DRAFT: Schmitt Filho, A., J. Farley, G. Alarcon, J. Alvez and P. Rebollar (2013). Integrating Agroecology and PES in Santa Catarina's Atlantic Forest. R. Muradian and L. Rival (eds.) Governing the provision of environmental services. Springer Verlag pp. 333-356

Abdon Schmitt, PhD [b]
Joshua Farley, PhD [a*]
Juan Alvez, ABD [c]
Gisele Alarcon [b], ABD
Paola May Rebollar [b] ABD

[a] Department of Community Development and Applied Economics, University of Vermont
205b Morrill Hall, Burlington, VT 05405, United States
phone: 802 656-2989
e-mail: jfarley@uvm.edu
[b]Departamento de Zootecnia e Desenvolvimento Rural, Centro de Ciencias Agrarias, Universidade Federal de Santa Catarina, Florianopolis, SC, Brasil
[c] Rubenstein School of Natural Resources and the Environment, University of Vermont
[*]Corresponding Author

1. Introduction to the Problem

Agroecology may be a uniquely viable solution to one of the most serious dilemmas currently facing humanity. On the one hand, there are a billion malnourished people on the planet. The global population is expected to increase by two billion by 2050 at that same time that income growth increases the demand for animal protein. Failure to increase food production by at least 70% by 2050 could have unacceptable humanitarian costs (FAO 2011). On the other hand, failure to restore global ecosystems and the life sustaining services they provide poses serious threats to human civilization. Unfortunately, with current technologies, agriculture is the greatest global threat to ecosystem services, including those that sustain agriculture (MEA 2005). Conversely, ensuring the continued provision of vital ecosystem services requires extensive ecosystem restoration, along with reductions in nitrogen, phosphorous, greenhouse gasses, toxic chemicals and freshwater use (Rockstrom et al. 2009), threatening food production. On our current path, we are forced to choose between ecological collapse and widespread malnutrition or worse. Since agriculture itself depends on the continued flow of ecosystem services, the best we can do with current agricultural technologies is stave off starvation.

The market economy is ill suited to solving this problem. While land, food, and raw materials provided by nature are typically market goods with market prices, many ecosystem services are public goods with no market price. A pure public good is both non-excludable, meaning that one cannot prevent others from using it, and non-rival, meaning that use by one person does not affect the quality or quantity left for others. If people cannot be prevented from using a resource whether or not they pay, they are unlikely to pay, and markets will fail to provide the resource. This explains the rapid degradation of ecosystem services around the planet. If use of a resource does not leave less for others, then market prices inefficiently ration use, creating artificial scarcity. For example, markets will ration access to patented technologies that protect our ecosystems, reducing their benefits to humanity in exchange for profits. Markets are not an option for non-excludable resources, and are not desirable for non-rival ones. As a result, the market system awards resource owners for the benefits of ecosystem conversion (e.g.

timber and farm land from cleared forests), but typically fails to award them for benefits of conservation (e.g. flood and climate regulation by intact native forests). Markets systematically favour conversion over conservation, regardless of their relative benefits to society. Because ecosystems exhibit highly complex, dynamic and nonlinear behaviour, including the presence of abrupt, irreversible thresholds (Farber et al. 2002; Folke 2006; Limburg et al. 2002), excessive conversion threatens the irreversible loss of essential services.

On the socio-technological end, agroecology may be uniquely capable of solving this dilemma. Agricultural systems designed to mimic natural processes may be capable of increasing the provision of ecosystem services from farmland and the provision of food, fibre and fuel from ecological restoration while reducing the use of non-renewable and toxic inputs. Despite minimal investments in agroecology relative to conventional agriculture, numerous studies suggest that it can simultaneously increase agricultural yields, farmer incomes, ecosystem services, and resilience in the face of extreme weather events (De Schutter 2010; Gliessman 2007; Pretty et al. 2005). However, a complete solution will require economic institutions that promote agroecology and are capable disseminating it rapidly to a global scale. This chapter proposes economic institutions that reward the provision of ecosystem services generate by agroecology. Though we draw largely on our agroecology research in Santa Catarina's Atlantic Forest for examples, we believe the basic approach we propose could be readily applied elsewhere.

1.1 Santa Catarina's Atlantic Forest

Brazil's Atlantic Forest offers an interesting case study of the conflict between agriculture and ecological resilience. Over 90% of the original 1.5 million km^2 has been lost to economic activities (Tabarelli et al. 2005). Though forest remnants still exhibit some of the highest levels of terrestrial biodiversity and endemism ever recorded (Conservation International 2001), they also harbour more threatened and endangered species than any other Brazilian ecosystem (Costa et al. 2005). A rough rule of thumb from island biogeography suggests that when an ecosystem decreases in size by 90%, species diversity decreases by 50% (MacArthur & Wilson 2001). Research in the south-eastern Atlantic Forest finds that over 60% of birds are extinct, critically endangered or vulnerable (Ribon et al. 2003), while in the northeast over a third of tree species are currently threatened with extinction (da Silva & Tabarelli 2000). Significant time lags between forest loss and extinction best explain why more extinctions have not yet occurred (Brooks & Balmford 1996; Metzger et al. 2009). While biodiversity is not an ecosystem service itself, it plays an essential role in sustaining all ecosystem services (MEA 2005), suggesting that without active intervention, the Atlantic Forest may be due for a catastrophic loss of biodiversity and the ecosystem services it sustains.

Brazil has outlawed continued deforestation of primary or advanced secondary Atlantic Forest. In addition, the Brazilian Forestry Code mandates a forest Legal Reserve (RL) on 20% of Atlantic Forest properties and a Permanent Protected Area (APP) of forest cover on hilltops, slopes over 45%, for 30 meters along rivers under 10 meters in width (increasing along larger rivers) and for 50 meters around springs. However, these environmental laws are poorly enforced (Laurance 1999; Ministério do Meio Ambiente 2011) for valid reasons: Enforcing the law would require many small farmers to reforest well over half their property, which would drive them into poverty. The region thus confronts an ecological threshold in terms of biodiversity and ecosystem service collapse in the absence of reforestation, and an economic threshold in the form of abject poverty if farmers reforest.

If we look at biodiversity collapse and the loss of ecosystem services as marginal costs of agricultural production, they increase very sharply as land clearing reaches the ecological threshold. On the other hand, from the perspective of poor land owners near the poverty threshold, the marginal benefits of agriculture are the satisfaction of basic needs, and hence are also extremely high. Brazil also makes a significant contribution to global food supply, where even small decreases in output can lead to dramatic increases in price. The marginal costs of food production (the supply curve in economic analysis) and marginal benefits (the demand curve) fail to intersect, as depicted in figure 1. The ecological threshold however confronts a significant time lag before it becomes irreversible, while the costs of poverty are more immediate and thus more difficult to ignore.

(Figure 1 about here)

The results of this conflict are particularly visible in Santa Catarina state which retains 23% forest cover, mostly in secondary forest (SOS Mata Atlantica 2009), but suffers the most rapid loss of Atlantic Forest in Brazil (Meister & Salviati 2009). Abundant evidence suggests that deforestation contributes to the frequency and severity of flooding and landslides in the region (Arcova et al. 2003; Faria & Marques 1999; Frank 1995; Ministério do Meio Ambiente 2011). Small family farms, few of which comply with Brazil's forest code, account for 87% of all properties and 44% of the land in the state (IBGE, 2006). One cause of deforestation has been declining incomes in rural relative to urban areas, leading farmers to clear more forests in order to increase short term income (Frank 1995). Santa Catarina suffered from catastrophic flooding in November 2008, which official documents describe as the worst tragedy in the state's history, and again in January 2011. The major cause of mortality and economic damage was from landslides, primarily on deforested hillsides, though also on hillsides with secondary forest (Defesa Civil Santa Catarina 2010). The state's major port remains heavily damaged, and as a result the state has lost significant port traffic to its neighbours. Nonetheless, in December of 2008, the state governor attracted national attention by announcing that the state had to choose between "crops or slums", and would therefore significantly reduce legal protection of remaining forests in direct defiance of the national forestry code (Souto 2009). This has triggered a nation-wide debate over the forestry code (Metzger et al. 2010).

1.2 Potential solutions and organization of the chapter

The solution to this conflict between ecological and economic thresholds must lie in developing land uses that simultaneously provide both ecological and economic services. In the context of Santa Catarina's Atlantic Forest, this means restoring some farmland with healthy ecosystems that generate economic benefits, and increasing the ecosystem services generated from agricultural land. However, changing land uses will require significant investments. Small farmers have no surplus capital available, and interest rates in Brazil are among the highest in the world, so simply borrowing money to invest is not a viable option. The solution therefore requires financing as well.

Agroecology and forestry systems offer a potential partial solution to this conflict by providing positive economic returns from ecological restoration and increasing ecological benefits from agricultural land. Unfortunately, markets fail to compensate for the public-good ecosystem services provided by agroecosystems, which means there may be inadequate incentives for adopting agroecology. Payments for Ecosystem Services (PES) that transfer revenue from the beneficiaries of ecosystem services to the individual farmers who provide them have been proposed as a solution to this problem (Pagiola et al. 2004; Pagiola et al. 2007a). One significant challenge to PES is capturing revenue from beneficiaries, especially when the ecosystem services in question are public goods that cross political boundaries. Another challenge is that the broad dissemination of agroecology requires substantial public sector investments in site specific research and development, agricultural extension, infrastructure required to bring products to market, and low risk, low interest financing mechanisms (De Schutter 2010). Individual farmers are unlikely to make public good investments, and the private sector is unlikely to provide affordable finance options. The rapid dissemination of agroecology may therefore require a significantly different type of PES, in which public sectors of those nations that benefit from national and global ecosystem services transfer resources to the public sectors of those regions adopting agroecology practices in order to invest the public goods required to promote it. Furthermore, if funding is needed to promote agroecology, it cannot be made available only after the services have been provided. We need instead a program of public-sector venture capital, in which those governments benefitting from the provision of non-excludable ecosystem services finance their provision, thus sharing the risks as well as the rewards.

This chapter will use a case study of efforts to promote agroecology on the mountain slopes of the coastal range (Encosta da Serra Geral) of Santa Catarina to provide insights into the effective integration of PES and agroecology. Section 2 very briefly describes the case study region. Section 3 discusses Brazil's national forestry code and its implication for ecosystem services and small farmers. Section 4 introduces agroecology; it presents two different agroecology systems, one for farmlands and one for APPs, and provides preliminary results from research into the ecological and economic benefits of recently initiated agroecology projects in the region. Section 5 examines PES as a financing mechanism. It focuses on bundling the services of carbon sequestration, biodiversity, and watershed regulation, and outlines potential payment schemes based on the physical characteristics of the services and institutional constraints.

2. Project Site Description

The Encosta da Serra Geral extends from the north to south in Santa Catarina, roughly parallel to the coast. It retains the State's last vestiges of primary Atlantic Forest, and sustains a wide variety of well-preserved Atlantic Forest ecosystems, ranging from broad leaved forests to mangroves and high altitude grasslands, which in turn support impressive levels of biodiversity and endemism. Our research is concentrated on the region surrounding the 87,405 hectares Parque Estadual da Serra do Tabuleiro (PEST), the largest conservation unit in Santa Catarina, which borders the capital Florianópolis (FATMA no date; Tabarelli et al. 2005). This region is the source of several important rivers, including those responsible for water supply to Florianópolis and a dozen adjacent communities.

The park is bordered by nine municipalities: Florianópolis, Palhoça, Santo Amaro da Imperatriz, Águas Mornas, São Bonifácio, São Martinho, Imaruí, Garopaba and Paulo Lopes (FATMA no date). Municipalities range from some of the wealthiest in the state to some of the poorest. Farming is one of the main sources of income, and is characterized by small family farms with low productivity and few inputs, focused primarily on staple crops and pasture

(Vieira et al. 2007). The Federal University of Santa Catarina (UFSC) has an active agricultural extension program in the region.

3. Brazilian Forestry Code: Implications for Ecosystem Services and Small Farmers

As briefly described in the introduction, the Brazilian Forestry Code (BFC) mandates forest cover in permanent protected areas (APPs) and the Legal Reserve (RL). APPs are intended to preserve hydrological resources, the landscape, geological stability, biodiversity, gene flows of flora and fauna, to protect the soil and to ensure the well-being of human populations (Ministério do Meio Ambiente 2011). Small farmers are allowed to extract non-timber forest products from APPs (CONAMA 369 2006), and to subtract the area in APP from the area required for RL (Brasil, 2001). The RL must be dedicated to the sustainable use of natural resources, the conservation and rehabilitation of ecological processes, the conservation of biodiversity, and shelter and protection for native flora and fauna, but is less restricted in its use than APPs (Metzger 2010). Unfortunately, there is very little enforcement of the BFC in general, and enforcement may be particularly lax in Santa Catarina (Souto 2009). The Brazilian congress is currently debating revisions to the BFC that would significantly weaken current levels of forest protection (Metzger et al. 2010).

If the current BFC were enforced, however, the impact on ecosystem services could be profound. The APP covers 10-20% of the land area in most Atlantic Forest states (Metzger et al. 2009; Tabarelli et al. 2005), and combined with the RL would bring forest cover to over 30%, considered the minimum necessary to avoid crossing critical ecological thresholds in the Atlantic Forest. Riparian forests increase the connectivity of existing forest fragments and their capacity to sustain biodiversity, though a 60-meter corridor may be inadequate for many species. A 30-meter margin does appear adequate however to capture most nitrate runoff from agricultural lands, thus improving water quality (Metzger 2010). Restoring forest cover on slopes and hilltops is likely to reduce landslides and slow runoff during storm events (Sidle & Ochiai 2006; Vanacker et al. 2007). The Atlantic Forest captures and retains airborne moisture, known as hidden rain, which can account for up to 45% of total water in the system. Forest restoration is therefore required to reduce drought and the negative impacts it has on agriculture, quality of life and the ecosystem itself (Anido 2002; Barboza 2007; Cavelier et al. 1996). Reforestation also increases carbon sequestration relative to pasture (May et al. 2005).

The problem is that many farmers in the municipalities surrounding PEST are at or near poverty level, and the APP and RL can make up the majority of the farmland for farms in our study area. In a pilot survey, we found only one farmer was in full compliance with the BFC regulations, while other farmers reported 30-90% in illegal uses, primarily agricultural production. Seventy five per cent of the interviewed farmers reported that compliance with environmental laws would decrease their income by at least 50%. In a separate, more comprehensive survey of farmers in the same region, 90% said they would only comply with the BFC if forced to do so (Farley et al. 2010a). Extensive field experience in the region supports survey results, and suggests that it is extremely difficult for small farmers using conventional technologies to comply with the BFC and remain viable. Agroecology may offer a solution to this problem.

4. Agroecology

The transdisciplinary field of agroecology recognizes that agricultural systems are subsystems of the global ecosystem, and obey the general principles of ecology (Gliessman 2000). Agroecology focuses on the productivity, stability, sustainability and equity of agricultural systems (Marten 1988), paying particular attention to the needs and aspirations of poor farmers in marginal environments (Altieri 2002). This project focuses initially on two agroecology systems. Agroforestry systems in APPs and RLs can increase farmers' income from areas primarily dedicated to conserving and restoring ecosystem services. Management intensive grazing (MIG), also know as Voisin grazing, can increase both ecosystem services and economic returns on established pasturelands.

In terms of figure 1, agroecology reduces the ecological costs of agriculture, thus shifting the ecological threshold and supply curve to the right. Agroecology also increases the monetary returns to agriculture and creates a new source of revenue from the APPs, shifting the poverty threshold and demand curve to the left. The result is the potential for socially and ecologically acceptable solutions, depicted in figure 2, in which there is no longer an unavoidable trade-off between ecological and economic thresholds.

(Figure 2 about here)

4.1 Agroforestry systems

While there are a wide variety of agroforestry systems (AFS), our goal is to adopt a successional approach prioritizing native species providing non-timber forest products, which seeks to recreate the structure and function of Atlantic Forest riparian zones and hence restore the full suite of ecosystem services they provide. Such systems in Brazil have been shown to eliminate the use of pesticides and fertilizers, filter polluted runoff into waterways, provide habitat for native flora and fauna, and sequester carbon, among other benefits (Bittencourt 2007; May & Trovatto 2008; May et al. 2005; Rodrigues et al. 2007).

Campello et al. (2007) estimated that implementing a successional AFS in the Atlantic Forest in which bananas and pineapples are succeeded by other fruit trees and timber species costs about R$13,500 (~US$7500) per hectare to implement with positive and increasing financial returns after only two years. May et al. (2005) estimated an internal rate of return of 18.4% for AFS relative to conventional agricultural in the Atlantic Forest of Rio de Janeiro.

A particularly promising species for AFS in Santa Catarina is the native jussara palm trees (*Euterpe edulis*), used for its fruit (marketed as açai[1]) and for heart of palm. Açai fruit is extremely high in anti-oxidants, shows rapid market growth in Brazil, and promises even more rapid growth as an export crop. The tree grows in the shade and has a small crown allowing other crops to thrive, even when planted at high densities, and production is highly profitable (Homma et al. 2006)[2]. Açai palms produce an average of four kilos of fruit per year, with prices ranging from R$ 0.70 for raw fruit to R$ 4.00 for frozen pulp. A density of 1000 trees per hectare allows for intercropping with other species, and earns from R$2800 to $16000 (about US $1500-8900), depending on the degree of processing (Fadden 2005). The açai palm is only one of dozens of

[1] The true açai palm (Euterpe oleracea) is found farther to the north, but we will refer to the fruit of E. edulis by its market name.

[2] Note that Homma is referring to Euterpe oleracea, native to northern Brazil. However, Euterpe edulis, native to southern Brazil, is quite similar. All other references are to E. edulis.

species native to the Atlantic Forest biome that can provide food and other non-timber products, though for many of these other species the lack of markets remains a problem.

The dominant costs in all the systems described above are labour and seedlings. Campello calculates that if labour costs are borne by family farmers and seedlings are found on site, implementation costs fall to R$1500/ha. Fortunately, through government/NGO partnerships, the region already has a "Viveiros Nativos" (Native Nurseries) project which produces high quality native seedlings at accessible prices (Vieira et al. 2007). Preliminary interviews suggest that regional farmers are particularly interested in açai production, and prone to plant their riparian zones if seedlings are provided.

Bringing all family farmers into compliance with the BFC through agroforesty projects could substantially reduce the threats of biodiversity and ecosystem collapse in the Atlantic Forest. There are currently two sources of incentives for farmers to comply: potential returns to agroforestry and fear over penalties for non-compliance. We are in the process of developing agroforestry systems with native species in an effort to improve the returns to agroforestry and set up pilot projects for educating farmers. However, scaling up our efforts to where they could have a significant impact would require some combination of more agroforestry extensionists with more resources for farmer education, better sources of finance, payments for the ecosystem services provided by agroforestry, or greater threats of punishment for non-compliance with the BFC.

4.2 Voisin Grazing Management

Pasture for milk and beef production accounts for nearly half the land use in the region study area. Soil erosion from lack of vegetation, applications of pesticides and fertilizers, use of rivers and springs as watering holes, and continuing deforestation of native forest for pasture all have serious environmental impacts (Pinheiro Machado 2004). Furthermore, economic returns from conventional pasture are generally quite low. EMBRAPA (2006) estimates that average returns from traditional cattle production in Brazil ranging from R$ 18 to R$ 180/ha-yr (~US$10-100).

A more ecologically and economically viable alternative is managing intensive grazing (MIG), in which pastures are divided into numerous plots with fences. Water is pumped to tanks in each plot to keep cattle away from riparian zones. Cattle are moved from pasture to pasture, mimicking their movements in nature and maximizing pasture growth rates. The resulting increase in pasture-grass biodiversity both increases and stabilizes production (Tilman & Downing 1994). Pasture is never allowed to be overgrazed, ensuring better ground cover, less erosion, and better capture of nutrients from manure, reducing the need for fertilizers. Stock rotation interrupts the reproductive cycle of insect pests, reducing the need for pesticides, while healthier, more biodiverse pasture reduces the need for fertilizers and herbicides. More productive pastures actually increase soil carbon content, sequestering CO_2 from the atmosphere (Lenzi 2003; Melado 2000; Melado 2007; Pinheiro Machado 2004).

On the economic side, MIG increases output while decreasing inputs. Extension professors at UFSC have implemented MIG projects in over 500 properties in the region. Initial surveys of participating dairy farmers (n=67) found that 91% were able to increase the number of cows per hectare, and 90% increased yield per cow total yield and revenue (Alvez, 2011 unpublished); 49% of farmers stated that labour requirements decreased, while 27% stated they had increased; 8% of farmers claimed that pasture grass improved in quality, 25% that it increased in quantity, and 65% that both quantity and quality improved greatly. Concerning herd health, the vast majority of farmers found that ticks, horn-flies (*Haematobia irritans*), worms and mastitis all decreased, in many cases significantly, while no more than 5% found that any of these diseases had increased. Over 98% of farmers said that their initial investment was generating the desired returns or more. Nearly 70% of farmers repaid the initial investment in the first year, and over 87% did so within two years. Perhaps most important, 85% claimed that the project improved their quality of life.

The same surveys also confirmed the positive ecological impacts. Prior to adoption of MIG, 73% of farmers used pesticides, 28% over the entire pasture; after adoption these numbers fell to 54% and 3% respectively. Over 72% of farmers claimed that manure decayed faster after MIG, and over 85% claimed their soil was moister during droughts. Total vegetation coverage increased from under 2% of pastures to over 72%, while areas with scant coverage decreased from over 73% to less than 2%. Over 85% of farmers noticed an improvement in soil quality.

Silvo-pastoral intensive grazing (SIG) systems further increase ecological and economic benefits. Silvopastoral systems combine fodder plants with trees and shrubs for animal nutrition and complimentary uses (i.e.: fodder banks, live fences, windbreaks, etc.) (Pagiola et al. 2007b). Trees provide essential shade for the cows, protect pastures from drying, cycle nutrients from deeper soil layers to the surface, provide additional fodder, and can also produce fruits and wood. Improved shade cover alone can increase production by 20% (Freitas 2008; Melado 2007; Pinheiro Machado 2004). We are currently initiating an experimental SIG system utilizing 60 different native species, including açai.

Implementing SIG or other agroecological production techniques on all degraded pastures in the case study area could dramatically increase the flow of ecosystem services from farmland. The evidence presented here suggests that the agroecology systems are more profitable than the agricultural systems they replace, and there is a convergence between private and social land use decisions. However, the vast majority of small family farmers in Santa Catarina's Atlantic Forest have not yet adopted them. Our research suggests that the major obstacles to the spread of SIG include the up-front investment costs and the time lag before the systems begin producing, which can be particularly problematic in Brazil where interest rates on loans can easily exceed 40% (Dantas 2010); the lack of education and extension services, whose costs were ignored in the results above; and the poor infrastructure which makes it difficult to get products to market (especially milk) or to add value.

5. Payments for Ecosystem Services

An increasingly popular approach to improving the provision of ecosystem services is simply to pay for them or for land uses associated with their provision (Engel et al. 2008; Ferraro & Kiss 2002). Hundreds of PES and PES-like schemes exist around the world (Duncan 2006; Landell-Mills & Porras 2002; Pagiola et al. 2002; Porras et al. 2008). In Brazil for example, the "Cordão de Mata" project has negotiated forest conservation easements with dairy farmers in the Atlantic Forest (Jenkins et al. 2004), the are numerous examples of public payments for water regulation services, and a number of Brazilian states have adopted an innovative PES scheme known as the ICMS ecológico, in which a portion of state sales taxes are refunded to municipalities roughly in proportion to the ecosystem services they generate (Loureiro 2002; May et al. 2002; Ring 2008). An appropriate PES scheme could finance and complement the adoption of agroecology projects.

There are two general approaches to PES, one based on trying to force ecosystem services into the market model with the goal of increasing economic efficiency, and the other based on adapting economic instruments to the specific characteristics of ecosystem services (e.g. rivalry, excludability and spatial distribution) in order to achieve a variety of goals, such as sustainability, justice and efficiency (Farley & Costanza 2010). The nature of the investments required to protect or restore ecosystem services also matter. If protecting ecosystems requires investments in private goods, then payments to private landowners may be appropriate. However, if the required investments are public goods, then the private sector is likely to under-invest, and payments to individuals may be inappropriate (Farley et al. 2011).

Proponents of market approaches recognize the market failures affecting the provision of ecosystem services, but believe "that the conditions that underlie market failure, namely non-rivalry and non-excludability, are dynamic" (Landell-Mills & Porras 2002 p. 11). The fact is however that rivalry is a purely physical characteristic, and not at all dynamic. For example, information is never depleted by use, but timber always is.[3] Excludability is in some cases a dynamic policy variable, but some ecosystem services, such as climate regulation, are inherently non-excludable as an immutable physical characteristic (Daly & Farley 2010; Farley & Costanza 2010). Only a minority of ecosystem services fit the market model, and we cannot change their inherent physical characteristics to improve their fit.

Furthermore, the investments required to promote agroecology, such as R&D, extension services, and infrastructure, have strong public good characteristics, and thus also fail to fit the market model of PES. There are real costs to protecting and restoring most ecosystem services and to developing and disseminating agroecology, and someone must pay them, but market-like mechanisms will generally be inappropriate. Instead, we should adapt economic institutions both to the physical characteristics of the services provided (e.g. rivalry, excludability and spatial distribution) and to the characteristics of the investments required to provide the services (e.g. public or private). We therefore follow Muradian et al. (2010) in defining PES as "a transfer of resources between social actors, which aims to create incentives to align individual and/or collective land use decisions with the social interest in the management of natural resources" (p. 1205). This definition allows for payments by the public sector in regions that benefit from ecosystem services and payments to the public sectors of regions that generate them. Some of the literature argues that private sector PES is more effective and efficient than PES schemes that involve the public sector (Engel et al. 2008; Wunder et al. 2008), but one would expect this result simply because collective action problems concerning non-rival or non-excludable resources are inherently more difficult to solve.

In the following sections we break down the problem of using PES to promote agroecology in Santa Catarina into two components: How to capture revenue from beneficiaries, and how to disburse payments to providers.

5.1 Capturing Revenue from Beneficiaries

As discussed in the introduction, the private sector is unlikely to voluntarily pay for the provision of non-excludable ecosystem services such as flood regulation, climate regulation or the ecological resilience promoted by biodiversity. Non-excludable services are open access by definition, and cannot be rationed among users. Price rationing and hence market based payment

---

[3] The error many economists make is confusing abundance with non-rivalry. For example, oxygen is currently abundant in the sense that my use does not affect your use, but it is also rival, because my use of oxygen transforms it into CO_2, leaving less for you to breath. When oxygen becomes scarce, such as when miners are trapped in a cave-in, the rivalry becomes obvious, but in normal conditions of abundance, it appears non-rival. The physical characteristic of oxygen as a rival resource cannot be affected by policy.

schemes are not an option. Instead, collective economic institutions are required, either to create and enforce excludable property rights so that market based payment schemes are possible, or to collectively pay for the provision of the open access services. The biggest challenge to collective action may well be the spatial distribution of the ecosystem services generated, which ignore political boundaries, sometimes covering only part of a political jurisdiction, and sometimes crossing over into several, both national and global. In either case, conventional models for public sector provision of public goods are sub-optimal (Olson 1969).

However, the fact that an ecosystem service can be made excludable does not automatically mean that market payments for the service are a good idea. If a service is non-rival, then using prices to ration access creates artificial scarcity, and paradoxically diminishes the monetary value of the service as measured by economic surplus (Daly & Farley 2010; Kubiszewski et al. 2010). If a service provides a commodity that is rival but also essential with limited possibilities for substitution, such as drinking water, then markets may systematically exclude the poor, depriving them of basic needs. If we accept the law of diminishing marginal utility, this may be inefficient as well as unjust.

Ecosystem services provided by agroecology cover all possible combinations of rivalry and excludability and all possible spatial distributions. This suggests that a variety of different approaches will be required to capture revenue from beneficiaries. We explore four different types of services.

5.2.3 Provisioning Services

Agroecology of course provides food, fibre and/or fuels directly to the landowners who adopt it, all of which are clearly market goods. Our research in Santa Catarina suggests that agroecology increases farmer income, which means that there is no opportunity cost from land use change. However, the investments required to develop agroecology are frequently public goods. National and State governments have historically invested in the public good R&D and infrastructure required for agriculture with an exceptional track record. In fact, it is public support of agriculture extension conducted by the Federal University of Santa Catarina that has made our project viable. A global meta-analysis found that rates of return to public sector agricultural R&D average 43% (Alston et al. 2000). Returns to public-good investments in rural Latin America are similarly high and non-declining. However, many government expenditures are used to subsidize private goods (e.g. fertilizers, pesticides), with low or even negative social returns, in part because such subsidies are readily targeted towards politically influential (i.e. wealthy) farmers (López & Galinato 2007; World Bank 2007). Simply shifting existing expenditures from subsidies to public investments could increase agricultural output by more than 40% in some Latin American countries. In fact research shows that "reducing the share of subsidies to private goods in the government's budget has a large and significant positive impact on rural per capita income, reduces certain undesirable environmental effects associated with output expansion, and contributes to poverty reduction." (López & Galinato 2007, p. 1072)

Another potential source of revenue is from consumers willing to pay a premium for certified 'green', organic, fair, or sustainable products. To be effective however, the premium must cover the costs of certification and verification, which can be high. Though the market in certified products has increased 200% in the last decade, it still represents only 2.5% of the global food and beverage market (Caroll 2008). In Santa Catarina, certification of agroecological products already exists under the label Ecovida. Many consumers buy such products for their health impacts, a private benefit, rather than for the ecosystem services they provide. This may be particularly true in Brazil, which has the world's highest use of agro-toxins (Pacheco 2009). To the extent that consumers are self-interested, they are unlikely to pay extra for the provision of public goods. Relying on altruistic behaviour may contribute to solving the problem but is unlikely to generate adequate revenue by itself.

5.2.3 Watershed Services

The recently adopted State Policy on Ecosystem Services in Santa Catarina (law 15.133/2010) covers a variety of ecosystem services, but its first application in March 2011 was for water regulation. Payments are made by the municipal water and sewage utility of the town São Bento do Sul to farmers willing to restore land in the APP along the Rio Vermelho river.

PES for water regulation is fairly straightforward. Water for household use is typically controlled by a water utility, which is a monopolistic (ideally publicly owned or regulated) intermediary between service providers and service beneficiaries, and can therefore serve as the monopsonistic purchaser of the land uses that improve water quality and stabilize water flow. A monopsony occurs when one buyer faces many sellers. While monopsonies in conventional market goods are undesirable because they allow the purchasers to set prices, upstream land owners can choose between current land uses or those that provide water, and hence need not accept the price offered by the monopsonist (Kemkes 2008). By passing price increases on to consumers, these utilities can ensure that all beneficiaries contribute to the payment. Since municipal water use is rival, payments for each unit used are appropriate as long as the poor are still able to satisfy their basic needs.

Tap water quality is notoriously poor in some of the municipalities in our research area. For example, in Paulo Lopes, none of the major municipal water sources regularly meets basic standards for coliform content or PH, and water-borne parasites are a major health problem. There is no testing for pesticides and other chemicals that are likely present as well. Much of the riparian zone of the rivers supplying water is deforested, with direct access for farm animals to the water (Vieira et al. 2007). Reforestation could potentially improve water supply for a lower cost than filtration and purification plants, as was the case for New York City (Chichilnisky & Heal 2000). One must be cautious when charging individual households the full cost for water provisions however, because water is essential and non-substitutable. Increasing water prices can potentially cause serious financial difficulties for the poor, who may receive the greatest marginal utility from clean water, but have the least capacity to pay.

Flood regulation in contrast is a pure public good service. If a forested watershed reduces flooding, there is no way to exclude specific groups or individuals in the floodplain from benefitting from this service, and one beneficiary's use does not leave less for others. The spatial distribution of flood regulation and hence the beneficiaries are easily identified, but there is no collective institution that represents solely those beneficiaries. In general, municipal, state and federal governments respond to floods with assistance for flood victims and rebuilding of public infrastructure, and hence are the appropriate collective institutions to pay for the reforestation which can reduce the incidence and severity of both flood events and the associated landslides that cause much of the damage. However, since watersheds typically cross numerous municipal borders in Santa Catarina, some form of state or federal payment may be most appropriate. To more accurately target revenue capture, it would be possible to impose a surtax on land in floodplains. We do not currently know of any PES schemes for flood regulation in Santa Catarina.

5.2.1 Carbon sequestration

The primary goal of carbon sequestration is to provide climate regulation, but the two are distinct services with distinct characteristics (Farley et al. 2010b). Climate regulation is an example of a pure global public good, both non-rival and non-excludable, so markets will not provide it. The global community must do so collectively. One possibility is for global institutions such as the Global Environmental Facility to finance climate regulation projects directly (UNDP-GEF 1998). The GEF is in fact financing relevant projects in Brazil, including a riparian forest restoration project in São Paulo (World Bank 2005). However, funding is based on grant proposals, reviewed by the centralized GEF bureaucracy. Grant writing skills may be more important than project viability, and the resources dedicated are negligible relative to the scale of the problem (Farley et al. 2010c).

Carbon sequestration in contrast is rival: if one country or firm uses an ecosystem's carbon sequestration capacity, there is less left for another to use. Collective institutions such as the Kyoto Protocol or the European Union are capable of making carbon waste absorption capacity excludable by capping the total amount of carbon that can be emitted, then auctioning off or assigning the right to emit in the form of emission certificates. Such caps allow price rationing of existing absorption capacity, and also allow firms in relevant[4] Kyoto Protocol signatory countries to pay for carbon sequestration if it is cheaper than purchasing emission certificates or reducing emissions. This has led to the emergence of carbon markets. The price of carbon however does not reflect the marginal benefits of carbon sequestration, but rather the political will to cap emissions. Existing caps are far too lenient to prevent runaway climate change (IPCC 2007), and carbon prices are correspondingly low. Furthermore, transactions costs to negotiate, monitor and enforce sequestration projects can be very high, particularly in the case of small family farmers.

While Santa Catarina's new PES law includes carbon sequestration as one of the targeted ecosystem services, the benefits of the service clearly cross political boundaries, so Santa Catarina is likely to under-invest in its provision in the absence of national or global agreements that force it to do so. Only more stringent global agreements are likely to create adequate payments for carbon sequestration.

5.2.2 Biodiversity conservation

Agroecology practices can enhance both species richness and abundance in a variety of agricultural landscapes (Batáry et al. 2011), and high yielding agroforestry projects can also promote high biodiversity (Clough et al. 2011). Furthermore, genetic information, essential for breeding new varieties of plants and animals capable of improving yields, ecosystem services and resilience, is a critical input into agroecology schemes. The Santa Catarina PES scheme includes biodiversity as a targeted service.

There are four basic types of PES schemes for biodiversity, reflecting in part the distinct physical characteristics of different aspects of biodiversity: private payments for bio-prospecting rights to genetic information, biodiversity offsets, conservation financing by collective institutions (including governments, NGOs and international institutions) that target the general public good benefits of biodiversity, and private payments for biodiversity friendly products (Landell-Mills & Porras 2002). Each of these has different characteristics and different mechanisms for collecting revenue.

[4] Annex I countries, which are the industrialized nations required to reduce emissions (UNFCCC, 1998).

Though genetic information is non-rival, global institutions make it excludable and hence amenable to private sector PES schemes. Clear laws and policies concerning genetic information facilitate such market-like transactions (Landell-Mills & Porras 2002). However, making genetic information freely available to all agroecology projects is required to maximize its value. Market payment schemes may provide some incentive for protecting biodiversity, but also reduce its value. National efforts to protect genetic information can further reduce its value by leading to restrictions on ecological research (Ten Kate 2002). Genetic information is best treated as a global public good, with global collective institutions contributing to its provision (Farley et al. 2011).

Biodiversity offsets function much like carbon offsets. A collective institution limits the total amount of habitat (e.g. wetlands) that can be converted for individual property owners or for society as a whole. Someone can exceed this limit only if they pay for restoration or conservation elsewhere. The Brazilian Forestry Code (BFC) currently permits such markets in legal reserves (RL). One major problem with such markets is that regulators are almost solely responsible for compliance; providers have an incentive to provide and purchasers to purchase the lowest quality that meets regulator standards (King & Kuch 2003). Another problem is the lack of incentive to engage in such markets when the BFC is not enforced.

Collective institutions currently finance most biodiversity conservation, as is appropriate for the largely non-rival, non-excludable global public good benefits it provides. The GEF is the main source of multilateral financing for biodiversity conservation, but is only able to solicit voluntary contributions from primarily wealthy nations. Global NGOs also play an important role, but collect only voluntary payments primarily from individuals and foundations. As a result, current global expenditure on biodiversity conservation are in the neighbourhood of $10 billion annually (Pearce 2007), while an estimated $317 billion/year would be required to maintain global biodiversity and evolutionary potential (James et al. 2001). Balmford et al. (2002) estimate that the social returns on the first $45 billion in annual investments would be 100:1. This suggests the need for a collective institution capable of mandating payments from all beneficiaries with ability to pay, essentially the wealthy nations, but no such institutions yet exists.

In summary, multiple funding streams are available for the different ecosystem services provided by agroecology. However, each one of them falls short of what would be required for optimal provision of a given service, much less for the optimal provision of all the ecosystem services generated by agroecology. The solution it seems would be to bundle the payments for all of these ecosystem services to generate the revenue necessary to fund the large-scale adoption of agroecology. It may cost little more to provide multiple services than to provide a single one (Venter et al. 2009). Both carbon markets and the GEF demand additionality, which is to say that one must prove the activities would not have occurred without the payment. Since no single payment stream is likely to cover the full opportunity costs of changing land uses, a case can be made for the additionality for each separate stream. Even if proves possible to bundle the revenue flows from each service, the challenge remains of investing the revenue where it is most capable of promoting agroecology. This will require particularly effective disbursement mechanisms.

5.2 Disbursement Mechanisms for Payments

While some PES schemes target community groups and cooperatives, and Brazil's ICMS ecológico targets municipalities, much of the literature on PES suggests that the gold standard is payments to individual landowners contingent upon service provision (Wunder et al. 2008). However, the appropriate recipient depends on the nature of the investments needed to promote the desired land uses, on transaction costs, and on the likely durability of the payments, which in the case of payments for public goods depend largely on political will. Furthermore, making payments contingent upon service provision will only work when the level of investment required to adopt the desired land use can be financed entirely by providers prior to receiving compensation.

As pointed out above and as discussed in the literature (De Schutter 2010; IAASTD 2008; Vanloqueren & Baret 2009; World Bank 2007), the broad dissemination of agroecology is best promoted by investments in public goods. Agroecology demands intensive knowledge of local ecosystems, cultures and markets. It is best spread from farmer to farmer, catalysed and facilitated by agricultural extensionists. The major requirements for disseminating agroecology are investments in R&D, agricultural extension, infrastructure required to bring products to market and low risk, low interest financing mechanisms. Payments to individual farmers do little to provide these services, especially if they are contingent upon provision. Public sector investments are required.

Since the public goods provided by these investments cross political boundaries, payments for these investments should flow from those governments or collective institutions that benefit to those that will provide the services, supplementing resources invested by the latter. This is known as an intergovernmental fiscal transfer, and was originally proposed for investments in cross-boundary public goods, not as payments for goods received (Olson 1969). Investments in agroecology promise very high returns in both crop yields and ecosystem services, but are risky. For governments in the regions providing the services, the risk is that these investments will provide lower monetary returns than those generated by public sector investments in more conventional agriculture. For the governments in the regions receiving the services, the risk is that agroecology practices will not be adopted, or will not generate the ecosystem services desired. If the efforts succeed, both sides can benefit, but the initial risk should be shared, which is in fact another goal of intergovernmental fiscal transfers (Bird & Smart 2002). We therefore propose a redesign of PES as a form of public-sector venture capital, in which wealthy countries and national governments that benefit from the ecosystem services agroecology provides transfer resources to less wealthy countries and local governments otherwise unable to fully finance the necessary public sector investments.

The goal of sharing risk should also scale down to the local level. Farmers investing in agroecology are risking the known returns from their current practices, and must invest both their land and labour. National or local governments should provide low interest, minimal risk loans to farmers adopting agroecology. Repayment schedules and interest rates would be determined by the increase in market returns attributable to agroecology. Brazil has already begun to provide low interest loans for agroforestry, but in insufficient quantities to restore the Atlantic Forest as rapidly as may be required to avoid crossing critical thresholds.

For the proposed transfers to be effective, recipient governments should have "a clear mandate, adequate resources, sufficient flexibility to make decisions and [be held] accountable for results" (Bird & Smart 2002, p. 899). The clear mandate must be to invest these resources in the public goods required to promote agroecology. Flexibility is increased by maximizing the input of local governments into investment decisions, based on the needs of their constituents. For international transfers, accountability for results is more difficult. Since many of the ecosystem services are local and regional, the governments providing the services would certainly have every incentive to succeed even without accountability. To increase this incentive, recipient governments could be allowed to sell a share of the carbon sequestered on carbon markets. Carbon payments to governments would incur far smaller transaction costs than payments to individual landowners, especially when land holdings are small and land tenure is weak.

Our suggestions are partially modelled after Brazil's ICMS ecológico, in which some Brazilian states transfer a share of the state sales tax to municipalities according to how effectively they provide ecosystem services. The approach has been very cost-effective, with minimal transaction costs. This system however rewards states after they have protected ecosystems, and does not provide the up-front resources necessary to do so (Farley et al. 2010c; Ring 2008).

There are two final reasons to promote agroecology over more conventional ecosystem restoration. First, if the political will for PES falters in the future, maintaining agroecosystems is justified by their higher returns even in the absence of payments. Second, food is a globally traded commodity. If all Brazilian farmers complied with the national forestry code, it could have an impact on global food production, leading to dramatic price increases due to the inelastic demand for food. Ecosystems around the planet must be restored, and agroecology may be the only approach that will simultaneously allow continued food production. Those governments that finance agroecology will benefit both from more ecosystem services and lower food prices.

In summary, there are no longer acceptable trade offs between agriculture and ecosystem services: both are essential and at risk. Agroecology may be uniquely capable of providing both. There are real costs to promoting agroecology that someone must pay, but any payment scheme must recognize that many of the services provided as well as the resources required to provide them are both public goods.

References

Alston, J. M., M. C. Marra, P. G. Pardey, and T. J. Wyatt. 2000. Research returns redux: a meta-analysis of the returns to agricultural R&D. Australian Journal of Agricultural and Resource Economics **44**:185-215.

Altieri, M. A. 2002. Agroecology: the science of natural resource management for poor farmers in marginal environments. Agriculture, Ecosystems & Environment **93**:1-24.

Anido, R. N. M. 2002. Caracterização hidrológica em uma microbacia experimental visando identificar indicadores de monitoramento ambiental. Page 69. Agriculture. Universidade de São Paulo.

Arcova, F. C. S., V. Cicco, and P. A. Rocha. 2003. Precipitação efetiva e interceptação das chuvas por floresta de Mata Atlântica em uma microbacia experimental em Cunha. Revista Arvore **27**.

Barboza, R. S. C. 2007. aracterização das Bacias Aéreas e Avaliação da Chuva Oculta nos Contrafortes da Serra do Mar – RJ. UFRRJ, Rio de Janeiro.

Batáry, P., A. Báldi, D. Kleijn, and T. Tscharntke. 2011. Landscape-moderated biodiversity effects of agri-environmental management: a meta-analysis. Proceedings of the Royal Society B: Biological Sciences **278**:1894-1902.

Bird, R. M., and M. Smart. 2002. Intergovernmental Fiscal Transfers: International Lessons for Developing Countries. World Development **30**:899-912.

Bittencourt, M. C. 2007. Avaliação de serviços ambientais gerados por unidades de produção familiar participantes do programa Proambiente no estado do Pará – Jaguariúna. Embrapa Meio Ambiente.

Brooks, T., and A. Balmford. 1996. Atlantic forest extinctions. Nature **380**:115-115.

Campello, E. F., G. T. A. Silva, P. O. Nobrega, A. L. M. Vieira, A. A. Franco, and A. S. Resende 2007. Sistemas Agroflorestais na Mata Atlântica: a experiência da Embrapa Agrobiologia. Circular Técnica 2. Seropédica, RJ.

Cavelier, J., D. Solis, and M. A. Jaramilo. 1996. Fog interception in montane forest across the central cordillera of Panamá. . Journal of Tropical Ecology:357-369.

Chichilnisky, G., and G. Heal, editors. 2000. Environmental Markets. Columbia University Press, NY.

Clough, Y., J. Barkmann, J. Juhrbandt, M. Kessler, T. C. Wanger, A. Anshary, D. Buchori, D. Cicuzza, K. Darras, D. D. Putra, S. Erasmi, R. Pitopang, C. Schmidt, C. H. Schulze, D. Seidel, I. Steffan-Dewenter, K. Stenchly, S. Vidal, M. Weist, A. C. Wielgoss, and T. Tscharntke. 2011. Combining high biodiversity with high yields in tropical agroforests. Proceedings of the National Academy of Sciences **108**:8311-8316.

Conservation International. 2001. Ecosystem Profile: Atlantic Forest.

Costa, L. P., Y. L. R. Leite, S. L. Mendes, and A. D. Ditchfield. 2005. Mammal Conservation in Brazil. **19**:672-679.

da Silva, J. M. C., and M. Tabarelli. 2000. Tree species impoverishment and the future flora of the Atlantic forest of northeast Brazil. Nature **404**:72-74.

Daly, H., and J. Farley 2010. Ecological Economics: Principles and Applications: 2nd edition. Island Press, Washington, DC.

Dantas, I. 2010. Brazil Interest Rates to Consumers Rise, Credit Jumps. Bloomberg. Retrieved from http://www.bloomberg.com/news/2010-11-29/brazil-interest-rates-to-consumers-rise-credit-jumps-update1-.html.

De Schutter, O. 2010. Report submitted by the Special Rapporteur on the right to food. United Nations Human Right Council, NY.

Defesa Civil Santa Catarina. 2010. Enchentes 2008. on-line: http://www.desastre.sc.gov.br/.

EMBRAPA, editor. 2006. Bovinocultura. Coeficientes técnicos, custos, rendimentos e rentabilidade. Sistemas de Produção, 4 - 2ª Edição. Embrapa Amazônia Oriental.

Engel, S., S. Pagiola, and S. Wunder. 2008. Designing payments for environmental services in theory and practice: An overview of the issues. Ecological Economics **65**:663-674.

Fadden, J. M. 2005. A Produção de açaí a partir do processamento dos frutos do palmiteiro (Euterpe edulis Martius) na Mata Atlântica. Agronomia. UFSC, Florianópolis.

FAO. 2011. How to Feed the World in 2050. on line:http://www.scp-knowledge.eu/sites/default/files/knowledge/attachments/How%20to%20Feed%20the%20World%20in%202050.pdf.

Farber, S. C., R. Costanza, and M. A. Wilson. 2002. Economic and ecological concepts for valuing ecosystem services. Ecological Economics **41**:375-392.

Faria, A., and J. Marques. 1999. O Desaparecimento de pequenos rios brasileiros. Ciência Hoje **25**:56-61.

Farley, J., A. Schmitt F., J. P. Alvez, and P. M. Rebola. 2010a. The farmer's viewpoint: Payments for ecosystem services and agroecologic pasture based dairy production. Advances in Animal Biosciences **1**:490-491.

Farley, J., A. Aquino, A. Daniels, A. Moulaert, D. Lee, and A. Krause. 2010b. Global mechanisms for sustaining and enhancing PES schemes. Ecological Economics **this issue**.

Farley, J., A. Aquino, A. Daniels, A. Moulaert, D. Lee, and A. Krause. 2010c. Global mechanisms for sustaining and enhancing PES schemes. Ecological Economics **69**:2075-2084.

Farley, J., and R. Costanza. 2010. Payments for Ecosystem Services: From the Local to the Global. Ecological Economics (in press).

Farley, J., A. Schmitt Filho, Juan Alvez, and N. Ribeiro de Freitas, Jr. 2011. How Valuing Nature Can Transform Agriculture. Solutions **2**:64-73.

FATMA. no date. Parque Estadual da Serra do Tabuleiro Fundacao do Meio Ambiente, Florianopolis, Santa Catarina.

Folke, C. 2006. Resilience: The emergence of a perspective for social-ecological systems analyses. Global Environmental Change-Human and Policy Dimensions **16**:253-267.

Frank, B. 1995. Uma abordagem para o Gerenciamento Ambiental da Bacia Hidrográfica do Rio Itajaí, com ênfase no Problema Enchentes. Engenharia. UFSC, Florianópolis.

Freitas, L. A. S. 2008. A Construção Participativa de Arranjos Silvipastoris em São Bonifácio – SC. Page 123. Zootechnology. UFSC, Florianópolis.

Gliessman, S. 2007. Agroecology: the ecology of sustainable food syste. CRC Press, Boca Raton, Florida.

Gliessman, S. R. 2000. Agroecology: ecological processes in sustainable agriculture. CRC Press LLC, Boca Raton.

Homma, A. K. O., O. L. Nogueira, A. J. E. A. d. Menezes, J. E. U. d. Carvalho, C. M. L. Nicoli, and G. B. d. Matos. 2006. Açaí: Novos Desafios e Tendências. Amazônia: Ciencias & Desenvolvimento, Belém **1**:7-33.

IAASTD. 2008. Executive Summary of the Synthesis Report of the International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD). . Available on http://www.agassessment.org. vailable on http://www.agassessment.org.

IPCC 2007. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change Cambridge University Press, Cambridge.

James, A., K. J. Gaston, and A. Balmford. 2001. Can We Afford to Conserve Biodiversity? BioScience **51**:43-52.

Jenkins, M., S. J. Scherr, and M. Inbar. 2004 Markets for Biodiversity Services: Potential Roles and Challenges. Environment **46**:32-42.

Kemkes, R. J. 2008. Policy Tool Choice for Ecosystem Service Provision: Payments and Public Information. Masters Thesis. Community Development and Applied Economics. University of Vermont, Burlington.

King, D. M., and P. J. Kuch. 2003. Will Nutrient Credit Trading Ever Work? An Assessment of Supply and Demand Problems and Institutional Obstacles. Environmental Law Reporter:10352-10368.

Kubiszewski, I., J. Farley, and R. Costanza. 2010. The production and allocation of information as a good that is enhanced with increased use. Ecological Economics **69**:1344-1354.

Landell-Mills, N., and I. T. Porras 2002. Silver Bullet or Fools' Gold? A Global Review of Markets for Forest Environmental Services and their Impact on the Poor. International Institute for Environment and Development London.

Laurance, W. F. 1999. Reflections on the tropical deforestation crisis. Biological Conservation **91**:109-117.

Lenzi, A. 2003. Desempenho animal e produção de forragem em dois sistemas de uso da pastagem: Pastejo Contínuo & Pastoreio Racional Voisin. Page 122. Zootechnology. UFSC, Florianópolis.

Limburg, K. E., R. V. O'Neill, R. Costanza, and S. Farber. 2002. Complex systems and valuation. Ecological Economics **41**:409-420.

López, R., and G. I. Galinato. 2007. Should governments stop subsidies to private goods? Evidence from rural Latin America. Journal of Public Economics **91**:1071-1094.

MacArthur, R. H., and E. O. Wilson 2001. Island Biogeography. Princeton University Press, Princeton, New Jersey.

Marten, G. G. 1988. Productivity, stability, sustainability, equitability and autonomy as properties for agroecosystem assessment. Agricultural Systems **26**:291-316.

May, P., and C. Trovatto, editors. 2008. Manual Agroflorestal para a Mata Atlântica. Ministério de Desenvolvimento Agrário, Brasília, DF.

May, P. H., C. B. Bohrer, K. Tanizaki, J. C. L. Dubois, M. P. M. Landi, S. Campagnani, S. N. O. Neto, and V. G. d. Vinha. 2005. Sistemas Agroflorestais e Reflorestamento para Captura de Carbono e Geração de Renda. CPDA-UFRRJ. on-line at http://www.ecoeco.org.br/conteudo/publicacoes/encontros/vi_en/mesa2/Sistemas_agroflorestais_e_Carbono.pdf

MEA, M. E. A. 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC.

Meister, K., and V. Salviati. 2009. O Investimento Privado e a Restauração da Mata Atlântica no Brasil. Revista Intertox de Toxicologia, Risco Ambiental e Sociedade **2**.

Melado, J. 2000. Manejo de Pastagem Ecológica – Um Conceito Para o Terceiro Milênio. Aprenda Fácil Editora, Viçosa – MG.

Melado, J. 2007. Pastagem Ecológica e serviços ambientais da pecuária sustentável. Rev. Bras. de Agroecologia **2**.

Metzger, J. P. 2010. O Código Florestal tem base científica? Conservação e Natureza **8**:preface.

Metzger, J. P., T. M. Lewinsohn, C. A. Joly, L. M. Verdade, L. A. Martinelli, and R. R. Rodrigues. 2010. Brazilian Law: Full Speed in Reverse? Science **329**:276-277.

Metzger, J. P., A. C. Martensen, M. Dixo, L. C. Bernacci, M. C. Ribeiro, A. M. G. Teixeira, and R. Pardini. 2009. Time-lag in biological responses to landscape changes in a highly dynamic Atlantic forest region. Biological Conservation **142**:1166-1177.

Ministério do Meio Ambiente. 2011. Relatório de Inspeçã:o Área atingida pela tragédia das chuvas: Região Serrana do Rio de Janeiro: Áreas de Preservação Permanente e Unidades de Conservação & Áreas de Risco: O que uma coisa tem a ver com a outra? in S. d. B. e. Florestas, editor. Ministério do Meio Ambiente, Brasília – DF.

Olson, M., Jr. 1969. The Principle of "Fiscal Equivalence": The Division of Responsibilities among Different Levels of Government. The American Economic Review **59**:479-487.

Pacheco, P. 2009. Brasil lidera uso mundial de agrotóxicos. O Estadão de S.Paulo, São Paulo.

Pagiola, S., P. Agostini, J. Gobbi, C. d. Haan, and M. Ibrahim. 2004. Paying for Biodiversity Conservation Services in Agricultural Landscapes. Environment Department Paper No. 96. Washington, DC: World Bank.

Pagiola, S., E. Ramírez, J. Gobbi, C. de Haan, M. Ibrahim, E. Murgueitio, and J. P. Ruíz. 2007a. Paying for the environmental services of silvopastoral practices in Nicaragua. Ecological Economics **64**:374-385.

Pagiola, S., E. Ramirez, J. Gobbi, C. Dehaan, M. Ibrahim, E. Murgueitio, and J. Ruiz. 2007b. Paying for the environmental services of silvopastoral practices in Nicaragua☆. Ecological Economics **64**:374-385.

Pearce, D. 2007. Do we really care about Biodiversity? Environmental and Resource Economics **37**:313–333.

Pinheiro Machado, L. C. 2004. Pastoreio racional voisin: tecnologia agroecológica para o terceiro milênio. Cinco Continentes, Porto Alegre.

Pretty, J. N., A. D. Noble, D. Bossio, J. Dixon, R. E. Hine, F. W. T. P. d. Vries, and J. I. L. Morison. 2005. Resource-Conserving Agriculture Increases Yields in Developing Countries. Environmental Science & Technology **40**:1114-1119.

Ribon, R., J. E. Simon, and G. T. De Mattos. 2003. Bird Extinctions in Atlantic Forest Fragments of the Viçosa Region, Southeastern Brazil. Conservation Biology **17**:1827-1839.

Ring, I. 2008. Integrating local ecological services into intergovernmental fiscal transfers: The case of the ecological ICMS in Brazil. Land Use Policy **25**:485-497.

Rockstrom, J., W. Steffen, K. Noone, A. Persson, F. S. Chapin, E. F. Lambin, T. M. Lenton, M. Scheffer, C. Folke, H. J. Schellnhuber, B. Nykvist, C. A. de Wit, T. Hughes, S. van der Leeuw, H. Rodhe, S. Sorlin, P. K. Snyder, R. Costanza, U. Svedin, M. Falkenmark, L. Karlberg, R. W. Corell, V. J. Fabry, J. Hansen, B. Walker, D. Liverman, K. Richardson, P. Crutzen, and J. A. Foley. 2009. A safe operating space for humanity. Nature **461**:472-475.

Rodrigues, E. R., L. Cullen Jr., T. P. Beltrame, A. V. Moscogliato, and I. C. d. Silva. 2007. Avaliação Econômica de Sistemas Agroflorestais Implantados para Recuperação de Reserva Legal no Pontal do Paranapanema, São Paulo. Revista Arvore **31**:941-948.

Sidle, R. C., and H. Ochiai. 2006. Landslides: Processes, Prediction, and Land Use. . Page 312 pp. Water Resources Monograph 18. American Geophysical Union, Washington, DC.

SOS Mata Atlantica. 2009. Divulgação do novo Atlas Mata Atlântica. on line at http://www.sosmatatlantica.org.br/index.phpsection=content&action=contentDetails&idContent=392

Souto, L. E. 2009. Código (anti) ambiental de Santa Catarina. O Eco **on-line: http://www.oeco.com.br/convidados/64-colunistas-convidados/21295-codigo-anti-ambiental-de-santa-catarina**.

Tabarelli, M., L. P. Pinto, J. M. C. Silva, M. Hirota, and L. Bede. 2005. Challenges and Opportunities for Biodiversity Conservation in the Brazilian Atlantic Forest. Conservation Biology **19**:695-700.

Ten Kate, K. 2002. Global Genetic Resources: Science and the Convention on Biological Diversity. Science **295**:2371-2372.

Tilman, D., and J. A. Downing. 1994. Biodiversity and stability in grasslands. Nature **367**:363-365.

UNDP-GEF 1998. GEF Operational Strategy. United Nations Development Program, New York.

Vanacker, V., F. v. Blanckenburg, G. Govers, A. Molina, J. Poesen, J. Deckers, and P. Kubik. 2007. Restoring dense vegetation can slow mountain erosion to near natural benchmark levels. Geology **35**:303–306.

Vanloqueren, G., and P. V. Baret. 2009. How agricultural research systems shape a technological regime that develops genetic engineering but locks out agroecological innovations. Research Policy **38**:971-983.

Venter, O., W. F. Laurance, T. Iwamura, K. A. Wilson, R. A. Fuller, and H. P. Possingham. 2009. Harnessing Carbon Payments to Protect Biodiversity. Science **326**:1368.

Vieira, P. F., A. M. Barbosa, A. L. A. d. A. Assis, J. M. Prudêncio, L. R. Ribeiro, M. L. Pereira, and M. F. Gasparini. 2007. Diagnóstico Socioambiental Exploratório e Subsídios para a Definição de uma Estratégia de Desenvolvimento Territorial Sustentável no Município de Paulo Lopes. UFSC, Florianopolis, SC.

World Bank. 2005. Project Appraisal Document on a Proposed Grant From The Global Environment Facility Trust Fund In The Amount Of US$7.75 Million to the State of São Paulo for a Ecosystem Restoration of Riparian Forests in São Paulo Project. World Bank, Washington, DC.

World Bank 2007. World Development Report 2008: Agriculture for Development. World Bank, Washington D.C.

Wunder, S., S. Engel, and S. Pagiola. 2008. Taking stock: A comparative analysis of payments for environmental services programs in developed and developing countries. Ecological Economics **65**:834-852.

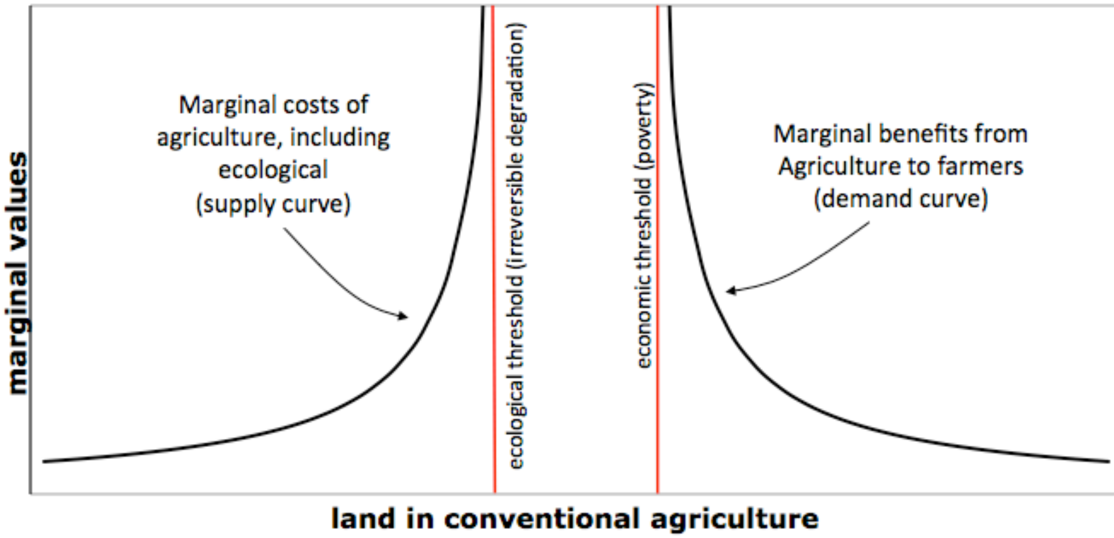

Figure 1: With nearly one billion malnourished people on the planet, the marginal benefits of increased food production may be immeasurably large. At the same time, conventional agriculture is one of the greatest threats to life sustaining ecosystem functions, and the marginal ecological costs are also immeasurably large.

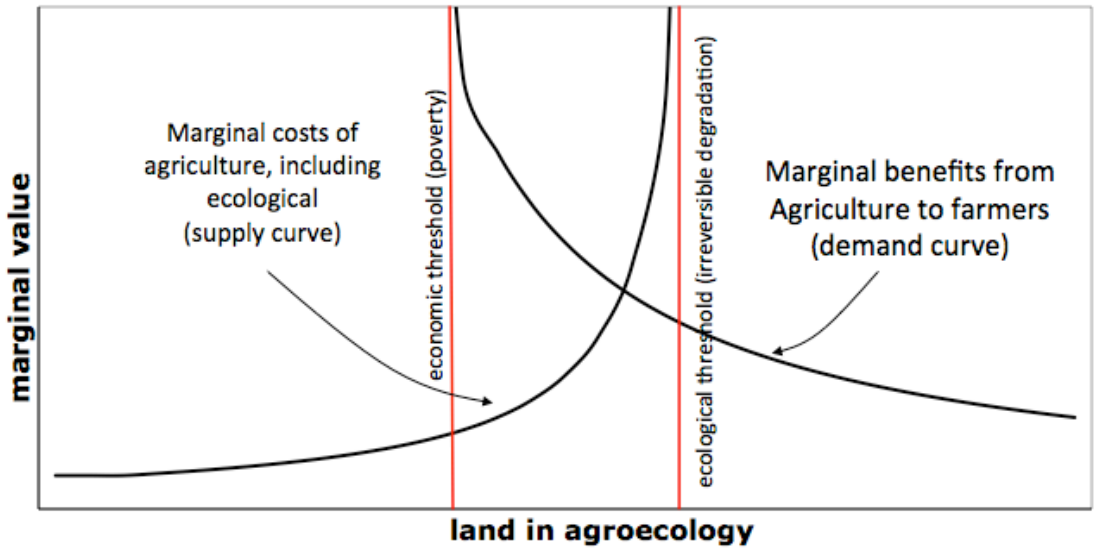

Figure 2: Agroecology systems can shift the supply and demand curve for agriculture. Increasing ecosystem services from agricultural land shifts the ecological threshold to the right, while increasing economic benefits from ecological restoration shifts the economic threshold to the left.