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## ARTICLE

# Payments, penalties, payouts, and environmental ethics: a system dynamics examination

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A generic system dynamics model was developed as an explicit thinking tool to investigate systems of payments for environmental services (PES) and possible feedback effects regarding environmental ethics. Healthy ecosystems may justify charges for environmental services, but damaged ecosystems will require payouts funded by other mechanisms, perhaps by penalties on ecodamage. Any payouts made may influence environmental ethics, but the direction of such influence is dependent on the level of payout, the influence that payouts have on the switchover to ecofriendly uses, and the changing attitudes of payout recipients. Payouts can cause a switchover to ecofriendly activities. If that switchover also reinforces a favorable environmental ethic it can lower the overall payout level needed to maintain ecofriendly resource-use activities.

**KEYWORDS:** environmental ethics, management tools, models, cost-benefit analysis, ecosystem management, resource utilization

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## Introduction

The concept of payments for environmental services (PES) has become popular among those interested in environmental conservation and those concerned with international development. The concept is that people could pay for ecosystem services normally viewed as free. Payments could fund payouts to encourage ecofriendly use of the environment. Some examples of these environmental services are the provision of clean water from well-managed watersheds, the availability of natural scenic areas, the protection of “biodiversity” for future generations, as well as the expectation of future climate stability (Scherr et al. 2004; WWF, 2006).

Human abuse of our natural environment has made the long-term realization of these benefits less likely. The PES concept recognizes that people who abuse the environment, and thus decrease benefits others receive, are sometimes merely trying to make a living. They may have difficulty changing their resource-use patterns without help. If environmentally degrading activities are to be lessened, this argument goes, and some compensation should be offered to assist resource users in making their activities sustainable. The underlying logic of these schemes assumes financial costs should be paid by those who receive environmental benefits. Such recipients might be individuals, communities, or society as a whole.

Do such schemes work? The cash-in value of tropical forests, for example, may be too high to be

offset by any reasonable level of payments for benefits (Rice et al. 1997). On the other hand, Janzen (1999) makes a good case for the many biodiversity values that tropical forests hold and provides specific examples as to how these values might be incorporated into contracts that benefit both forest owners/users and outside beneficiaries of environmental services provided by those forests.

Landell-Mills & Porras (2002) provide a number of examples of these payment schemes. Conservation groups see such arrangements as a means of providing funding for protection of critical biodiversity areas. International development specialists view these programs as supplementing income for poor farmers and forest dwellers (Pagiola et al. 2005). Payment schemes may also encourage better management of carbon dioxide in our atmosphere—a major cause of global warming. Wunder (2005; 2006; 2007) has provided a comprehensive review of the concept.

The notion of payment for ecosystem services assumes that an ecosystem, if well managed and cared for, will provide certain services—for example, watershed protection. As various land uses degrade the ecosystem, services also become degraded. If people pay for the service provided—for instance high-quality water—this money can be transferred to individuals who own or use the ecosystem, providing an incentive for resource use that protects and restores the ecosystem.

An alternate view is that ecosystems, and the services they provide, belong to humankind, and re-

source users are morally obligated to use resources in a sustainable way. While appealing, this view may only be realistic in wealthy societies. The sad fact is that most resource users in the world have little incentive or means to alter their behavior without encouragement, including financial assistance.

On the other hand, many societies have strong traditional ties to their environments and a well-designed system might help awaken a favorable environmental ethic. Any reasonable policy should provide incentives to support environmentally sustainable activities, but at the same time avoid perverse incentives that could undermine existing environmentally friendly attitudes and activities (for example, see Pagiola et al. 2004). Under what circumstances might payouts for environmental services degrade the concept of land (or resource) stewardship, or enhance it?

Where economic pressures create incentives for intensive, unsustainable resource use, payouts for environmental services can provide a counterbalance to destructive economic pressures—a way of explicitly providing cash value for a benefit that is normally taken for granted. The typical example is of farmers who need to harvest their land more intensively to cover costs and provide a modest livelihood. This intensification not only leads to degradation of ecosystem services (e.g., watershed protection or biodiversity), but can also undermine the usefulness and profitability of the resources for future generations.

Clearly, the intended role of payouts is not merely to reimburse land owners for the environmental services that they provide, but to counterbalance wider economic pressures that compel the adoption of ecologically damaging land uses. That is, payouts for environmental services increase the profitability of sustainable resource uses so that they can compete successfully against damaging use options (Pagiola et al. 2003).

Existing PES schemes involve considerable money: US\$2.5 billion per year according to Scherr et al. (2004). This figure might be disputed because it includes values that some consider resource use rather than environmental services. Thus, at some point we may need to differentiate between “services” and “uses.” Extraction of timber from a forest is a use of the forest, not an ecosystem service like aquifer recharge, water-quality improvement, or carbon sequestration. However, the distinction between resource uses and environmental services is not always clear. Scherr et al. (2004) assume that non-timber forest products (e.g., rattan) are ecosystem services while timber production is a resource use. Most authors treat all “products” as results of resource use (e.g., Wunder, 2005). Ultimately, the PES concept tends to place a monetary value on all products and

services, including items generally not considered to have monetary value.

This article examines PES systems from a big picture, generic perspective, as opposed to more detailed case studies that some feel are more helpful (Tomich et al., 2004). I examine the following questions: Conceptually, how does the PES system work? What is the relationship between penalties for abusing a resource and payments for good resource management? Might a system of payments deplete or reinforce a favorable environmental ethic based on the concept of stewardship?

## A Model—A Thinking Tool

The model described here represents one of many possible conceptualizations as to how PES systems could function. It is presented as a tool to assist thinking about these issues, especially in relation to environmental ethics. The model is deliberately generic, but incorporates the essentials of an environmental resource-payment system. System dynamics modeling, an approach for analysis of complex issues, emphasizes examination of system structure. The approach typically incorporates a stock/flow, differential equation, modeling paradigm and highlights feedbacks within a system. Detailed treatments of this approach are available (e.g., Ford, 1999; Sterman, 2000). This model was implemented with Vensim software.<sup>1</sup>

## Factors Causing Changes in Resource-Use Patterns

In a simplified view, we can assume that any resource, such as timber, can be used in either an ecofriendly or a damaging way. The profitability of each approach determines the extent to which each is implemented within a given environment. PES systems help tilt market forces toward ecofriendly uses, but such payments may influence nonmarket forces, such as environmental ethics, which also affect ecosystem integrity.

Within the model, all resource use falls into one of two stocks:<sup>2</sup> *ecofriendly activities* or *damaging activities*.<sup>3</sup> The more profitable alternative will

<sup>1</sup> Details on Vensim are at <http://www.vensim.com>. The full model is available from the author.

<sup>2</sup> Stocks represent components in the model that are believed to change slowly. These factors are also called levels or state variables. Stocks are the integration of flows over time. Using a commonly accepted system dynamics format, a stock is represented in the figures by an outlined box with a capitalized name.

<sup>3</sup> Model components that appear in the simplified model diagrams in Figures 1 through 3 are italicized when first mentioned in the text.



### The Role of Payments and Penalties

Payments collected from recipients of environmental services are one means of funding payouts to resource users to increase the financial attractiveness of ecofriendly resource activities. In theory, payouts are based primarily on environmental services provided, but in a severely degraded ecosystem such services may be minimal. Other funds can be obtained with penalty payments per unit of damaging activity (e.g., special taxes) charged to recover some portion of the value of lost environmental services (Figure 1).

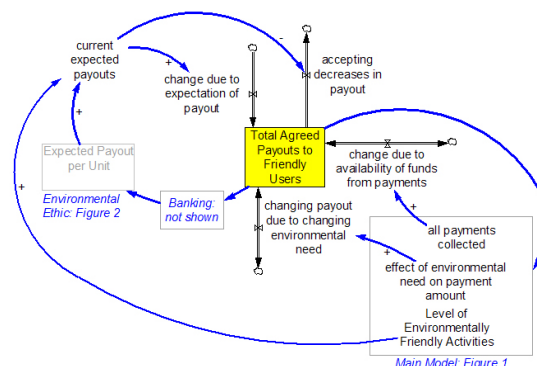
For practical reasons, penalty payments may be impossible, or may be capped at some fairly small fraction of damaging use profitability (e.g., 10%), that may represent only a small part of lost environmental services. Resource users may be unable to pay, and may not be responsible for past damage to the environment. Note, however, that environmental services recipients may also be unable to pay for those services (e.g., poor people living in flood prone areas may not have funds to pay resource users for watershed protection). It is possible, even likely, that payments and penalties will be insufficient to significantly raise the relative profitability of ecofriendly activities above the profitability of damaging activities.

Importantly, the model uses the value of environmental services provided, or lost, as the means of funding payouts or charging penalties. Money collected is paid out, following a negotiation process, to ecofriendly resource users. Since the *total agreed payouts to friendly users* is divided among the current number of ecofriendly resource units, the payout per unit will vary (Figure 1).

Resource users develop an expectation of a payout large enough to affect their resource-use decisions. The *expected payout per unit* of ecofriendly resource activity is partially based on the current profitability difference between ecofriendly and eco-damaging activities. Once made, payouts for environmental services come to be expected. The anticipated payout per unit is thus also based on recent benefit payouts per unit. For example, if payments exceed what was projected, the expected amount will increase, other things being equal. Increased expectations of payment are lowered by relative increases in favorable environmental ethic (Figure 2).

The determination of the total agreed payouts to ecofriendly users involves the expected payout per unit and the total of all payments collected from fees for environmental services or penalties. An additional influence is the actual remaining need for ecosystem improvement.<sup>7</sup> If this need is low, then (optionally in

the model) the amount of payouts will be lessened (Figure 3).



**Figure 3** Factors determining the total agreed payouts to resource units employing environmentally friendly approaches.

### Environmental Ethics

In many cultures there is an underlying belief that living in harmony with the natural world has a value of its own. In the late 1940s, North American forester and conservationist Aldo Leopold was already lamenting the loss of the land ethic and requests by land owners for cash payments to improve land use (Leopold, 1949).

The model attempts to address both the idea of an environmental ethic and the possibility that payouts might degrade or enhance it (Figure 2). The model assumes that an environmental ethic is strengthened when users actively switch to ecofriendly activities even if that switchover is influenced by payouts for environmental services. This logic follows the idea that proenvironmental actions help build an environmental awareness (Leigh, 2005). As people work on conservation activities, including those for which they are paid, or at which they make a living, they become more environmentally aware.

An increasing environmental ethic can also increase the likelihood that resource users will switch to environmentally friendly activities. In the model, an increasing realized environmental ethic causes an upward adjustment in the apparent profitability of environmentally friendly uses, making such activities more attractive (Figure 1). The act of switching to ecofriendly uses, in turn, enhances the current underlying environmental ethic (Figure 2). However, if payments are excessive, compared to typical profitability, there is a degradation of environmental ethic, based on the idea that payments become viewed merely as a source of income, rather than a reward for environmental stewardship. Similarly, penalty payments, if applied, are accepted as reasonable un-

<sup>7</sup> This model component is omitted from Figure 1.

less they are higher than a modest percentage of damaging use profitability. Within the model, environmental ethic is considered as a community quality reflecting many individual views.

The current underlying environmental ethic is tempered by reality in the form of financial need. Thus, realized environmental ethic may be less than the current underlying environmental ethic. Realized environmental ethic will increase as income increases, until it matches the underlying ethic. Such increases in current income can be derived from either damaging or ecofriendly activities (Figure 1). In the model, financial need is represented by relative income: current income compared to an arbitrary amount expected to be obtained from the resource.

## Results

### Basic Approach

The model uses a fixed number of resource units, starting with 50 under ecofriendly use and 50 under damaging use. Initially, both resource uses have a profitability of \$100 per unit per year. In most runs random pink noise is added to the profitability of damaging use (Sterman, 2000). This addition has stan-

dard error of plus or minus 5% of the base profitability unless otherwise noted.

In a typical test scenario, damaging use annual profitability is increased by \$15 over a two-year period (2030–2032) followed by a five-year phase-in (2040–2045) of a system of payouts for ecofriendly uses (Table 1). Details of different runs are described below.

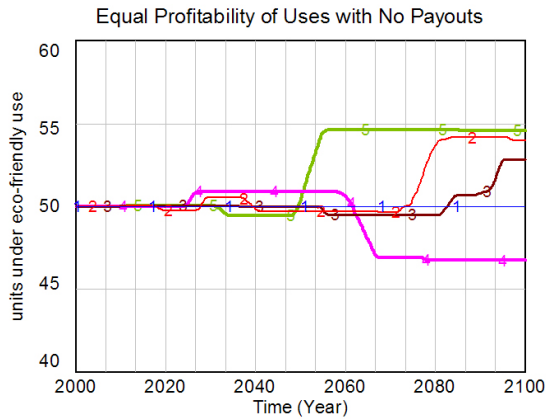
### No Payments or Penalties

When profitability of the two resource-use types is identical, then, without random fluctuations in profitability, there is no change in the relative proportion of the uses. If the underlying profitability of damaging use fluctuates, a range of outcomes is possible (Figures 4 and 5). There is a slight tendency toward more ecofriendly use caused by the hypothesized feedback effect of switching to ecofriendly use and the build-up of a favorable environmental ethic. All model runs include this feedback unless otherwise stated. Changes in ecosystem status and ecosystem services closely follow changes in the level of ecofriendly activities, but these ecosystem changes are delayed and occur more gradually than the changes in activities.

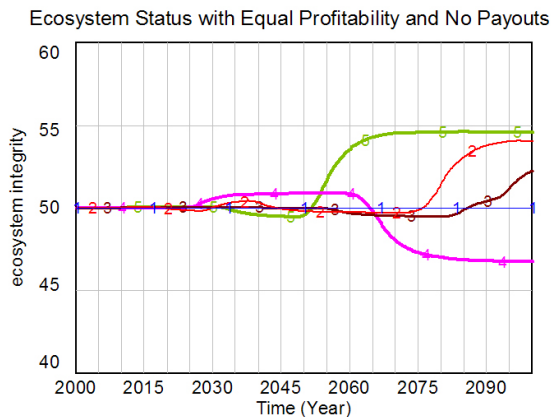
**Table 1** Baseline values of basic components of the model. Values used are based on typical situations as reported in the literature.

| Model Component                                      | Base Value | Units         | Typical Change Applied                       | Comments   |
|--|------------|---------------|--|--|
| Level of environmentally friendly activities         | 50         | Units         |  | Units are under either of two uses. Total is 100 units.  |
| Level of environmentally damaging activities         | 50         | Units         |  |  |
| Value of environmental services provided             | 20         | \$(Year*unit) |  | Based on a benefit worth \$20 for every fully functional ecosystem unit.                       |
| Profitability of ecofriendly activities              | 100        | \$(Year*unit) |  |  |
| Profitability of damaging activities                 | 100        | \$(Year*unit) | +15  | Added over the 2-year period 2030–2032. Some runs include random normal fluctuations—see text. |
| Fraction of ecosystem services charged to recipients | 0          | Dimensionless | Raised to 1.0                                | Added over the 5-year period 2040–2045.  |
| Penalty rate on damaging uses                        | 0          | Dimensionless | Raised to 8.0% of damaging use profitability | Added over the 5-year period 2040–2045.  |



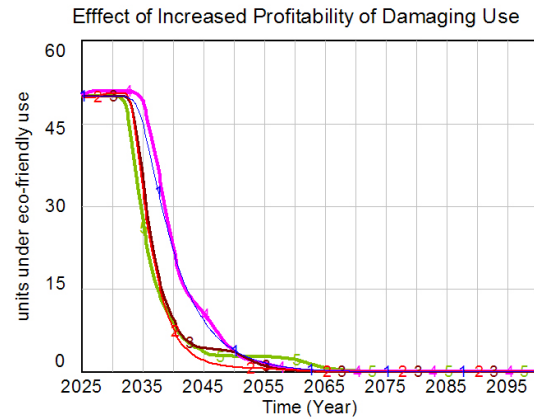


**Figure 4** Changes to level of environmentally friendly activities when profitability of the two activity types is equal and there are no payouts or penalties. Line 1: no random component. Lines 2-5: examples with random variation in profitability of damaging use.



**Figure 5** Changes to ecosystem status with equal profitability of the two use types. Model runs same as in previous figure.

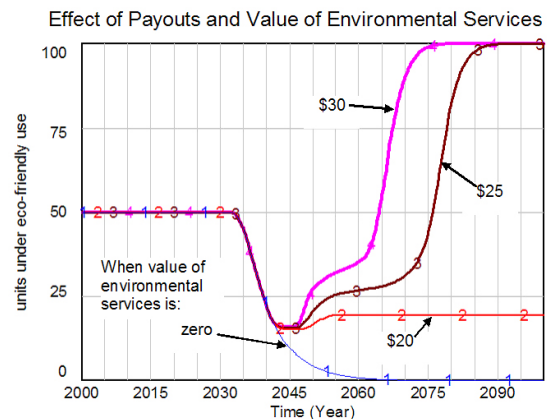
Increasing profitability of ecodamaging use, as expected, causes a switch to such use, and in the process decreases ecosystem benefits (Figure 6). In this example, no payouts for ecofriendly use are expected, none are provided, and profitability determines the use to which the resource is put. A 15% rise in profitability is sufficient to convert all the resource to damaging use within 30 years. Adding a random variation to profitability of damaging use does not substantially change the outcome, which rapidly leads to depletion of the environment and the services it provides. Environmental ethic is also diminished by the complete switchover to environmentally damaging uses.



**Figure 6** Level of ecofriendly use if damaging use profitability is raised by 15%. Line 1: no fluctuations. Lines 2-5 with random normal variations in damaging use profitability.

### A System of Payments

A system of payments takes the following form. As above, profitability of damaging use is raised by 15% between 2030 and 2032. As the resource declines, a system of payments is phased in over five years, starting in 2040. This system bills recipients at 100% of the value of received environmental services, and uses this money as a basis for paying ecofriendly resource users. Initially, the payout expected by the resource users is the difference between the profitability of the two use types, but it is influenced by several factors including environmental ethics.

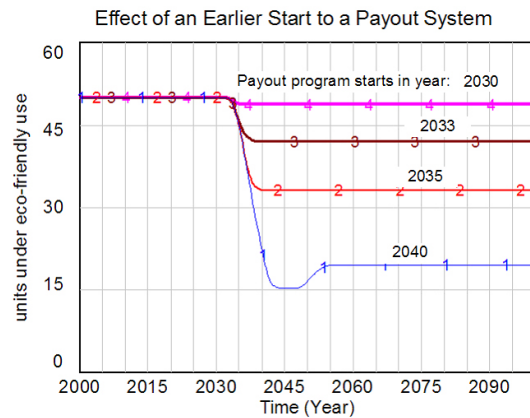


**Figure 7** A system of payouts for environmental services can help recover the ecosystem, but only if the value of environmental services is sufficiently large.

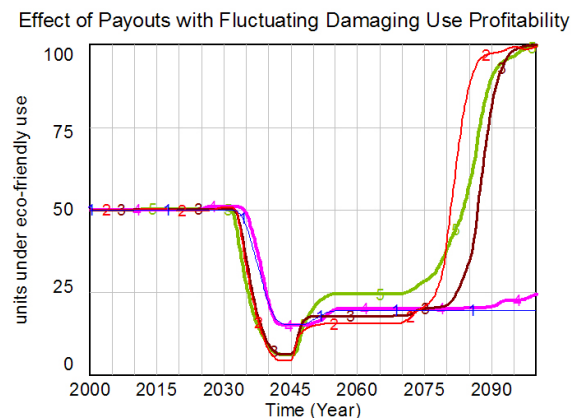
The value of the services provided is critical. In the baseline example, this value, while preventing collapse of the system, is not sufficient to create a recovery. By assuming higher values for ecosystem services we can create a complete recovery (Figure 7). Nevertheless, the recovery is delayed partly be-

cause funds from ecosystem services are limited at first due to the degraded nature of the resource.

Collapse can also be prevented if a payment system is implemented sooner (Figure 8), but recovery will not occur unless payments are sufficient. The payout expected by resource users also plays an important role because high expectations can lower the beneficial effects of payouts both via a direct effect on environmental ethics and via the active feedback effect that switching to ecofriendly uses has on environmental ethic. Fluctuations in profitability tend to help ecosystem recovery. Each time profitability of ecofriendly uses increases sufficiently to cause switchover, there is a slight increase in environmental ethic, which, after some delay, helps further increase apparent profitability (Figure 9).

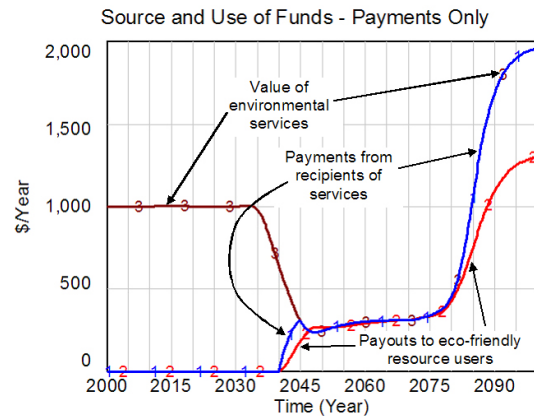


**Figure 8** An earlier start to a payout system can help prevent ecosystem deterioration. All runs are based on a value of ecosystem services of \$20 per fully functional resource unit.

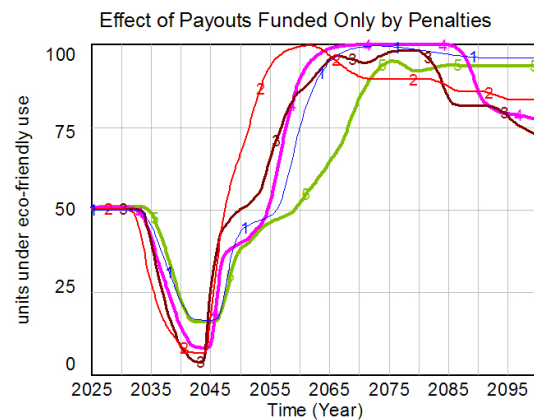


**Figure 9** Fluctuations in profitability may assist ecosystem recovery. Here line 1 is the same as the \$20 line (line 2 in Figure 7). The other lines have only a random component added to damaging use profitability.

The collection and distribution of funds depends on the value of services provided, the need for ecosystem improvement, and the expectation of payout by the resource users. Payments can exceed payouts, creating a positive cash flow for the system (Figure 10). This is because incoming funds are only one factor determining expected payouts (Figure 2).



**Figure 10** Sources and use of funds in a payments-only program. This run incorporates the same random influence as line 2 in Figure 9.

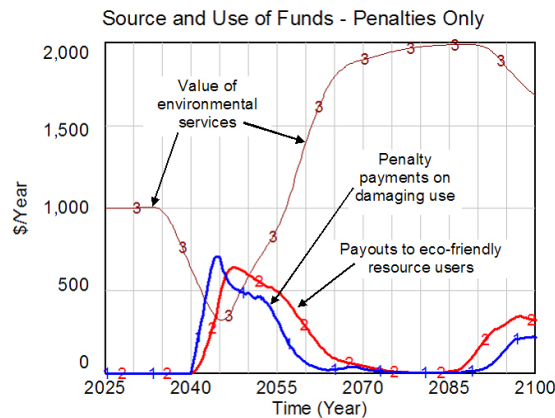


**Figure 11** Payouts funded by penalties alone lose funding and run a deficit as the ecosystem recovers. All except line 1 incorporate random fluctuations in damaging-use profitability.

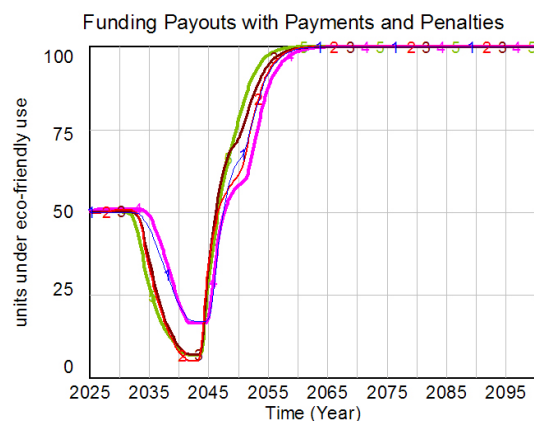
### Using Penalties

Penalty payments applied to ecodamaging uses lower profitability, making that use less attractive, and can also help fund payouts to ecofriendly users. A system of penalties alone can lead to ecosystem recovery (Figure 11). However, penalties are dependent on ecodamaging use, which disappear as a switchover to ecofriendly uses occurs. As incoming funds diminish, expected payout also drops, but does not disappear. Payouts drop below expectation, low-

ering environmental ethic, and making the long-term maintenance of the ecosystem less likely. A system of payouts based on penalty payments alone will be unlikely to maintain an ecosystem recovery, especially if damaging use profitability varies significantly (Figure 12). Such a system, when resulting in recovery, will likely require deficit spending or outside funding.



**Figure 12** A system using only penalties to fund payouts.

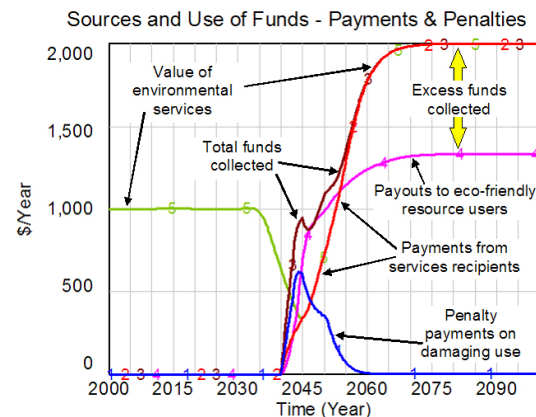


**Figure 13** A system of penalties and payments allows a more rapid recovery of the system and provides for a stable future status by providing both startup and long-term funding.

### ***Payments Plus Penalties: The Best Option?***

Payouts for implementation of ecofriendly resource uses can be funded by a system of payments received from recipients of environmental services. But if those services are low, as in a degraded ecosystem, then few funds are available. Penalties can fund payouts when ecosystem services are still small or nonexistent. Penalties also lower profitability of ecodamaging activities making those activities less attractive. PES systems provide long-term funding to maintain higher profitability of ecofriendly resource

uses. For these reasons, a combination of payments and penalties might be the best solution for funding payouts leading to a permanent recovery of an ecosystem and the services it provides (Figure 13). The difference between payouts and total funds collected reflects the difference between payouts expected by resource users and the value of environmental services provided. If this difference is large, then there may be no need to charge recipients of environmental services for the full value of received services (Figure 14).



**Figure 14** Source and use of funds in a system of payments and penalties.

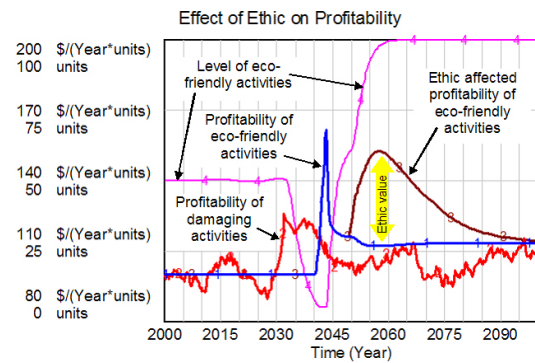
### ***The Role of Environmental Ethics***

I have hypothesized that a favorable environmental ethic can increase apparent profitability of ecofriendly uses thereby lowering the level of monetary profitability needed to implement such uses. Importantly, the act of switching to ecofriendly use helps to further build environmental ethic. Even when only random changes in profitability make ecofriendly use temporarily more profitable, resource users switching to that use thus stimulate the build-up of environmental ethic. This positive feedback between environmental ethic and ecofriendly use makes an ecosystem recovery more likely (Figure 15). In many cases, this effect promotes ecofriendly use even when its profitability (blue line 1 in Figure 15) falls below damaging-use profitability (red line 2, Figure 15). Nevertheless, the role of environmental ethics is important primarily when profitability differences between the two uses are small.

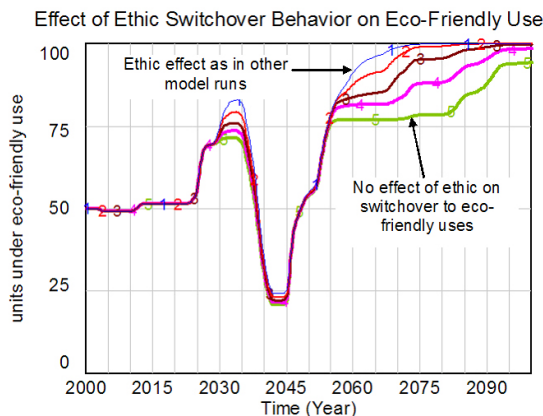
Any relationship between a favorable environmental ethic and a switchover to ecofriendly uses would be difficult to assess. Different hypothesized relationships indicate possible effects on a recovering system where a system of payouts has been implemented (Figure 16). These relationships determine how much a changing environmental ethic might



increase the ethic-effected profitability of ecofriendly use. Maximum values for lines presented in Figure 16 are 24%, 18%, 9%, and zero (top to bottom). This effect only becomes important when realized environmental ethic is large compared to long-term environmental ethic (between time 2060 and 2062 in the figures).



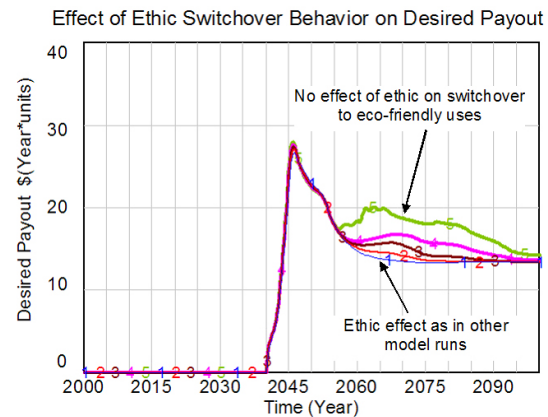
**Figure 15** Illustration of the effect of environmental ethic on the profitability of ecofriendly activities. The yellow arrow represents the apparent change in profitability caused by environmental ethic.



**Figure 16** Illustration of the effect of different relationships between environmental ethic and the switchover to ecofriendly resource use. Top line (1): relationship as in other model runs. Lines 2-4: with progressively less influence of environmental ethic. Bottom line (5): with no effect of environmental ethic on switchover. In all runs the same random component added to damaging use profitability.

In the model, a rising environmental ethic also lowers expected payout below what would be anticipated with no effect of environmental ethic (Figure 17).<sup>8</sup> If, for some reason, environmental ethic later drops, raising expectations, the current payment level will be insufficient, causing a reversion to ecoda-

maging use. Rising environmental ethic also increases direct enhancement activities, although results of such activities are limited by the current potential of the ecosystem, based on resource-use types.



**Figure 17** A favorable environmental ethic can lower desired payout. Model runs as in the previous figure.

Managers may be interested in policies that minimize the level of payouts needed for full ecosystem recovery, particularly in cases where charging for the ecosystem services in question (e.g., clean water) might be politically sensitive (Tognetti, 2005). Although penalties can provide additional funding, permitting lowered charges for environmental services, penalties eventually disappear as the ecosystem recovers.

It is hypothesized that a favorable environmental ethic is effective in making the switchover to ecofriendly uses occur at a lower monetary threshold. As modeled, the switchover then further reinforces environmental ethic. We can also see this effect in an additional simple example whereby environmental ethic is directly stepped up by 20% for five years. This would be similar to the effect of an environmental “awareness program.” Such a change in ethic in the model is sufficient to cause a long-term switchover to ecofriendly uses, but this change can only occur when profitability of the two resource-use types is similar, a circumstance that payouts for environmental services could create.

## Discussion

The concept of a PES system is a challenging subject for investigation with system dynamics modeling. The model presented here attempts to mimic a real PES system. It may differ from the actual world, particularly in that funding for payouts in the model is directly linked to environmental services actually provided and in that sense parallels Wunder’s (2007)

<sup>8</sup> For the complete model and model equations see the author’s website at <http://pws.prsvr.net/RGDudley/dudspbs.html>.

definition of PES systems. The amount that each resource unit receives, or pays, will depend on the total amount of ecosystem services provided or lost, and also on the number of units within which each type of activity is carried out. In the real world such links may be less well defined. In fact, real-world payouts often consist of a flat fee paid for each resource unit (e.g., per hectare of land) on which ecofriendly uses are being applied. The fee may be comparable to a long-term gross estimate of actual environmental services provided, but often, even under the best systems, payouts are not directly linked to specific, measured environmental services (e.g., see Pagiola, 2007). Monitoring and sanctions for non-compliance with goals may also be insufficient (Ibarra & Hirakuri, 2007).

In the model, as more of the ecosystem comes under ecofriendly uses, ecosystem status, ecosystem benefits, and associated payments all approach a maximum. Consequently, payouts can decline somewhat, lowering the profitability per ecofriendly unit. This implies an incentive for self-enforcement of ecofriendly standards, because each new unit categorized as ecofriendly can decrease the per unit payout.

The model differs from many PES discussions by incorporating penalty payments applied to damaging uses as a possible source of funding for payouts for ecofriendly uses. Under this funding approach, increasing profitability of damaging use will also increase profitability of ecologically desirable activities. Penalties help environmentally friendly uses remain competitive, but time lags make such payments less helpful than we might expect. Also, penalty charges are rare in the real world, where taxes are based on economic value rather than on damage to the environment.

Use of penalties is only rarely mentioned in the PES literature (e.g., Gutman, 2003), perhaps because it deals primarily with situations where resource users are less financially secure than recipients of environmental services. However, a counterexample would be the situation where holiday villas of the wealthy built in a formerly forested watershed cause flooding of poor downstream farming and urban communities. In such a case, it seems reasonable that taxes on villa construction could supplement income from upland farm and forest activities, thus discouraging further villa construction. Penalties are most likely available when resources have been degraded, and may be most useful in restoring degraded ecosystems. Situations involving both payments and penalties would support the catchment-care principle of Hatfield-Dodds (2006).

Under circumstances when profitability varies substantially, temporary crashes can occur because the payment system, as modeled, is slow to respond

compared to the changeover to damaging use. In the model, payments are based largely on the changing value of environmental services. Because ecosystem services are slow to recover, their value can lag behind changes in the resource-use pattern. Payments for services are also delayed, in some cases sufficiently to allow damaging uses to rise, pushing down benefits and payouts.

For model testing a basic price differential of 15%, plus normal random variation, was considered a realistic value for a PES model. In the real world, price differentials can be much larger, but as Wunder (2005) points out PES systems are less viable when profitability differentials are big, due in large part to the typically limited value of environmental services.

While the model may appear overly complex to some observers, the model boundary is actually fairly restricted. In fact, some of the excluded components may be of interest in similar models. In the real world, the adoption of one particular resource use may accelerate further such adoption. For example, if some farmers switch from tree crops to growing chilies then other farmers may do the same as local marketing capacity for chilies improves. The model presented here does not include that sort of influence. It is also possible that the value of ecosystem services will change with their availability. Demand for biodiversity products might increase as the products became more widely known, but excessive availability may cause a drop in value of these products. The model has an (optional) feedback that decreases payments as the environment recovers, but includes no specific adjustment in value per service provided as amount of services change.

The model also does not address any influence of resource users' knowledge that they are generating useful services. Formal or informal community recognition of the environmental services provided may positively influence environmental ethics, but when environmental services are very high they may be taken for granted. In a completely degraded ecosystem the value of ecosystem services may be forgotten, but it is possible that the costs of replacing lost environmental services influence a community's awareness of that lost value. Community awareness of environmental services will enhance support for better ecosystem management. These types of relationships might be included in site-specific models.

The model illustrates how environmental ethics might interact with payments, but only fairly tricky field inquiries can determine how real people will respond to payments. In the model, an increasingly favorable environmental ethic increases the likelihood of switching to ecofriendly uses, primarily by lowering the monetary threshold needed to switch to those uses. This observation supports the idea that

issues other than profitability may influence resource users. In a rural part of the United States, only 23.5% of farmers who received PES compensation wanted to maximize profits. Other goals included soil and water conservation, maintaining a rural lifestyle, and ensuring that the farm would be passed on to family members (Lant et al. 2001). In the real world, as in the model, payouts allow resource users to shift their goals away from purely economic considerations. If both ecosystem status and the community's environmental ethic are high, then there will be less need for PES disbursements and these payments could be reduced.

We desire policies that protect and restore ecosystem status regardless of higher profitability of damaging uses. Under some circumstances, this goal may be attained through a PES system alone. Penalties on damaging uses can help fund payouts and lower damaging use profitability. If either of these options is sufficiently high, then ecofriendly uses can dominate. A system of payments plus penalties may work best, especially if the ecosystem is already degraded. In all cases, reaching the goal is more probable if policies also maintain or enhance environmental ethic. Typically, the limited value of environmental services means that PES systems are only likely to be useful in situations where the profitability difference between the two uses is relatively small.

Some interesting issues remain unanswered. If ecosystem services are normally viewed as free, then what is the long-term, larger-scale effect of paying for them? Do payouts for ecosystem services create incentives for others to request, or demand, payments for similar ecosystem protection? Who is it that actually owns the "ecosystem" in question—private resource owners/users or the public at large? What resource-use obligations do resource owners/users have? Is the implication that, without payment, they can do whatever they want? How can society distinguish among reward, payment, reimbursement, incentive, bribery, and extortion? Do these distinctions matter if the end result—protection of the ecosystem and its services—is attained?

Recent comments by McCauley (2006b) and subsequent debate (Costanza, 2006; Marvier et al. 2006; McCauley, 2006a; Reid et al. 2006) have highlighted the need for better means of integrating concepts such as environmental ethics into PES systems. If both payment and a favorable environmental ethic are useful in better managing natural resources, then both, and the interplay between them, should be explicitly stated in exploratory models of such systems. Likewise, issues such as the expectation of payment and its subsequent effect on desired payments can be explicitly defined in the models to allow discussion and investigation of these issues. Importantly, the

structure of a system dynamics model attempts to assess causality. That is, model outcomes should not only be reasonable, they should be reasonable for the right reasons.

Exploratory system dynamics models like the one presented here are sometimes criticized on the grounds that they contain many poorly known relationships among model components. For example, the exact influence of a favorable environmental ethic on resource-use patterns is difficult to know. However, omitting such important components merely because we do not have (or cannot get) accurate information is clearly faulty. In these cases, approximate information is better than none. Nevertheless, due to the highly interlinked nature of system dynamics models the incorporation of some uncertain model elements can lead to high variability in model outcomes. Thus caution, or better information, is needed when attempting to use such models to derive policies.

In fact, the usefulness, rather than absolute accuracy, of a model is the real measure of its value (e.g., see Barlas, 1996), although ultimately satisfying both criteria would be ideal. Exploratory models are certainly useful as research-planning tools to help identify where new information is needed. Causal models could also be important in developing the type of conservation-evaluation programs suggested by Ferraro & Pattanayak (2006). This modeling approach can harmonize the work of many disciplines attempting to craft a sustainable future (Fiksel, 2006; Hjorth & Bagheri, 2006).

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## References

- Barlas, Y. 1996. Formal aspects of model validity and validation in system dynamics models. *System Dynamics Review* 12(3):183–210.
- Costanza, R. 2006. Nature: Ecosystems without commodifying them. *Nature* 443(7113):749–749.
- Ferraro, P. & Pattanayak, S. 2006. Money for nothing? A call for empirical evaluation of biodiversity conservation investments. *PLoS Biology* 4(4):e105.
- Fiksel, J. 2006. Sustainability and resilience: toward a systems approach. *Sustainability: Science, Practice, & Policy* 2(2):14–21. <http://ejournal.nbii.org/archives/vol2iss2/0608-028.fiksel.html>.
- Ford, A. 1999. *Modeling the Environment: An Introduction to System Dynamics of Environmental Systems*. Washington, DC: Island Press.
- Gutman, P. (Ed.). 2003. *From Goodwill to Payments for Environmental Services: A Survey of Financing Options for Sustain-*

- able *Natural Resource Management in Developing Countries*. Washington, DC: World Wildlife Fund, Macroecoeconomics for Sustainable Development Program Office.
- Hatfield-Dodds, S. 2006. The catchment care principle: A new equity principle for environmental policy, with advantages for efficiency and adaptive governance. *Ecological Economics* 56(3):373–385.
- Hjorth, P. & Bagheri, A. 2006. Navigating towards sustainable development: A system dynamics approach. *Futures* 38(1):74–92.
- Ibarra, E. & Hirakuri, S. 2007. Institutional conflict and forest policy effectiveness: The case of the Costa Rican institutional reform. *Forest Policy and Economics* 9(6):591–601.
- Janzen, D. 1999. Gardenification of tropical conserved wildlands: Multitasking, multicropping, and multiusers. *Proceeding of the National Academy of Sciences* 96(11):5987–5994.
- Landell-Mills, N. & Porras, I. 2002. *Silver Bullet or Fools' Gold? A Global Review of Markets For Forest Environmental Services and Their Impacts on the Poor*. London: International Institute for Environment and Development.
- Lant, C., Loftus, T., Kraft, S., & Bennett, D. 2001. Land-use dynamics in a southern Illinois (USA) watershed. *Environmental Management* 28(3):325–340.
- Leigh, P. 2005. The ecological crisis, the human condition, and community-based restoration as an instrument for its cure. *Ethics in Science and Environmental Politics* 2005:3–15.
- Leopold, A. 1949. *A Sand County Almanac: And Sketches Here and There*. New York: Oxford University Press.
- Marvier, M., Grant, J., & Kareiva, P. 2006. Nature: Poorest may see it as their economic rival. *Nature* 443(7113):749–750.
- McCauley, D. 2006a. Nature: McCauley replies. *Nature* 443(7113):750.
- McCauley, D. 2006b. Selling out on nature. *Nature* 443(7107):27–28.
- Pagiola, S. 2007. Payments for environmental services in Costa Rica. *Ecological Economics* (in press).
- Pagiola, S., Agostini, P., Gobbi, J., Haan, C., Ibrahim, M., Murgueitio, E., Ramírez, E., Rosales, M., & Ruiz, J. 2004. *Paying for Biodiversity and Conservation Services in Agricultural Landscapes*. Environmental Economics Series No. 96. Washington, DC: World Bank Environmental Department.
- Pagiola, S., Arcenas, A., & Platais, G. 2003. *Ensuring That the Poor Benefit From Payments for Environmental Services*. Paper Presented at Workshop on Reconciling Rural Poverty Reduction and Resource Conservation: Identifying Relationships and Remedies. May 2–3. Cornell University, Ithaca, NY.
- Pagiola, S., Arcenas, A., & Platais, G. 2005. Can payments for environmental services help reduce poverty? An exploration of the issues and the evidence to date from Latin America. *World Development* 33(2):237–253.
- Reid, W., Mooney, H., Capistrano, D., Carpenter, S., Chopra, K., Cropper, A., Dasgupta, P., Hassan, R., Leemans, R., May, R., Pingali, P., Samper, C., Scholes, R., Watson, R., Zakri, A., & Shidong, Z. 2006. Nature: The many benefits of ecosystem services. *Nature* 443(7113):749.
- Rice, R., Gullison, R., & Reid, J. 1997. Can sustainable management save tropical forests? *Scientific American* 276(4):44–49.
- Scherr, S., White, A., Khare, A., Inbar, M., & Molnar, A. 2004. *For Services Rendered: The Current Status and Future Potential of Markets For the Ecosystem Services Provided By Tropical Forests*. ITTO Technical Series No. 21. Yokohama: International Tropical Timber Organization.
- Sterman, J. 2000. *Business Dynamics: Systems Thinking and Modeling for a Complex World*. Boston: Irwin/McGraw-Hill.
- Tognetti, S. 2005. Review: Payments for watershed services and water as a human right—is there a conflict? *Flows Bulletin* 10:1–3. <http://www.flowsonline.net/data/Flows10.pdf>.
- Tomich, T., Thomas, D., & van Noordwijk, M. 2004. Environmental services and land use change in Southeast Asia: From recognition to regulation or reward? *Agriculture, Ecosystems & Environment* 104(1):229–244.
- Wunder, S. 2005. *Payments for Environmental Services: Some Nuts and Bolts*. CIFOR Occasional Paper 42. Bogor, Indonesia: Center for International Forestry Research.
- Wunder, S. 2006. Are direct payments for environmental services spelling doom for sustainable forest management in the tropics? *Ecology & Society* 11(2):23. <http://www.ecologyandsociety.org/vol11/iss2/art23>.
- Wunder, S. 2007. The efficiency of payments for environmental services in tropical conservation. *Conservation Biology* 21(1):48–58.
- World Wildlife Fund (WWF). 2006. *Payments for Environmental Services: An Equitable Approach for Reducing Poverty and Conserving Nature*. Washington, DC: World Wildlife Fund.