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Analysis

Ecosystem services as substitute inputs: Basic results and important implications for conservation policy☆

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ABSTRACT

In recent decades conservation advocates have often emphasized the contributions of ecosystem services to the production of other products. A demonstration of the value of ecosystems as inputs into production would motivate their conservation. Such arguments often offer the observation that ecosystem services can substitute for purchased inputs, and thus reduce costs. If this is true, however, it has another important implication: a producer who is preserving local ecosystems so as to maximize her own profit will produce less output if she further increases her reliance on ecosystem services. This may induce "leakage," by which one producer's greater reliance on ecosystem services indirectly motivates others to preserve fewer natural ecosystems. I demonstrate this result in a simple but canonical model, and calibrate my findings to a celebrated example to show they could be quantitatively significant. My results suggest another reason that appeals to ecosystem services as a motivation for conservation should be made with care. At the most basic level, they emphasize the importance of being clear about what we mean by conservation: do we want to save some diversity in many places, or nearly all indigenous diversity in a few places?

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1. Introduction

Tremendous enthusiasm has been expressed in recent years for "ecosystem services". Ecologists Daily and Matson (2008) write that there is "…a growing feeling of Renaissance in the conservation community. This flows from the promise in reaching, together with a much more diverse and powerful set of leaders than in the past, for new approaches that align economic forces with conservation." The literature on ecosystem services argues that when land use decision-makers forgo more intensive use of the landscapes under their control they preserve systems that provide a host of valuable services. These may include climate moderation, scenic views, recreational amenities, pest control, pollination, protection of biodiversity, water purification, and nutrient cycling, among others (see, e.g., Daily, 1997 for a more comprehensive and annotated list).

An ecosystem services approach to conservation has proved problematic, however. Despite the considerable enthusiasm the idea has generated, and notwithstanding recent advances in both natural science and economic valuation, evidence has not yet been marshaled that preserving habitats generally provides greater economic value than would converting them to other uses. While Kareiva and Ruffo (2009) write, "[N]ow more than ever, we need to embrace ecosystem services as a basis for conservation," they go on to lament that "we do not have enough science to back up our hypotheses....we have not proven, on the ground, that these ideas work."

Even if we do "prove, on the ground, that these ideas work," however, we would still be faced with tough questions. If these ideas do, indeed, "work," why have they not been more widely implemented? The most obvious problem involves a mismatch of scale; *local* people make land use choices that provide both local and *global* benefits. In particular, any benefits that arise from the preservation of biodiversity per se are pure public goods. The aesthetic or moral appreciation of the continued existence of the full array of life forms on the planet is not limited to those close enough to experience it directly. To the extent that compensation for global public goods is lacking, local decision makers may overexploit their resources relative to globally optimal use (Kremen et al., 2000; Naidoo and Ricketts, 2006; Pearce, 2005).

A number of contributions to the literature have emphasized the benefits local communities might realize by maintaining habitats to, for example, support pollinators (Ricketts et al., 2004), provide coastal protection (Costanza et al., 2008), or manage urban runoff (Stratus Consulting, 2009). If local people appreciate these ecosystem services, it should not be difficult or expensive to get them to maintain at least marginally more of the ecosystems than provide them: if local people are optimizing, they would, by construction, be indifferent between converting the marginal hectare of land under their control to production directly as opposed to continuing to provide the ecosystem services

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that enhance production. Thus, only small payments ought to be required to induce a little more preservation of natural ecosystems.

Moreover, local people might *not* allocate the land under their control optimally between production and the provision of ecosystem services. There might be reciprocal externalities: owners of adjacent orchards might, for example, maintain too little area to shelter native pollinators. This might occur because the pollinators one landowner protects might also service her neighbor's trees, and so the first landowner would not be compensated for sheltering the pollinators. Or it might simply be that local people do not fully understand the benefits ecosystems afford them in an increasingly developed world.[1]

Arguments that conservation might be achieved cheaply are certainly attractive to conservation advocates who often lack adequate resources to pay for large-scale land acquisition (see, e.g., Pearce, 2005, who laments the apparent unwillingness of the international community to put its money where its mouth is to pay for conservation).

Is there any catch? In this paper I suggest that there may be. My central result is a simple syllogism. If ecosystem services are substitutes for purchased inputs, and if local people preserve or restore habitat so as to provide themselves with the level of ecosystem services that maximizes their own profits, then output would *decline* if *more* land were preserved or restored to provide ecosystem services. This would then imply that the price of output would increase, and more people would be induced to enter production.

The syllogism is only as credible as are its major and minor premises. If ecosystem services and purchased inputs are *not* substitutes, the output effect I posit would be reversed. However, much of the literature on ecosystem services emphasizes that they can be substituted for inputs that would otherwise have to be purchased. I give some examples to support this assertion in the second section of the paper.

How about the minor premise, "and if local people are optimizing with respect to their own interests"? Even if local people were *not* preserving the areas of natural ecosystems they should be in order to maximize their own objectives, however, the result would hold in the neighborhood of the optimum. It begs the question of how far conservation advocates should push the argument that local people will benefit from increased conservation (see also footnote one above).

What difference would it make if, in relying more on ecosystem services, output were to decline? The problem is that if an appreciation of the contributions of ecosystem services induces each farmer who increases her reliance on them to reduce her output, pressure will grow elsewhere to expand production. This, in turn will motivate clearing new land and a consequent reduction in ecosystem services provided elsewhere. In short, if ecosystem services are substitutes for purchased inputs, greater reliance on ecosystem services may induce "leakage" or "slippage" by which increased conservation in one area results in more extensive use of land in production elsewhere (for an analogous case, see Wu, 2000 for a study of leakage under the Conservation Reserve Program).[2]

Now let me lay out the intuition underlying the result. It may, on first inspection, seem counterintuitive that if greater reliance on ecosystem services would help producers, they would produce *less* if they relied on ecosystem services *more*. The key is that ecosystem services can help producers either by enhancing the productivity of the other inputs they employ, or by allowing them to economize on their purchases of those other inputs. If the latter effect dominates, the cost savings from substituting to less expensive inputs could exceed the value of production lost when the purchased inputs are displaced. The producer's profits could go up even as her production goes down.

Natural systems provide local land owners with ecosystem services such as pollination, pest control, and flood and erosion protection. These are valuable to a landowner to the extent that they contribute to her profits. Enhancing the provision of such services will have different implications for conservation, however, depending on whether the ecosystem services in question are *substitutes for*, or *complements to*, the other inputs she purchases. Many of the ecosystem services we often hear about are substitutes, rather than complements. If a farmer maintains more land to shelter pollinators, she can substitute native pollinators for the rental of commercial bees. If she keeps more land fallow she can substitute natural regeneration of soil fertility for the purchase of commercial fertilizers. If a developer maintains part of a new housing development in wetlands rather than building on every square meter of a parcel he can substitute natural flood control and water purification processes for "gray infrastructure" of concrete and steel.

Consider a landowner who is optimizing her intensity of land use with respect to her own interests. This means she is indifferent between using land a little more intensively — say, cutting down the marginal hectare of forest to plant crops — and preserving it to provide pollinator habitat, flood protection, or other services. Now if an ecosystem service such as pollination by native insects is a substitute for a purchased input such as renting a colony of honey bees, the landowner who maintains a little more area in forest will obviate the need to rent the marginal colony of bees. She saves the rental cost of the bee colony, *but if she were indifferent to clearing another hectare of land, she must be forgoing an equal value of crop produced*. So, if she preserves the extra hectare of forest her output must decline even though her earnings do not.

If our hypothetical landowner/farmer's output declines it means less food is produced. That means that the price of food will increase, and that has two implications for conservation. First, it will mean that farming will be more profitable to anyone who wishes to take it up, and so land is likely to be used more intensively elsewhere. Second, the choice of where to set the balance between preserving land to provide ecosystem services and purchasing inputs to substitute for such services depends on relative prices of inputs and outputs. If one farmer relies more on ecosystem services the process of supply contraction and price increase I have just described will generate incentives for other farmers *not* to emulate her decision.

So, the argument I have just summarized suggests that, in addition to determining exactly what incentives the values of ecosystem services provide to landowners, we must also consider how incentivizing landowners to conserve more will actually affect conservation policy. We must consider the effects of one landowner's preservation choices on the incentives facing others.

The remainder of this paper is divided into several sections. In the next section I discuss a couple of examples in which ecosystem services may be substitutes for purchased inputs and their implications for conservation policy. Following that I develop a canonical model of production with ecosystem services. One often encounters references to "ecological production functions" in the ecosystem services literature (see, e.g., National Research Council, NRC of the National Academy of Sciences, 2006; Polasky, 2008). There could, of course, be any number of different production processes relating different purchased inputs and different ecological attributes to different outputs. There should, however, be underlying commonalities that allow us to develop principles of ecological production, just as we have a theory of industrial

[1] I offer these observations for the sake of argument. There is a large literature (see, e. g., Ostrom, 1990, or Baland and Platteau, 1996) noting that local people do, in fact, often solve problems of reciprocal externality. Moreover, a local landowner might take with a grain of salt a conservation advocate's suggestion that the landowner would be better served by choices that also happen to be in the conservation advocate's interest.

[2] There is an extensive literature dealing with related issues. Economists have long appreciated that landscapes are productive assets capable of performing a number of functions and producing multiple output (see, e. g., OECD, 2001; Abler, 2004; though see also Vincent and Binkley, 1993, who argue that separating production and conservation activities in specialized areas may be more efficient in some landscapes). While there are certainly instances in which the interests of commercial production and conservation may be aligned, such "win–win" outcomes are typically limited to a range of the production vs. conservation space. As in my analysis, some other authors have noted that the nature of the interaction between natural and purchased inputs — whether they are complements or substitutes — may have important implications for conservation policy (see, generally, Wossink and Swinton 2007, and in the specific context of tradable permit markets, Heberling, Garcia, and Thurston, 2010), although I am not aware of any previous demonstration of the results I emphasize here.