NaturEtrade:

Economics, Auction Design, and Review of Contracts

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Designing a trading platform for the private provision of ecosystem services

Abstract

Although ecosystem services are central to sustaining human existence and well-being, they are not commonly an object of private-market transactions owing to intrinsic market failures such as strategic free-riding, lack of information, and high transaction costs. As a result, where ecosystem services are recompensed, it is almost exclusively via external incentives provided by government or charitable donation. This paper examines research into the private provision of public goods and empirical studies of payments for ecosystem services to outline how recent technological advances in the physical, natural, and social sciences can be exploited to develop an ecosystem services trading platform which can mitigate many of ecosystem services' intrinsic market failures and therefore incentivise greater private provision of them.

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1. Introduction

Although ecosystem services are central to sustaining human existence and welfare, they are not commonly an object of private-market transactions owing to intrinsic market failures that render them unmarketable. All too often the consequence of this market disconnect is environmental and human tragedy. Not surprisingly, heretofore the dominant approach to successful ecosystem service provision has been through; government regulation, government subsidy, or charity. However, recent technological advances in the physical, natural, and social sciences may make it possible to design a trading platform for ecosystem services which can mitigate some of these market-failures and thereby increase the privately-feasible levels of their provision.

For the purposes of designing this trading platform, incentives for the provision of ecosystem services can be usefully categorised as either being externally driven, such as by government or charitable donation; or internally driven by the direct needs of private individuals and businesses. External incentives from government can either take the form of a tax or a subsidy. The theoretical possibility of efficient provision of goods that have significant external effects (such as ecosystem services) through taxes and subsidies was first put forward by Pigou (1920). This framework for dealing with the collective goods problem was widely advocated after influential work by Samuelson (1954), but later critiqued by Tiebout (1956), Buchanan and Tullock (1962), and Ostrom (1990). Famously, the possibility of spontaneous and efficient provision of goods with external effects via internal incentives was argued by Coase (1960). The now eponymous theorem from this paper argued that if transactions costs are low enough and property rights well-defined, then the parties concerned will transact amongst themselves to bring about efficient levels of goods with external effects. Of course, the lynchpin of this entire argument hinges on the question of transaction costs. For truly public goods whose positive benefits are spread widely, the transactions costs of coordination will be enormous relative to the social benefits derived from them, and market provision will fail. It is therefore unsurprising that in practice the charitable and Pigouvian (external incentives) modality of ecosystem service provision has dominated the marketplace for environmental goods. However, if transactions costs could be sufficiently reduced, the Coase Theorem predicts that both buyers and sellers of ecosystem services could spontaneously arrive at an efficient solution.

NaturEtrade has been uniquely designed to facilitate this Coasean vision. It will do this via an online trading platform, bringing together buyers and sellers to create a managed-fund-like format, automatically generating contracts between them at auction, and reducing monitoring costs through the application of remote measurement technology of ecosystem services via satellite. Although the focus of NaturEtrade is to facilitate the private provision of ecosystem services, these innovations have the potential to assist charity and government in increasing their ability to provide these goods as well.

The remainder of this paper is structured as follows. First we provide an overview of the market-failures that should theoretically impact the efficient provision of ecosystem services so as to understand how these failures can be mitigated. Next a literature review is conducted on papers describing actual Payment for Ecosystem Services (PES) agreements in practice, with particular focus on schemes which are user-financed and therefore follow the Coasean PES approach. Next, insights from this theoretical and empirical examination of PES are then applied to auction theory to propose an auction format for NaturEtrade. Finally, a review of actual ecosystem services contracts is conducted to inform the creation of an automated contract generation system within NaturEtrade.

2. Market-failures in Ecosystem Services Provision

As mentioned previously, ecosystem services are not generally an object of market transactions (and therefore markets do not price them) due to a number of intrinsic market failures. To a greater or lesser extent, ecosystem services possess the non-rivalrous-ness and non-excluded-ness properties of classic public goods, and therefore are subject to under-provision by market forces alone. Whereas rivalrous-ness is an intrinsic property of the good, excluded-ness is dependent upon both the intrinsic properties of the good (for example attenuation with distance), and social rules governing consumption rights. Although no mere trading platform could address either of these shortcomings directly, NaturEtrade can potentially mitigate some of the negative market outcomes which arise from them.

In Figure 1 below we reproduce the classic rivalrous-excluded economic goods matrix. Within this framework, we categorise various ecosystem services and remark on the theoretical feasibility of these services being provided through a private PES scheme.

Figure 1: Economic good-types, ecosystem services examples, and PES potential

	Excluded	**Non-Excluded**
Rivalrous	**Private goods**	**Common goods**
Examples	-Private fishing/hunting rights -Food -Soil erosion protection (fertility)[1]	-Common fishing/hunting rights
PES Potential	*Markets exist, PES likely redundant*	*Requires property rights, PES likely ineffective*
Non-rivalrous	**Club goods**	**Public goods**
Examples	-Clean water services -Flow regulation services -Pollination services -Pest control (crop yield increase) -Soil erosion protection (clean water)	-Biodiversity -Nutrient cycling -Carbon sequestration (Climate regulation) -Pest control (biodiversity) -Soil erosion protection (dust storms)
PES Potential	*Greatest scope for private PES*	*Requires government or charitable intervention, scope for private PES limited*

[1] Note that many common names for 'ecosystem services' actually refer to multiple different economic goods, and therefore potentially multiple different economic good-types. For example, the term 'soil erosion protection' simultaneously embodies benefits from; i) preventing soil from eroding on one's own property and thereby reducing fertility; a private good, ii) preventing eroded soil from fouling rivers; a club good, and finally iii) preventing soil being from blown up into dust storms; a public good. Moreover, common names for ecosystem services 'Goods' in one context may also embody 'Bads' in another. For instance, 'soil erosion protection' is actually a social 'Bad', producing negative externalities where silted rivers and airborne dirt provide beneficial fertilisation.

As we can see from Figure 1, the greatest potential for NaturEtrade to have an impact on private PES provision resides with club goods. This is because ecosystem services markets will likely already exist for private goods, and unlike common and public goods, the ecosystem service benefits of club goods will accrue disproportionately to the payers; thus discouraging free-riding and incentivising private payment. Although non-charitable private payments for ecosystem services public goods do exist, in general these schemes will also contain a club good component bundled in with them which is in fact the fundamental driver of payment incentives.

Many ecosystem services are not only subject to market failure as a result of their public good-like nature, but also due to problems in forging an agreement between buyers and sellers together. The market failures stemming from these two sources can be categorised as either strategic free-riding or transaction costs.

Free-riding

i. Free-riding

An immediate consequence of the non-excluded-ness of ecosystem services is that it creates the incentive for consumers to strategically withhold payment. This is because, “people are unlikely to pay for something they can receive for free” (Jack, Kousky et al. 2008, p. 9468). The result of this strategic ‘free-riding’ is systemic under-provision of the good in question. Fortunately, empirical work shows that not all economic actors are narrowly self-interested, and will often violate self-interest for the greater good (Andreoni, 1990; Brekke, Kverndokk, & Nyborg, 2003; Koellner, Sell, & Navarro, 2010; Lévy-Garboua, Masclet, & Montmarquette, 2009). This is particularly true for ecosystem services, where interested parties such as agricultural producers may sacrifice some income in order to increase their provision (Ribaudo, Greene, Hansen, & Hellerstein, 2010). This fact will be exploited in the proposed design of NaturEtrade auctions.

Transaction costs

Transactions costs prevent otherwise mutually advantageous trades from being realised (Ribaudo et al., 2010), and are considered to represent a large fraction of total PES programme outlays (Börner et al., 2010; Hegde & Bull, 2011; Wunder & Albán, 2008). In the context of a private trading platform for ecosystem services, transaction costs may take on a number of forms. Most notably these include;

ii. Lack of knowledge on the economic benefit of ecosystem services and how best to provide them

Engel and Schaefer (2013) note that many potential PES agreements are never signed because sellers simply aren’t aware of how changes to their land management practices could benefit buyers and vice-versa. Furthermore, Wunder (2007) explains that a major obstacle to more widespread PES is a lack of knowledge as to how to most efficient deliver ecosystem services. For any given parcel of land, the economically feasible actions that will yield the greatest increase in the desired ecosystem services are generally unknown. Not only does this make it more difficult for ecosystem services sellers to choose apposite actions, but it inserts an element of risk that the expected increase in ecosystem service provision will not in fact be realised. Therefore either the seller or the buyer must bear this risk, which has important consequences for the drafting of contracts (discussed in a following section).

iii. Bringing together legitimate buyers and sellers

Making buyers and sellers aware of each other's existence and verifying each other's legitimacy implies costs. For instance, buyers will wish to know whether the purported ecosystem seller actually own the land they propose to manage, and conversely sellers will wish to verify that the buyers actually have sufficient resources to meet their financial obligation.

iv. Coordinating bids of multiple buyers and/or offers of multiple sellers

Depending upon the ecosystem service in question, non-rivalrous-ness will make it efficient for multiple buyer/beneficiaries to coordinate payments with each other in order to maximise contributions. In addition, multiple sellers may wish to coordinate ecosystem service provision in order to economise on costs (Alston, Andersson, & Smith, 2013). The need for coordination between separate buyers and possibly separate sellers implies additional negotiation costs, and the more numerous these are the greater these will be (Alston et al., 2013). Government run schemes, which are able to negotiate on behalf of all of their constituent buyers can economise on these costs (Alston et al., 2013; Blackman & Woodward, 2010).

v. Negotiating a mutually acceptable price between buyer(s) and seller(s)

The club goods that can be expected to feature centrally in private PES agreements generally *are* club goods *because* the limited geographical scope of their ecosystem services renders them 'excluded'. The spatial non-fungibility of this ecosystem service implies that buyers and sellers are bilateral monopolists for this good, which further implies that each possess a degree of market power – or the ability to set prices. In such cases, relative bargaining power between the buyer and seller determines the distributive outcome. However, in effort to extract additional rents from the other party, each side may refuse to accept offers which exceed their reservation prices, giving rise to the so-called 'hold-out problem'. For instance, Vittel appears to have experienced strategic bargaining when recruiting farmers in its catchment to engage in more environmentally friendly production methods (Depres, Grolleau, & Mzoughi, 2008). When trades are ultimately undertaken in the presence of holdout the result is purely distributive, rather than allocative, and therefore market efficiency is not affected. It is only when strategic rent-seeking causes negotiations to be abandoned altogether that market efficiency fails.

vi. Legal costs

In order to legitimise an agreed transaction, legal costs of contracting will further distance the possibility of being able to reach a mutually beneficial agreement. NaturEtrade will attempt to lower these costs by automatically generating proven ecosystem service contracts that can be customised by the seller.

vii. Monitoring cost

Monitoring is necessary in PES agreements in order to ensure contractual compliance. However according to Kroeger and Casey (2007) , a lack of low-cost measurability is currently a significant barrier to more widespread PES adoption. A fundamental innovation of NaturEtrade is that it will enable lower ecosystem service monitoring costs via remote observation by satellite. As such, NaturEtrade is designed to verify levels of ecosystem service performance.

However, a complicated monitoring issue arises with respect to whether ecosystem service contracts stipulate that the seller produce certain *actions* believed to bring about a desired level of ecosystem service performance, or whether they are obliged to achieve the *performance* itself (Wunder, Engel, & Pagiola, 2008). While verifying that specific actions have been taken is relatively simple, ecosystem service performance verification is fraught with measurement error (as a result of the necessary use of proxies) and natural variability. The decision to base payment conditionality on the execution of an action transfers the risk of ecosystem service provision to the buyer, whereas basing payments on performance transfers this risk to the seller. Naturally, the relative costs of monitoring either *actions* or *performance* will depend on the particular ecosystem services demanded. Therefore the choice of whether action or performance monitoring is efficient for a given PES will depend on both the parties to the transaction and the ecosystem services at hand.

A particular benefit of targeting private PES noted by Alston et al. (2013) is that such schemes may be subject to lower monitoring costs than in the public sector due to better aligned incentives.

Political barriers

Competing subsidies

In some cases regulation may compete with PES transactions. In the EU for instance, former subsidies from the government for intensive farming competed directly with the provision of ecosystem services. In particular, the Arable Area payments programme incentivised the conversion of inappropriate lands such as flood plains to agricultural use, and livestock headage payment incentives have been responsible for considerable environmental damage.

Uncertain property rights

While it is more common for property rights to be unclear or for there to be a separation between de jure and de facto property rights in developing nations (Alston et al., 2013), even developed nations may suffer from ambiguities in property right determination. This may be the case for instance in watersheds that straddle multiple country borders. Where property rights are uncertain, otherwise strong incentives for PES break down because buyers cannot be assured that they will be able to capture benefits from their investment.

Institutional barriers

At other times, the feasibility of PES schemes are not undermined by underlying economics or policy, but by social norms. Van Hecken, Bastiaensen, and Vásquez (2012) and Börner et al. (2010) find that despite the economic viability of, respectively, watershed services in Nicaragua and carbon sequestration in Brazil, people were reluctant to pay landowners for these services.

Although reducing political and institutional barriers to private PES markets is beyond the possible purview of NaturEtrade, the other free-riding and transaction cost obstacles intrinsic to private PES provision identified in (i-vii) above may have potential for mitigation. The design of NaturEtrade's trading platform will attempt to, where possible, lessen the extent of these problems.

3. Payment for Ecosystem Services Examples

Given the public goods nature of ecosystem services, the vast majority of PES schemes have been, in some capacity, incentivised by government through either subsidy or penalty. A much smaller fraction has consisted of bilaterally voluntary 'Coasean' schemes where no external incentives are generated via government or charity. For instance, in a meta-analysis of 457 ecosystem services papers published since May 2011, Schomers and Matzdorf (2013) found that only 7 of the 102 separate PES schemes examined in these papers relied on purely private incentives, and concluded that, "Pure Coasean PES examples are hardly described in the literature". To compound the problem, often authors will confuse a PES scheme as Coasean, when in fact it is actually indirectly financed by government. A common such mistake is to classify PES schemes as private and 'user-financed' when payments are in fact obliged by the government. Other times authors will miscategorise schemes as solely 'user' financed when in fact charities and government are also large contributors[2]. Even so, truly Coasean PES are likely more common in practice than the literature would suggest. This is because it is large-scale national PES schemes which tend to both attract research attention and to be financed by the government, whereas Coasean PES may be most common as small-scale local or individual schemes that may be overlooked by researchers.

The literature review of PES schemes was conducted as follows. Relevant PES examples were taken from both scholarly and non-scholarly sources. The literature search for scholarly articles on PES was conducted using Science Direct, Scopus, International Biography of the Social Sciences, and Google Scholar for 'ecosystem services', 'payment for ecosystem services', and 'environmental services'. Non-scholarly articles were searched on Google using the same terms. Papers were then surveyed for relevant PES schemes and references to other papers which might have relevant PES schemes. When a relevant scholarly article was found, all the search engines' recommended articles based off of this selection were reviewed. All pure Coasean schemes identified from this literature review are included in Table 1, and are indicated by the only source of finance being classified as 'User'. The focus of this literature review is on 'User' financed schemes, since the primary goal of NaturEtrade is to facilitate these transactions to the greatest extent possible. 'Charity' and 'Government'- financed schemes are less directly relevant to the design of NaturEtrade because the incentive to participate

[2] See for instance Project Cuencas Andinas described in Brouwer, Tesfaye, and Pauw (2011).

of at least one party to the transaction is generated externally[3]. However, particularly archetypal, unique, or instructive examples of ‘Charity’ and ‘Government’ - funded schemes are included for comparison purposes. Table 1 is sorted according to ‘Good type’ then ‘Finance source’, then ‘Number of direct buyers, then ‘Number of direct sellers’. In distinguishing between whether a public good is financed by a ‘User’ or ‘Charity’, the deciding factor is whether the financier could be expected to receive benefits from the scheme that are disproportional to those generated for the general population.

[3] The distinction between 'User' and ‘Government’ financed schemes may be somewhat ambiguous when the government is the direct user. Such schemes are classified here as ‘Government’ unless there is evidence that the local community had direct decision-making power in the scheme rather than politicians.

Table 1: Notable PES examples

	Location	Ecosystem service targeted	Good type	Finance source	Number of direct buyers	Number of direct sellers	Third-party broker	Monitoring criterion	Reference
Las Escobas River Basin	Guatemala	Clean water	Club Good	User	1	1	No	Action	Corbera, Kosoy, and Martínez Tuna (2007)
Vittel	France	Clean water	Club Good	User	1	27	No	Action	Depres et al. (2008)
Evian	France	Clean water	Club Good	User	1	Many	No	Action	www.apieme-evian.com
Coca-Cola Tagua Reservoir	Portugal	Clean water	Club Good	User	1	Many	No	Action	United Nations (2013)
Bionade Trinkwasserwald	Germany	Clean water	Club Good	User	1	Many	No	Action	United Nations (2013)
Henniez SA	Switzerland	Clean water	Club Good	User	1	Many	No	Action	United Nations (2013)
Bayern drinking water reservoirs protection cooperative	Germany	Clean water	Club Good	User	1	Many	No	Relative performance (nutrient levels)	Mangelsdorf and Attenberger (1999) cited in Zabel and Roe (2009)
San Pedro del Norte	Nicaragua	Clean water	Club Good	User	125	5	Yes	Action	Corbera et al. (2007)
Jesus de Otoro	Honduras	Clean water	Club Good	User	5,200	18	Yes	Action	Kosoy, Martinez-Tuna, Muradian, and Martinez-Alier (2007)
Panama Canal ForestRe Bond	Panama	Clean water Flow regulation	Club Good	User	Many	Many	Yes	Action	Forest Trends, The Katoomba Group, and UNEP (2008)
Los Negros Valley	Bolivia	Clean water	Club Good	User Government	1	46	Yes	Action	Asquith, Vargas, and Wunder (2008)
The Nature Conservancy Water Funds	South America	Clean Water Flow regulation	Club Good	User Charity Government	1 to Many	Many	Yes	Action	www.nature.org
Sumberjaya RiverCare Group	Indonesia	Clean water	Club Good	Charity	1	Many	Yes	Absolute performance (reduced siltation)	Huang, Upadhyaya, Jindal, and Kerr (2009)
Tar-Pamlico Basin Agricultural Management	USA	Clear water	Club Good	Charity	16	Many	Yes	Action†	Sattler and Matzdorf (2013)
Cidanau River	Indonesia	Clean water	Club Good	Government	1	Many	Yes	Action	Leimona, Pasha, and Rahadian (2010)
Hewitt Creek	USA	Clean water	Club Good	Government	1	Many	Yes	Action	Zabel and Roe (2009)
Catskills – NYDEP	USA	Clean Water	Club Good	Government	1	Many	No	Action	TNC (2012)
Pago de Servicios	Mexico	Clean water	Club Good	Government	1	Many	Yes	Action	Muñoz-Piña, Guevara,

Ambientales Hidrológicos									Torres, and Braña (2008)
Pimampiro Watershed Protection Scheme	Ecuador	Clean water	Club Good	Government	1,350	19	Yes	Action	Wunder and Albán (2008)
Bird Hunting Abstention Program	Cambodia	Biodiversity (refrain from customary action)	Club and Public Goods	User	1	Many	Yes	Absolute performance (bird sightings)	Clements et al. (2010)
Simanjiro Plains Eco-tourism	Tanzania	Biodiversity (refrain from customary action)	Club and Public Goods	User	5	1	No	Action	Nelson et al. (2010)
Bird Nest Protection Program	Cambodia	Biodiversity	Club and Public Goods	Charity	1	Many	Yes	Absolute performance (birds fledged)	Clements et al. (2010)
Sea Turtle Nesting Payments	Kenya	Biodiversity	Club and Public Goods	User Charity Government	Several	Many	Yes	Absolute performance (nest counts)	Ferraro and Gjertsen (2009)
Pagos por Servicios Ambientales, FONAFIFO	Costa Rica	Clean water Biodiversity Carbon sequestration Scenic beauty	Club and Public Goods	User Charity Government	Many	Many	No	Action	Blackman and Woodward (2010)
US Conservation Reserve Program	USA	Clean water Biodiversity Soil erosion protection	Club and Public Goods	Government	1	Many	No	Action	NCEE (2001)
Sloping Lands Conversion Program	China	Clean water Soil erosion protection	Club and Public Goods	Government	1	15 million	No	Action	Xu, Bennett, Tao, and Xu (2004)
Shade Coffee Certification Program	Mexico	Biodiversity	Public Good	User	1	Many	Yes	Action	Perfecto, Vandermeer, Mas, and Pinto (2005)
Nurture Lakeland	UK	Scenic beauty	Public Good	User	Many	1	Yes	Action	DEFRA (2013)
Chicago Climate Exchange	USA	Carbon sequestration	Public Good	User Charity	Many	Many	Yes	Action	Ribaudo et al. (2010)
PROFAFOR	Ecuador	Carbon sequestration	Public Good	Charity	1	152	Yes	Action	Wunder and Albán (2008)
Rio Bravo Carbon Project	Belize	Carbon sequestration	Public Good	Charity	Many	Many	Yes	Action	Corbera et al. (2007)
Silvopastoral Ecosystem Management Project	Nicaragua	Biodiversity Carbon sequestration	Public Good	Government	1	100+	Yes	Action‡	Pagiola et al. (2007)
Bush Tender – DEPI	Australia	Biodiversity	Public Good	Government	1	Many	No	Action	DEFRA (2013)
Indian House Crow Eradication Program	Seychelles	Biodiversity (pest control)	Public Good	Government	1	Many	No	Absolute performance (animals killed)	Zabel and Roe (2009)
Countryside Stewardship Scheme	UK	Scenic beauty	Public Good	Government	1	Many	No	Action‡	Dobbs and Pretty (2008)
Payments for Biodiversity,	Mexico	Biodiversity	Public Good	Government	1	Many	Yes	Action	Corbera, Soberanis, and

Carbon and Agroforestry Services		Carbon sequestration							Brown (2009)
West Country Angling Passport	UK	Biodiversity (Fishing Rights)	Private Good	User	Many	Many	Yes	Action	DEFRA (2013)

†Payments to landowners are in fact conditional on actions only, and the voluntary nutrient effluent reduction component of the scheme is not a PES because no transaction occurs. See definition in Wunder (2005).
‡Zabel and Roe (2009) erroneously label this scheme as performance-based when in fact their 'performance' metric is completely determined by the actions rendered.

Although only suggestive, the summary of PES schemes above can be examined for patterns, providing insight into the schemes that are feasible from a Coasean perspective, and what potential pitfalls there may arise.

PES trades

Across all financing modalities, we find that PES schemes primarily target one of four ecosystem services; Clean water/Flow regulation, Biodiversity, Carbon sequestration, and Scenic beauty.

Table 2: All financier-type ecosystem service breakdown (n=37)

Ecosystem Service Type	Observations
Clean water/Flow regulation	19
Biodiversity	8
Carbon sequestration	3
Scenic beauty	2
Soil-erosion protection	0†
Pollination	0
Pest control‡	0
Mixed	5

†Present in two 'Mixed' schemes.
‡Refers to 'pest control' for the purpose of increased crop yield. Pest-control schemes whose fundamental goal is actually increased biodiversity are classified as 'Biodiversity' schemes, see Zabel and Roe (2009) for such examples.

Although widely studied in the ecosystem services literature[4], there were zero explicit examples found of either pollination services or pest-control for crop yield as objects of PES programmes. This is perhaps unsurprising given that such services would only be valued in very particular locations for very particular needs (Hayek, 1945). Moreover, the level of naturally sustainable pollination and pest control services that are feasible on a given land plot may be insufficient for the needs of intensive local cultivation. As a result, these ecosystem services may more closely resemble a private rather than club good in practice, as evidenced by the fact that honey bees are widely hired out by individual farms during flowering seasons, and non-'organic' crops are generally sprayed with pesticides. Similarly, soil erosion protection schemes were also conspicuously lacking, with only two programmes explicitly targeting it; none of which were user-funded; and only in conjunction with other ecosystem services.

It is also clear from Table 1 that payments for the vast majority of PES schemes are predicated upon some degree of engaging in new activities that increase levels of positive ecosystem externalities (35 instances), rather than simply refraining from a formerly customary activity that decreased these levels (2 instances). This is interesting because in a Coasean framework, one would not necessarily expect a marked disparity between payments for acts of commission or omission. However, the market appears to have a clear preference for paying for acts of commission. Whether this is due to an actual preferential bias in PES buyers for new actions which increase ecosystem service provision, or whether actions which cause negative externalities are currently illegal is indeterminate from the data.

[4] See for instance Chaplin-Kramer, de Valpine, Mills, and Kremen (2013) and Garibaldi et al. (2013).

In total, 15 purely private 'User'-financed schemes were identified from the literature review. The breakdown of these by ecosystem service type is as follows;

Table 3: 'User'-financed ecosystem service breakdown (n=15)

Ecosystem Service Type	Observations
Clean water/Flow regulation	10
Biodiversity	4
Carbon sequestration	0
Scenic beauty	1
Soil-erosion protection	0
Pollination	0
Pest control	0
Mixed	0

Given our theoretical assertion that club goods would dominate the private-PES space, it is no surprise that Clean water and excluded-Biodiversity feature most prominently among the recompensed ecosystem service types. This result corroborates the findings of Koellner et al. (2010), who found that private firms ranked a list of ecosystem services according to willingness to invest in a similar order; i) watershed protection, ii) biodiversity conservation, iii) carbon sequestration, and iv) scenic beauty; and Alston et al. (2013) who state that; private watershed services, carbon sequestration, and biodiversity PES schemes are more common than scenic beauty. Interestingly, no private-PES scheme explicitly targeted more than one ecosystem service. It appears therefore that ecosystem service users usually have specific requirements that are narrowly defined.

Although common goods featured in no PES schemes, within the 15 solely 'User'-financed schemes, pure public goods were in fact observed twice. The first of these, the Shade Coffee Program, is based off of product certification and eco-friendly purchases from consumers, and the second, Nurture Lakeland, is funded from voluntary contributions from local tourists. Both of these programmes rely on a very large pool of consumers, the majority of which are making spontaneous and one-off choices to contribute tiny amounts. As such, even though user-based PES for public goods do exist, it is unlikely that such consumers would be willing to contractually and meaningfully contribute to a PES agreement.

Surprisingly, a private good PES scheme was also identified. The programme in question is the Angling Passport, wherein the West Country Rivers charity has negotiated river conservation with regional landowners in exchange for granting fishing rights to paying anglers. A possible explanation for why a private good PES scheme can exist in this instance is that a third-party broker may have been necessary due to exceptionally high transactions costs related to simultaneously negotiating with multiple landowners across multiple watersheds, and coordinating them with a large national pool of anglers.

PES finance

Four schemes described in Table 1 have multiple sources of financing, and it may be instructive to examine the breakdown in funding between these different sources. Costa Rica's PSA scheme is financed by users, charities, and the Costa Rican government. Blackman and Woodward (2010) find that 96% of hectares in the scheme were financed by either government or charity, with government being the primary contributor. Users on the other hand only contributed 3% of total funds. Of this 3%, 52% was contributed by firms operating in watershed services, 15% in agriculture, 14% for carbon sequestration, 13% tourism, and 6% other such as an association or individual. The Los Negros Valley watershed scheme receives payments from both the government and users, however the user-provided funds are a very small fraction of the total payments. Ferraro and Gjertsen (2009) do not provide payment breakdowns between charity and hotels for in their description of the sea turtle nesting payment scheme, and we were unable to find breakdowns for the Chicago Climate Exchange. From what data we do have, it is clear that when government finances PES schemes, the scope for attracting user funding is limited. However it is not clear the degree to which the lack of additional user funding is due to intrinsically low demand from the private sector or rather government provision cancelling-out private demand.

Aside from purely Coasean motives, Blackman and Woodward (2010) propose that private-parties may choose to participate in partly government-funded PES schemes in order to obtain preferential treatment from regulators. They cite evidence that this was the case for the U.S. Environmental Protection Agency's voluntary programme, where participants received 'regulatory relief'(Kosoy et al., 2007; Marcus, Geffen, & Sexton, 2002), and that U.S. firms which participate in voluntary abatement obtain regulatory permits more quickly (Cothran, 1993; Decker, 2003). Therefore, voluntary PES payments from corporations may reflect a form of competitive rent-seeking. However, unlike the classic case described in Kreuger (1974), the vehicle of competition (PES) represents a positive externality to society rather than a deadweight loss. Corporations may also wish to participate in PES schemes from a standpoint of corporate social responsibility, where they may gain positive reputational effects (Kosoy et al., 2007), and pre-empt or prepare for anticipated future regulations (Porter & Kramer, 2002, 2006).

PES transaction costs

User-funded PES schemes are characterised by a majority (9 out of 15) being funded by a single buyer. In addition, 7 out of these 9 funders are large multinational corporations. This suggests that sufficient scale may be necessary in order to internalise sufficient benefits to make PES profitable. Kosoy et al. (2007) for instance found that companies participating in PES tended to be statistically larger than average. The prevalence of single buyers also implies that that transaction costs related to coordinating multiple buyers may be an important obstacle in PES adoption. For instance, looking at the full sample of PES observations, it is interesting to note that whenever there are multiple buyers to a scheme, they are practically always either funded by government or have a third-party broker which helped to coordinate these separate interests. In the sole case where this was not true (Simanjiro Plains Eco-tourism), there were only 5 buyers. Therefore, the existence of many buyers appears to imply that a central body is necessary in order to coordinate their common interests. A direct corollary of this result is that ecosystem services which have the most potential buyers, namely public goods, will likely require a third-party in the form of either government or an independent broker to overcome their considerable transaction costs. On the other side of the transaction, the presence of multiple ecosystem service sellers appears to bear no direct relationship to the necessity of a centrally coordinating body, and therefore does not appear to be an important consideration in scheme feasibility. Consequently, it can be argued that, if trade-offs must be made, a private trading platform for ecosystem services should focus on mitigating problems related to coordinating many buyers rather than coordinating many sellers.

PES monitoring

There are three types of monitoring criteria identified by the literature review. These are; i) action-based monitoring, ii) absolute performance-based monitoring, and iii) relative performance-based monitoring. Each of these three monitoring modalities also has particular advantages and disadvantages. Action-based schemes circumvent the immediate need to understand the relationship between actions and performance on each particular location and are immune to the variability of performance metrics due to natural causes. Performance metrics, on the other hand, are able to directly target the relevant benefits to the buyers, and retain flexibility of the seller to use the knowledge of their land in determining how to most efficiently provide this benefit (Derissen & Quaas, 2013; Zabel & Roe, 2009). However, since in NaturEtrade sellers will specify the monitoring terms of their contract, if action-based monitoring is used, sellers are still able to specify the most effective actions. As in the action-based monitoring case, relative performance monitoring allows natural variability to be implicitly controlled for. However unlike the standard action-based contract, under relative performance monitoring the seller can still decide on the most effect actions to undertake. For these reasons Derissen and Quaas (2013) suggest that performance-based payments may be best suited for schemes where conservation of an already given state is desired, whereas action-based payments are better suited to contracting for a hitherto unprovided ecosystem service. Consistent with expectation, Gibbons, Nicholson, Milner-Gulland, and Jones (2011) also find that the relative costs of action and performance-based monitoring for any given scheme is an important consideration in the choice of payment conditionality.

Whereas action-based monitoring saddles the ecosystem service buyer with the risk of non-performance, absolute performance-based monitoring places this risk on the seller. In the relative performance case on the other hand, both parties bear some performance risk. Economic theory suggests that it is most efficient for the least risk-averse party in a transaction to bear the most risk. Where risk allocation can be negotiated with low transaction costs, buyers and sellers will come to an efficient risk-bearing arrangement. Gibbons et al. (2011) suggest that the most efficient risk-sharing arrangement is for a fixed payment to be combined with a variable payment for results, where the proportion of fixed to variable payments is determined by the relative risk aversion between the buyer and the seller. In practice however such a complex payment format would; (i) increase transaction costs, (ii) be impractical to estimate accurately, and (iii) could discourage seller entry altogether.

Compared to action-based PES monitoring, empirically absolute and relative performance-based monitoring are the exceptions, consisting of only 6 of the 37 scheme observations in Table 1[5]. The finding that PES schemes are disproportionately monitored by actions rather than performance was also remarked in a review of the literature by Alston et al. (2013).

[5] However, it must be borne in mind that although all performance-based schemes identified in the literature review were included in this sample not all action-based schemes were. Therefore this ratio over-represents the actual frequency of performance-based schemes in practice.

Table 4: Performance monitoring modality, all PES financiers (n=37)

	Observations
Action	31
Absolute performance	5
Relative performance	1

Table 5: Performance monitoring modality, solely 'User'-financed PES (n=15)

	Observations
Action	13
Absolute performance	1
Relative performance	1

For purely user-financed schemes in particular, absolute and relative performance-based monitoring were only identified for two schemes. The 'absolute performance'-based scheme (Bird-hunting abstention programme) relies on animal counts as the basis for payment conditionality on biodiversity, while the 'relative performance'-based scheme (Bayern drinking water) uses comparisons of soil nutrient-level samples for clean water provision. In both cases the measurement of these quantities is straightforward. For the Bird-hunting abstention programme, animal counts *are* the directly relevant metric for biodiversity provision, and no proxies are needed to infer the delivery of the desired ecosystem service.

The relative performance-based scheme on the other hand (Bayern drinking water), uses an indirect proxy for clean water provision, nutrient levels in soil. The reason why relative-performance is used is due to intrinsic natural variability in local soil nutrient levels; and the reason why soil is used as a proxy for water eutrophication is than soil has a point source pollution (the landowner), whereas waterways are non-point source (collective pollution). Therefore compared to an absolute performance-based scheme, the natural variability of the relevant ecosystem service benchmark is controlled for; and in contrast with a direct measurement of water quality, the soil proxy is superior in creating private incentives. The ability to implicitly control for natural variability is a key feature of relative performance-based schemes (Pagiola et al., 2007).

However, the benefits of using absolute and relative performance-based monitoring appear to be associated with only a few very specific ecosystem services. For instance, four of the five absolute performance-based monitoring schemes indicated in Table 4 relied on simple animal counts. And a recent survey of 23 performance-based PES programmes by Zabel and Roe (2009), with one exception[6], only identified schemes which were based on animal counts. Where tourism is the primary driver for biodiversity demand, the observability of large charismatic animals *is* the relevant metric. But where species diversity at a more micro or potentially less affable scale is the goal, the applicability of this measure would fail. Relative performance-based schemes by contrast would not be feasible unless; i) a relevant control group can be identified, ii) participants cannot deliberately or collusively shift the benchmark, and iii) there are low levels of natural heterogeneity in the

[6] Namely, the Sumberjaya RiverCare project outlined in Table 1 and discussed in the preceding paragraph.

benchmark between sellers (Zabel & Roe, 2009). But the feasibility of absolute and relative-performance monitoring both depend on the availability of a cheap and relevant metric for relevant (to the buyer) ecosystem service performance, which in many cases will not be forthcoming.

The problem of efficient risk apportionment in performance-based schemes may also be a further limiting factor in its wider adoption. For instance, the bird-nest protection programme did not place all performance risk on the sellers, as payments were still delivered if it could be ascertained that birds succumbed to natural predation (Clements et al., 2010). And in the only non-animal count absolute performance-based scheme observed (the Sumberjaya RiverCare project), performance risk was entirely borne by a charity and not the direct ecosystem service seller. Given the lack of direct risk-bearing in this scheme on the part of sellers, it is perhaps unsurprising that it ultimately failed to realise the proposed decreases in siltation due to a large unexpected landslide and a miscalculation by the charity in the necessary size of the catchment (Huang et al., 2009).

What we can draw from this discussion of the potential arrangements of payment conditionality is that the optimal monitoring format will depend on many particulars to each ecosystem service scheme that are not necessarily knowable to an auction designer in advance. Therefore an optimal contract design would provide participants with the flexibility to choose the monitoring regime that is most appropriate for their individual situation. That said, if given the option, in all likelihood buyers and sellers in NaturEtrade would predominately choose payment conditionality to be determined by actions rather than performance.

4. Auction Design

NaturEtrade completely abstracts from the complex problem of assigning a social monetary value to ecosystem service provision. Rather, the sale prices of ecosystem service at auction only represent lower bounds on the private values of this ecosystem service to the buyers only. Technically, the auction format proposed here for NaturEtrade consists of a cooperative, discrete public goods subscription game of incomplete information and asymmetric preferences. The auction is 'cooperative' in the sense that the maximum bid of each bidder are summed with those of other bidders, and this sum represents the total amount the seller is paid if his reserve price is met. 'Subscription game' refers to the fact that individuals privately contribute money, and if contributions are sufficient the good is provided, otherwise contributions are refunded (Admati & Perry, 1991). The 'cooperative' and 'subscription game' elements of NaturEtrade are similar to the crowd sourcing/funding mechanisms that have become popular through the internet. However, NaturEtrade differs from these schemes in that information is 'incomplete' because buyers do not observe the preferences or bids of other buyers, and buyers will not know the reserve price of the seller. It should also be pointed out that the reverse auction design prevalent in many government or charity-funded ecosystem service schemes is not generally applicable for the user-funded case due to the inherent market power of club good ecosystem service sellers. Due to the limited potential for seller competition in the provision of geographically constrained club goods, a reverse auction will fail to generate efficient outcomes. The remainder of this section outlines how we arrived at our proposed auction format and identifies remaining questions with respect to our proposed auction design.

Unfortunately, not a great deal is known about the theoretical properties of subscription games of incomplete information, and designing auctions that work well in the field still poses significant challenges for even experienced theorists, with the literature littered with examples of well-intentioned failure (Cason & Gangadharan, 2004). The little that is known about such auctions is that unless strong simplifying assumptions are made, even static two-player problems generate a profusion of equilibria (Rabotyagov, Tóth, & Ettl, 2012). We do however know that subscription games which refund contributions when reserve prices are not met are more efficient than the case without refund, and the possibility of continuous as opposed to binary 'all-or-nothing' contributions facilitates provision (Cadsby & Maynes, 1999; Menezes, Monteiro, & Temimi, 2001).

Objective function

Optimal auction design depends upon the objective of the auctioneer and the characteristics of both the goods traded and the traders. As auctioneer, NaturEtrade's explicit goal is to improve the trend of biodiversity losses in Europe. However since actual increases in biodiversity arising from fulfilling NaturEtrade contracts are not directly observable at scale, maximising reductions in biodiversity loss will be proxied by maximising the sum of total bids from successful auctions. More formally and without loss of generality, if we assume that sellers offer the non-mutually exclusive ecosystem service contracts v from the pool of possible contracts V, and that the seller has cost c_v of fulfilling these contracts, and that there are I bidders i who bid b_{iv}, The relevant objective function for the design of NaturEtrade's auction format is;

$$\max_b \sum_i^I \sum_v^V b_{iv}$$

Subject to each contract being feasible;

$$\sum_i^I b_{iv} \geq c_v$$

We argue that the existence of positive externalities due to the public goods-nature of ecosystem services means that this objective function, which maximises the total bids of successful projects, may yield greater social welfare than a canonical profit maximisation case. Although it is beyond the scope of this paper to derive theoretical results from this objective function, it will serve as useful benchmark in the explanation of our proposed auction design.

Joint bidding

The NaturEtrade auction will use cooperative joint bidding to fund the provision of ecosystem services. This decision follows naturally from the preponderance of club and public good types observed in the user-funded schemes in Table 1, both of which are non-rivalrous. This non-rivalry means that depending on the excluded-ness of the good in question, multiple buyers can benefit if the good is provided to anyone. By allowing multiple parties to bid jointly on the same good, the positive externalities of the non-rivalrous good are effectively internalised.

Mitigating free-riding

A further consequence of non-rivalry in provision is that it introduces the potential for bidders to ‘free-ride’ on the contributions of others. One of the ways that NaturEtrade proposes to deal with the free-riding problem is to keep others’ bids hidden by default initially, but also allowing each bidder to later decide whether to reveal their contribution to others. In addition, individual bidders will not know how many bidders are participating or who these bidders are unless a particular bidder chooses to reveal this information. The ability of each bidder to bid strategically is reduced when they do not know the amounts others have pledged (Tóth, Ettl, & Rabotyagov, 2010). This is corroborated by the results of Croson and Marks (1998) who find that when anonymous information about others’ contributions in a public goods game is revealed, contributions significantly decrease and the variance of contributions increases. Where bidding is secret, an individual bidder will likely be less concerned about over-bidding relative to his colleagues and may bid closer to his true reserve price out of fear of non-provision. However, Jerdee and Rosen (1974) find that when bidders have had previous social interaction and individual contributions are identified, average contributions increase and contribution variance decreases. Whether or not revealing bids is an efficient strategy will therefore likely depend on the relationships of the auction’s participants. We therefore allow each bidder to decide which scenario they are in (high or low social cohesion), and choose whether or not to reveal their bid or identity accordingly.

It should also be noted that profit-maximisation is not likely the only relevant paradigm with which to analyse the participation of bidders. Farmers, for instance, often have a long-term intergenerational mind-set and considerable goodwill with their surrounding communities and may therefore behave more altruistically with respect to ecosystem service delivery. Work of Kosoy et al. (2007) corroborates this assertion by observing that ecosystem service sellers in their sample most commonly operated at a loss. Moreover, in experimental settings cooperative bidders often do not behave as purely self-interested as theory would suggest. For instance, (Lévy-Garboua et al., 2009) argue that social norms increases public good provision in practice, and Brekke et al. (2003) suggests that moral motivations are important in collective action problems, while Andreoni (1990) explores how the act of giving itself and cooperative outcomes may confer utility on the giver through ‘warm-glow’ effects. In ecosystem services in particular, Koellner et al. (2010) finds that the primary motivation firms had for investing in ecosystem services was human welfare and ecological responsibility. Therefore, even where free-riding cannot be fully eliminated, we can expect many bidders to contribute significantly to NaturEtrade auctions regardless.

Buyer Communication

Although it has been proposed that buyer communication may increase incentives for cooperation and help overcome the coordination problem (Agastya, Menezes, & Sengupta, 2007; Aumann & Hart, 2003; Baliga & Morris, 2002; Farrell & Rabin, 1996), empirically the results are mixed. Rabotyagov et al. (2012) and Tóth, Rabotyagov, and Ettl (2009) find that buyer communication had no statistical effect on public goods provision. Whereas other work by (Isaac, McCue, & Plott, 1985; Krishnamurthy, 2001; Vossler, Poe, Schulze, & Segerson, 2007) found increases in contribution levels. However, because buyer communication would implicitly reveal the existence of additional bidders, in NaturEtrade this will only be possible among bidders that have revealed their identity.

Non-Joint Selling

Due to economies of scale and complementarities in in the value of providing ecosystem services at scale (Bockstael, 1996; Margules & Pressey, 2000; Newmark, 1991; Wilson & Willis, 1975), it may be most efficient for ecosystem services to be sold by sellers/landowners in concert rather than separately. However, one potential problem with this approach is the complexity it adds to the contracting process. First of all, all sellers must agree on how to apportion payments from buyers. Secondly, when multiple sellers provide some basket of services under a common contract, if one becomes in breach of the contract, it is not necessarily straightforward to set out what the implications are for continued payment to the sellers who are still in compliance. Furthermore, Ferraro (2008) has found that allowing only a single landowner to offer an ecosystem service rather than several simultaneously discourages hold-out and collusion because to some degree neighbouring parcels may compete for buyer funds, thereby driving reserve prices lower. Because of these considerations, and because complementary land parcels can successively enter into an agreement with ecosystem service buyers of a neighbouring parcel at any time, NaturEtade has chosen only to allow a single ecosystem service seller in each contract.

Seller proposes the contract

Joint ecosystem service buying combined with non-joint ecosystem service selling imply that transactions costs will be lower if the seller rather than the buyers proposes the project's contract. Moreover, under this format the seller will be able and incentivised to bring to bear their private site-specific knowledge to increase the value of the ecosystem services provided for a given cost.

Buyers may communicate with sellers/landowners

However, as a result of the seller writing the contract, there may be a disconnect between the ecosystem services buyers want and what the seller in fact offers. This discrepancy can be mitigated by allowing buyers to communicate with sellers/landowners, and of course via auction trial and error.

Non-combinational auction

Although multiple ecosystem services may be ideally packaged and sold as a bundle due to complementarities of this bundle on a single parcel of land, we argue that a combinational[7] auction is not necessary to internalise these positive externalities. This is because the non-rivalrous-ness of ecosystem services means that unbundled goods which are complementary and previously sold are

[7] More commonly referred to as a 'combinatorial auction'. The canonical example is auctions for spectrum.

always automatically 're-bundled' later with any new ecosystem service sold. Since benefits of providing ecosystem services accrue to everyone relevant for the auction, the value in packaging these goods for simultaneous sale in 'bundles' is annulled. This result differs from the complementary private goods case, such as spectrum auctions, where bidders compete for access to combinations of rivalrous goods. Moreover, as we saw in Table 3, no 'user'-financed scheme identified consisted of more than one explicit ecosystem service. This further supports our conclusion that there is indeed little market for simultaneous sales of multiple ecosystem services. This result is useful for our purposes, as combinational auctions are significantly more complex than the singular case, and the general public will be unfamiliar with their operation. Therefore, if unbundled ecosystem services can be offered at auction with little loss of efficiency, then we argue that this loss will easily be compensated for by far lower transactions costs for buyers and sellers.

Single-bidding rounds

A further possible extension to the standard auction design is to the use of multiple bidding rounds. In this format, preliminary auction rounds are run with no bearing on contractual obligations and the outcomes of these 'trial' auctions are observable to all. Then a final round is run in order to produce a binding contract. This auction design may have advantages when bids need to be coordinated. For instance, it is argued that repeated rounds may help participants to learn, give them market feedback, and help them to understand that they should reveal their true opportunity costs (Bernard, 2005; Cason & Gangadharan, 2004; List & Shogren, 1999). In addition, allowing bidders to learn about others' valuations during the auction can make them more comfortable with their own assessments and less cautious (Klemperer, 2002).

However, multiple bidding rounds also incur higher administrative and transaction costs (Cason & Gangadharan, 2004), and incur additional risks of strategic behaviour (Latacz-Lohmann & Van der Hamsvoort, 1997). For instance, bidding in earlier rounds may implicitly reveal the seller's reserve price and therefore reduce the incentive of sellers to participate in the first place. Furthermore, Bagnoli, Ben-David, and McKee (1992) find that in an experimental setting, public goods auctions are less likely to be efficient where multiple unit games are used instead of a single unit game. For these reasons we follow the assertion of Stoneham, Chaudhri, Ha, and Strappazzon (2003) that the application of single bidding rounds is an appropriate vehicle for conservation auctions and adopt this format to NaturEtrade.

Threshold non-disclosure

By revealing reserve price thresholds to buyers, sellers would be incentivised to raise the reserve price to some desired level of profit which is higher than the costs of ecosystem service delivery. Whereas if reserve prices are hidden, the seller's dominant strategy is to set the reserve price equal to cost. In both cases buyers may pay more than the actual cost of the service, but in the case where reserve prices are hidden, more feasible schemes can be successful. Ferraro (2008) also highlights the superior information sellers have about the costs of ecosystem service delivery, and therefore that reducing this source of informational rents may be a key element of auction design. Hidden thresholds effectively incentivise sellers to reveal their true costs. Moreover, since seller entry is a function of expected payoffs, the lure of potentially large profits with blind reserves may entice more sellers to participate.

Related theoretical work by McBride (2006) on a public goods provision game where there is no refund and buyers make all or nothing contributions, found that when the value of the public good is high(low) blind (revealed) reserves produces greater (lower) incentives to contribute than the revealed (blind) case. However, a later empirical test of this prediction by McBride (2010) found only moderate support for this analysis. Using a comparable auction format, Rabotyagov et al. (2012) found that seller profit was lower by 10% on average when thresholds were revealed, and that some bidders may find it objectionable to participate in an auction where threshold costs are not revealed. Ex ante the auction cannot know whether the value to the buyer is relatively high or low. Therefore, given that McBride (2006) explains his results with reference to the fact that bidders believe their contributions are pivotal, and since spatially bounded ecosystem service externalities like club goods will likely be in a similar situation with respect to buyers, it makes sense to set the NaturEtrade default to hidden thresholds. However, if it can be determined that an auction is a public good, revealed thresholds may improve efficiency.

Auction Summary

In sum, our interpretation of the evidence on ecosystem service auction design is that NaturEtrade will function most effectively with the following characteristics.

1. Joint bidding
2. Initially secret bidding with individually adjustable anonymity and bid-disclosure settings
3. Buyers may not communicate with another buyer unless that buyer has revealed their identity
4. Non-joint selling
5. Seller Proposes the contract
6. Buyers may communicate with sellers/landowners
7. Non-combinational auction
8. Single bidding round
9. Hidden reserve price threshold

Possible Extensions

1. Sellers able to lower hidden reserve prices in the middle of the auction
2. Sellers able to increase the duration of contracts in the middle of the auction
3. Sellers unable to observe buyer identities
4. Modifying the auction format according to the economic characteristics of the goods sold (ex. reverse price auction for pure public goods).
5. Bidders can choose to be 'pinged' if an auction close to them starts
6. Parcels on the same watershed 'linked' in searches

5. Contracts

One of the ways that NaturEtrade intends to reduce transaction costs is to facilitate the creation of contracts. It will do this by lowering verification and legal costs for both the buyer and the seller, and assuring a level the playing field between them.

Participant Verification

A crucial element for the success of any ecosystem service agreement is trust between the buyers and the sellers (Asquith et al., 2008). To this end NaturEtrade will automatically undertake a variety of verification checks on all auction participants to ensure their legitimacy. Each participant will separately pay for their own necessary checks before they can begin offering and bidding for ecosystem services.

Buyer verification

1. Identity check

Verify that the buyer is the person that they claim to be. This will ensure that the person can be made legally accountable for the bids they offer. Identity can be ascertained via linking bank accounts or professional agencies such as CIFAC.

2. Credit check

Ascertain the credit-worthiness of each buyer, and if insufficient allow them to prepay into an escrow account if acceptable to the seller. Credit-ratings can be gathered from professional agencies such as Equifax, CallCredit, YES-secure.com.

3. Reputational monitoring

Ideally sellers should be able to provide feedback on the performance of their buyers for previous and current ecosystem service agreements.

Seller verification

1. Identity check

Verify that the purported seller is the person they claim to be.

2. Property rights check

Verify that the seller in fact holds the relevant property rights for the required duration (whether free-hold or lease-hold) to provide the indicated ecosystem service. Ferraro (2008) identifies this as an important criterion for attracting buyers. Property rights can be confirmed through deed verification.

3. Verification of land-plot additionality

Verify that the offered ecosystem service has not been contracted previously through government grant or NaturEtrade agreement. For the UK, all government grant data is freely available online through DEFRA.

4. Reputational monitoring

Ideally buyers should be able to provide feedback on the performance of their sellers for previous and current ecosystem service agreements.

Contract Items

Contracts for ecosystem services may contain a number of clauses and specifics which vary according to the ecosystem service offered and the requirements of the buyers and the seller. Where multiple buyers fund the same ecosystem service, it is recommended that a separate purchase agreement be issued with each buyer, rather than utilise a single contract signed by all buyers. The following exposition of contract items draws extensively upon the ecosystem service contract guidance documents; Duke Law, Forest Trends, and The Katoomba Group (2010) and Forest Trends et al. (2008).

Title

Simple but descriptive title of the agreement, and not need include the names of both parties

Intro

Identification of the parties and date of the agreement. Date of the contract should ideally be the date of signing for the last party to sign the agreement.

Recitals

Relevant background information such as; goals of the agreement; background information about the project, the parties; and any relevant agreements existing between the parties, or any party and one or more third-parties.

Parties

Names, principal, legal, or registered addresses of the parties

Verify that buyers are dealing with an authorised entity so as not to violate anti-money laundering laws

Project

Start and end dates

Description of legal rights of each party
Rights – What parties *may* do

Responsibilities of each stakeholder
Obligations – What parties *must* or *must not* do

-Project activities/goals
-Mitigation of risk
-Project governance

Detail of physical area the project will impact

Assurance that there is free, ongoing, prior and informed consent by all participants

Delivery

Define and state actions to be agreed upon by both parties

Affirm local additionality of project

Price and Payment

Payment amounts and due dates

Escrow accounts may be used where there is significant pre-payment by the buyer

Performance assurance
If sellers are concerned about buyer solvency they can require that they produce an acceptable form of performance assurance

Taxes

Address which party is responsible for taxes assessed in connection with the agreement

Representations and Warranties

Statements of fact that are made by each party to an agreement in order to remove uncertainties and induce the other party(s) to enter the transaction. For example statements that each party is legally authorised to enter into and perform its obligations under an agreement.

Monitoring and Verification

Address how monitoring is to be conducted; either through verification of action, absolute performance, or relative performance. Indicate at what frequency monitoring will occur – possibly random. Specify the party responsible for monitoring. Outline which party(s) must pay for monitoring.

Default and Remedies

Definition of default event, outline cure period and remedies

Consequences of failure to make or accept delivery

Force Majeure Clause

Dispute Settlement

Define procedures for settling disputes such as consultation, mediation, and arbitration

Procedures for modifying the contract

Accepted rules for voiding contract

If contract is long-term, dates for which the contract can be reviewed and potentially amended

Interpretation and Definitions

Clarify terms

Miscellany

Conditions precedent

Outlining the event or state of affairs that is required before performance under a contract becomes due

Allowed roles of third-parties

Confidentiality

Assignment of rights
Rules regarding how contractual rights can be transferred, for instance in the case of property sale

Waiver against forfeiture of rights
Failure to enforce provisions of the agreement by any party is not a waiver for the breach of any provision.

Non-Recourse and Limitations of Liability

Reporting obligations
The kinds of reporting required and when these are due.

Severability
Illegal, unenforceable or invalid provisions of the agreement shall be deemed 'severed' and the remainder of the agreement shall remain in effect.

Survival provisions
Description of clauses which are intended to survive the termination or expiry of the agreement, such as indemnity.

Insurance requirements

Contract binding on Successors

Notices
Explanation of how to formally correspond with both parties.

Signatures

Affiliation, Signature, Date, Title
Online signatures allowed

Annexes

Contains important background information, templates, and information that would be too unwieldy to include in the body of the agreement, such as; description of the physical area where the contract applies.

Contract Examples

Table 6 below surveys actual ecosystem services contracts or contract templates from different sources, and identifies which of the contract items described above are included in them. This sample was collected by directly soliciting 55 buyers of ecosystem services and from contracts downloaded via internet research.

Table 6: Ecosystem Services Contract Examples

Contract Source	Title, Intro, Recitals	Parties	Project	Delivery	Price and Payment	Taxes	Representations and Warranties	Monitoring, Reporting, Verification	Default and Remedies	Dispute Settlement	Interpretation and Definitions	Miscellany	Signatures	Annexes
Ontario Land Trust Alliance Conservation Agreement	X	X	X	X	X		X	X	X		X	Indemnity Notices	X	Land description
Cambodia Chumnoab Habitat Protection	X	X	X	X	X			X	X				X	
Cambodia Tatai Leu Forest Protection	X	X	X	X	X			X	X				X	
Certified Emissions Reduction Agreement (CERSPA)	X	X	X	X	X	X	X	X, Letter of credit updates	X	X	X	Conditions precedent Notices Confidentiality Survival provisions Waiver	X	
Nova Scotia Conservation Easement	X	X	X	X	X		X	X	X		X	Notices	X	Land description
California Conservation Easement	X		X	X		X		X	X			Indemnity	X	Land description
Marin County California Conservation Lease		X	X	X	X	X			X			Indemnity Notices Binding on Successors	X	Land description
Chumbe Island Sanctuary Management Agreement	X	X	X	X	X								X	
Cheshire Land Trust Conservation Restriction Agreement	X	X	X	X	X	X			X			Indemnity Severance	X	
North Carolina Conservation Easement	X	X	X	X	X	X		X	X			Indemnity Notices Waiver	X	Land description
Dunn Conservation Easement	X	X	X	X	X	X	X		X			Indemnity Notices	X	
U.S. Department of Agriculture Conservation Reserve Program	X	X	X	X	X		X		X		X		X	
U.S. Department of Agriculture Natural Resources Conservation	X	X	X	X	X			X	X		X		X	
Australia DEPI BushTender	X	X	X	X	X	X			X		X	Indemnity Waiver Severance	X	Land description
NY Catskills Conservation	X	X	X	X	X	X	X	X	X	X	X	Indemnity	X	

Easement												Notices Waiver Severance		
Virginia Department of Forestry ‘Forests to Faucets’	X	X	X	X	X			X	X				X	
South West Water Upstream Thinking Grant	X	X	X	X	X	X	X	X	X		X	Conditions Precedent Indemnity Waiver Severance	X	
Texas Parks and USFWS Conservation Agreement	X	X	X	X	X			X	X	X	X		X	
North Carolina Military Training Land Conservation	X	X	X	X	X		X	X	X			Notices	X	Land description
Wyoming Association of Conservation Districts	X	X	X	X	X			X	X			Indemnity	X	
Dampier Archipelago Australia Conservation Agreement	X	X	X	X	X			X		X	X	Notices Waiver Severance	X	Land description
United Utilities Water PLC Deed of Variation	X	X	X	X	X					X	X		X	Land description
United Utilities Water PLC Stewardship Agreement	X	X	X	X	X					X	X	Notices	X	Details of obligations

Table 7: Contract Item Frequency

Always Present	Usually Present	Not Usually Present
Project Delivery Signatures	Title, Intro, Recitals Parties Price and Payment Monitoring, Reporting, Verification Default and Remedies Miscellany	Taxes Representations and Warranties Dispute Settlement Interpretation and Definitions Annexes

Given the great deal of diversity and uncertainty in what specific ecosystem services sellers will offer and what buyers will demand, the NaturEtrade contract should be flexible and adaptable to deal with this potential variety. Nevertheless, many contract clauses can be made standard from contract to contract, and for those clauses that may need to vary between contracts, the process of clause creation can be simplified for the seller by providing defaults and a selection of pre-approved clauses that are likely to be relevant from drop-down lists. Such a pre-arranged contract creation framework would greatly simplify the contracting process and reduce legal costs on behalf of both the buyer and seller.

6. Conclusion

The purpose of this paper is to inform the development of an online trading platform for ecosystem services called NaturEtrade. To do so we first explore theoretical explanations for why ecosystem services are under-provided in the marketplace. Drawing upon the Coase Theorem, it was argued that free-riding and a number of transaction costs related to coordinating buyers and sellers are responsible for this chronic under-provision, and therefore that club goods would dominate the marketplace for existing private PES. This prediction was corroborated with an extensive literature review of user-funded PES schemes, finding that Clean water/Flow regulation services and excluded Biodiversity were the primary ecosystem services demanded from them. Applying this understanding of private PES markets to the existing economics literature on the private provision of public goods, an auction format was proposed that can both address many of the market-shortcomings of ecosystem services and take account of their unique economic characteristics. Finally, a second literature review of actual PES contracts was then conducted to inform the clauses and structure of NaturEtrade’s automatic contracting facility. Although the attempt to completely correct the market-failures affecting ecosystem services provision may be a quixotic quest, it is hoped that the existence of NaturEtrade will create private incentives for the provision of ecosystem services where formerly there were none. In addition, NaturEtrade may help generate increased awareness of the human necessity to conserve ecosystem services and inspire entrepreneurs and other market actors to discover new ways of incentivising better stewardship of our natural capital.

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