Ecosystems as Natural Assets

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Abstract

It is now standard in economics to model natural resources as a special form of capital that can be depleted or accumulated. The following review shows how such an approach can be extended to ecosystems, implying that they are a form of natural asset that produces a flow of beneficial goods and services over time. The review includes a discussion of valuing ecosystem services, focusing on the problem of benefits that vary spatially across landscapes and illustrated with the example of coastal ecosystems. The starting point of the basic natural asset model is the assumption that any ecological landscape that is conserved must compete with other assets in the portfolio of wealth owners in the economy. The model shows the importance of valuing ecosystem services to the optimal allocation of landscape among competing uses. It includes the possibility of an ecological transition, when it becomes technologically feasible to restore developed land as ecological landscape. The basic model is then extended to allow for the value of an ecosystem service and the costs of maintaining this service to vary with the spatial distance across the natural landscape; for the implications when the economy is opened to trade; and finally, for examining the effects of the risk of ecological collapse.

Contents

1

Introduction

An important contribution of natural resource economics has been to treat the natural environment as a form of capital asset (Clark and Munro, 1975; Dasgupta and Heal, 1974, 1979; Scott, 1955; Smith, 1968). The more recent literature on ecosystem services implies that these environmental systems can also be viewed as *natural assets* that produce a flow of beneficial goods and services over time (Barbier, 2007; Daily, 1997; Heal et al., 2005; Millennium Ecosystem Assessment, 2005; Pagiola et al., 2004; World Resources Institute, 2001). The purpose of the following review is to explore this literature and related modeling to show explicitly how the concept of ecosystems as natural assets translates into the traditional "natural capital" approach of resource economics.

An immediate barrier to such an approach is that, in ecology, the concept of an ecosystem has been difficult to define or to measure quantitatively (O'Neill, 2001; Pickett and Cadenasso, 2002). However, some ecologists suggest that most ecological processes are influenced by the spatial extent, or *landscape*, that defines the boundary of the system (Bockstael, 1996; O'Neill, 2001; Perry, 2002; Pickett and Cadenasso, 1995, 2002; Turner, 2005; Zonneveld, 1989). As shown in this review, by adopting ecological landscape, or land area, as the basic unit, modeling the ecosystem as a natural asset is relatively straightforward. Integrated economy-ecosystem models have started using a similar starting point, to examine human transformation of an ecological landscape through land use conversion, leaving the residual land for ecological processes and habitat for species (Brock and Xepapadeas, 2002; Eichner and Pethig, 2006; Finnoff et al., 2008; Tschirhart, 2000). But whereas these integrated models focus on modeling the complex ecological processes and feedback effects on multiple ecosystem services that arise through land conversion, the approach in the following review is to adopt a much simpler model of land use change. Such models of competing land use have been employed in many contexts to analyze the allocation of land between alternative uses (Amacher et al., 2009; Barbier and Burgess, 1997; Benhin and Barbier, 2001; Crocker, 2005; Hartwick et al., 2001; McConnell, 1989; Parks, 1995; Parks et al., 1998; Rowthorn and Brown, 1999; Stavins and Jaffe, 1990).

In applying competing land use models to ecosystems, the starting point is the assumption that the amount of an ecological landscape that is preserved must compete with other assets in the portfolio of wealth owners in the economy. The remaining landscape area yields a flow of ecosystem services, which have value but are non-marketed. The first version of the basic model considers a one-time irreversible development of the landscape. Land that is converted and developed has a market value, and the rate of appreciation of land awaiting development must equal the opportunity cost of the land investment, which includes an adjustment for the ratio of the value of ecosystem services to the capital value of the developed land. This basic model is extended to the case of continuous conversion of the ecological landscape over time, taking into account the costs of converting land and any capital gains from increases in the value of unconverted land. The model is solved to show the conditions under which a positive amount of ecosystem land is conserved rather than converted to commercial use. Finally, the basic model examines the case of a possible *ecological transition*, whereby it becomes technologically feasible to restore developed land as ecological landscape, leading to a new phase of land use in which ecological restoration occurs.

Three further extensions to the natural asset model are developed in this review.

The first extension examines the case in which both the value of an ecosystem service and the costs of maintaining this service vary with the spatial distance across the natural landscape of an ecosystem. This geographical variation may be due to the biophysical functioning of the ecosystem that generate different services at different locations across the landscape, and also due to the higher costs incurred of maintaining a larger landscape area. Allocating natural landscape now becomes a spatial problem. To avoid landscape conversion, at each location the marginal willingness to pay for the ecosystem services must be sufficiently large to offset the maintenance cost of those services at that location and the marginal opportunity cost of foregone rents from developing the entire landscape. This condition is less likely to hold if there is any "spatial" discounting effect due to the unidirectional decline of ecological functions across the landscape.

The second extension looks at the implications to the model when the economy is opened to trade. It is shown that rising terms of trade lead to two opposite effects. There will be increased land conversion as exports of the marketed production from converted land become more profitable. However, if imports are a substitute for domestic consumption of the marketed output, then there is less pressure to increase land conversion. Thus the impacts on the amount of ecosystem land conserved are ambiguous, as are the effects on overall welfare. In comparison, an international transfer, in the form of *payment for ecosystem services*, slows down the initial conversion of natural landscape, and encourages more landscape conversion in the long run.

The last extension examines the vulnerability of the ecosystem to collapse as land conversion proceeds. Following Reed and Heras (Reed and Heras, 1992) the risk of ecosystem collapse is modeled as a hazard rate function, where the hazard rate is defined as the probability at any time t that the ecosystem will collapse given that it has not collapsed up until that time period. The stochastic optimization problem is converted to a more tractable deterministic control problem and solved for the conditions determining the risk of collapse.

The outline of the review is as follows. Section 2 discusses ecosystem services and ecological landscapes as the basis of representing ecosystems as a natural asset. Simple two-period diagrammatic examples of the conversion of an area of coastal zone to commercial development are used to illustrate the basic concepts and issues. The section ends with the example of valuing ecosystem services of mangroves in Thailand to show how such valuation can influence both the decision to convert mangrove landscapes to shrimp aquaculture and whether or not to restore mangrove ecosystems after shrimp ponds are abandoned. Section 3 develops the basic natural asset model of an ecosystem by employing the competing land use model. The first version of the model considers a one-time irreversible development of an ecological landscape. The second version examines continuous conversion of the ecological landscape over time, and is extended to allow for an *ecological transition* where restoration is feasible. Section 4 begins by returning the example of coastal landscapes and discusses ecological evidence that the basic functions of these systems are spatially variable. Evidence of spatial heterogeneity of landscapes is explored further, with the example of non-linear wave attenuation across a mangrove landscape that affects the value of the coastal protection service and how it affects the mangrove-shrimp farm competing use problem in Thailand. The section ends by demonstrating how a spatial model of allocating natural landscape can be developed to incorporate some of these features of geographical variation of ecological functions. Section 5 revisits the basic natural asset model of competing uses of an ecological landscape and extends it to an open economy setting. The extension allows for consideration of trade interventions versus international payments for ecosystem services as incentives for greater ecosystem conservation. Section 6 extends the basic model to consider the problem of ecological collapse, and shows that more of the ecological landscape will be preserved compared to when the threat of collapse is absent. Section 7 concludes the review.

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