074
	Non-market value of ES	1516	615	685
	NMV/ES value	0.27	0.16	0.64

Estimation of the economic value of ES in this study is limited for a number of reasons. These methods assessed ES as a 'snapshot' in time but as more and better information becomes available better estimates of the total value of these ES can be obtained. The same benefit should not be counted more than once in estimating the economic value of ES. However, ecosystems may simultaneously produce different ES such as climate/water regulation, nutrient cycling and recreation as services. In this study, double counting error is reduced by assessing ES individually and then by adding together to get an estimate of total economic value.

Australian agriculture contributes 3% to the GDP of the country and utilises 65% of natural resources and covers 60% of the total land area. ES provided by this sector remain un-accounted for the lack of current policies and practices. These policies do not advocate the inclusion of natural capital into general accounting. There is now a shift in the global trend from previous practices. There are markets for carbon trading and agricultural/ managed landscapes offer great potential to store and trade carbon at national and international level. Similarly, global agriculture is changing from being a primary producer to multifunctional agriculture, for example producing food, feed, energy and ES (Porter *et al*., 2008). Therefore, the need is to design agroecosystems that can maintain production and protect ES upon which they depend to promote social well-being of rural communities, industry and society as a whole. The challenge lies in developing a holistic framework of how Australian agriculture industry can address the loss of biodiversity and declining natural resources and introduce ES strategies to minimise the impacts of changing environment.

Conclusion

The conceptual model identified here provided framework for the evaluation of ES in '*engineered*' ecosystems and also underpins the evaluation of economic value of ES in agroecosystems. These studies showed that agroecosystems provide a range of ES (market and non-market) which has economic worth. As there has been no market for some of these ES, current agroecosystems planning do not incorporate measures to enhance them. However, considering the fact that these non-marketable ES are of high economic value and underpins food and fibre production, management of agroecosystems should provide necessary structure for them to provide these vital function/services.

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