The Economics of Biodiversity Loss in Agricultural Landscapes

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ABSTRACT

This paper offers a framework for analysing the economic drivers and effects of agrobiodiversity loss, focusing on *in-situ* conservation at both farm and landscape levels. We distinguish between the proximate and fundamental causes of biodiversity loss in terms of the decentralised (microeconomic) behaviour of farming households. Special attention is paid to the interplay between micro- economic decisions and the meso-economic factors (i.e., institutional and market conditions) that determine the effects of government policies. We interpret agricultural landscape changes as the product of explicit or implicit decentralised farm-level decisions to (dis)invest in biodiversity as a strategic asset that provides flows of ecological services on- and off-farm. Several case studies are used to illustrate how '*downstream*' or '*forward*' effects feed back into agricultural production and stability ('*backward effect*'). This framework can be used to assess the effectiveness of policies to address underprovision of agrobiodiversity-supported ecological services that are socially (locally and globally) welfare enhancing.

Keywords: Ecological-economics, valuation, economic incentives, meso-economy, decentralised behaviour,

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1. Introduction

The main anthropogenic cause of biodiversity loss at the landscape level is the loss of habitat that follows land-use change. The main consequence of biodiversity loss is a change in the flow and nature of ecosystem services. In agroecosystems, both intensification[1] and extensification of agriculture have led to a loss of wild biodiversity, especially in biodiversity rich developing economies (Tilman et al. 2001; Green et al, 2005). New calls are being heard for a second (ever-)green agricultural revolution to allow the increase in food and fiber production required by a growing human population, whilst reducing the impact on remaining 'natural' habitats (Conway, 2000). This reflects a debate in ecology and conservation biology which assumes that agricultural growth and biodiversity conservation is a zero sum game. Intensification is seen as a mechanism for reducing impacts on non-agricultural habitats in order to save remaining wild biodiversity. But since the advent of agro-ecology and agro-forestry a new literature on agrobiodiversity science has developed that recognizes the importance of on-farm biodiversity. Biodiversity-related loss of ecosystem services matters both on- and off-farm, and may matter more in biodiversity-poor managed or heavily impacted systems than in biodiversity-rich 'wild' or lightly impacted systems. This has significant implications for biodiversity conservation strategies in agroecosystems (Perrings, 1996).

Farming communities have traditionally exploited a range of knowledge systems and technologies to adapt the ecological processes of agroecosystems to meet their needs. Certain species have been deliberately excluded in order to enhance the productivity of others that are more valuable from either a cultural or economic perspective. The driver of agrobiodiversity change in such cases has been individual farmers' decisions, although the impact on agrobiodiversity has had consequences for ecosystem services at larger scales. It follows that the scale at which the problem should be analysed is given by the scale at which ecosystem services are delivered.

In this paper we consider the economic drivers and effects of agrobiodiversity loss at both farm and landscape levels. In particular, we consider the causes and effects of farmers' decisions to 'disinvest' in agrobiodiversity. In so doing, we interpret changes in agrobiodiversity as the

[1] Here, agricultural intensification refers to the increased use of nonrenewable inputs, such as pesticides and fertilizers, substitution of mechanization and fossil fuels for human labor, and high capital invested per unit of land area.

product of explicit or implicit decentralised farm-level decisions whose effects include both farm and landscape level changes in a range of ecosystem services.

Decentralized decisions regarding the desired level of in-situ agrobiodiversity, mostly at the crop and livestock genetic level, are mediated by a myriad of socio-economic factors (Smale et al, 2001; Scarpa et al, 2003; Smale and Drucker, *forthcoming*). Some factors are relatively easy to be identified (e.g. population pressure). Others are more subtle and intertwined making them more durable (in time) and far reaching (in space). These include, for example, the role of poverty, the institutional environment and the state of food and labour markets. In this paper we consider these intertwined 'fundamental' or indirect causes of agrobiodiversity loss, paying special attention to their effects on the difference in the value that individual land users and the wider society put on agro-biodiversity.

Individual land users reap short-run benefits in the marketplace from deliberately degrading biodiversity through agricultural specialization, ignoring the 'external' consequences for changes in ecosystem services. Since the social insurance benefits of high levels of crop-genetic diversity are not rewarded by the market, for example, farmers have no incentive to take them into account. The optimal decision for the farmer is frequently to grow only a few crop varieties, and not to invest in conservation of the less 'profitable' varieties. At the international level, farmers who maintain in-situ crop genetic diversity (a global public good) are in effect net-subsidizers of modern agriculture and food consumers worldwide (Boyce, 2005). Such free-riding behaviour by modern agriculture is another potent reason for the underprovision of genetic diversity at the global level. The result is that the custodians of such genetic portofolios are left uncompensated for the potential global benefits that they could provide. This negatively affects their incentive to invest in biodiversity conservation. Add this to the fact that existing policies and economic incentives allow the varieties favored by markets to drive out less 'profitable' alternatives and the problem is compounded.

While the direct or proximate drivers of biodiversity loss may be found in land use change by farmers, the fundamental or underlying drivers lie in the mismatch between the financial incentives to farmers and the effect of farmers' decisions on wider society. Of course, there are other factors involved including demographic, social, political and cultural change occurring over longer time horizons. These are frequently exogenous to the communities affected by farmers' decisions, and are thus uncontrollable by them (Lambin et al, 2003). Institutions pay a crucial role in mediating the effects of such exogenous forces.[2] Understanding the nature of the meso-economy, i.e., the interface domain in which institutions are developed and function, is thus important in developing incentives to address the mismatch between the private interests of farmers and those of the community. Developing adequate (stable and resilient) institutions other than the market is frequently a prerequisite for the protection of the socially-optimal level of biodiversity in agroecosystems.

The rest of this paper is organized as follows: The next section addresses the problem of agrobiodiversity loss from an ecological-economic perspective. A conceptual framework is used to show the links between individual farmers' behavior and the role of meso-economic institutions, and the way in which market and wider institutional and policy failures cause biodiversity loss at the landscape level. In Section 3 we consider the consequences of biodiversity loss, in terms of the indirect instrumental value of agrobiodiversity, and in section 4 relate this to the institutional environment and incentive measures. A final section recapitulates the main points and draws out the main implications for the conservation of agrobiodiversity.

2. The value of agrobiodiversity: an ecological-economic framework

The problem we wish to consider is the interaction between micro-economic decisions and meso-economic factors such as market institutions and government policies. Agrobiodiversity typically changes as result of explicit or implicit decentralised farm-level decisions to (dis)invest in biodiversity. In what follows, the description of the relationship between biodiversity stocks, ecosystem services, economic behavior and the institutional environment is highly stylised. Notwithstanding that in complex adaptive systems there is seldom a single driver of the system dynamics, we begin with decisions at the farm level. These are constrained by, on the one hand, the biophysical environment, and on the other by rules of use (either formal or informal) that are determined by culture, institutions and regulatory restrictions. The combined effect of the actions of many spatially and temporally disaggregated individuals shapes the agro-ecological landscape.

[2] We take the concept of 'institution' generally throughout the paper. It encompasses formal rules (e.g. laws, constitutions) and informal constraints (norms of behavior, self-imposed codes of conduct) that govern land users' behavior. They can also be referred to as 'rules in use' (North 1990).

Figure 1 shows the relationships (represented by arrows), between biodiversity stocks (L), the flow of ecosystem services (S) and their economic value (V). Such relationships exist in nested ecological-economic hierarchies (H), including the farm-field/household, the agroecological landscape and the meso-(institutional) and macro-economic environment.

[FIGURE 1 AROUND HERE]

We pay particular attention to the way that farm-field level changes in biodiversity affect ecosystem services at the landscape level. Farmers' land use management and technology choices affect (i) the level of biodiversity (e.g. species mix vs. varieties mix or managed vs. associated biodiversity), (ii) the temporal scale of change (e.g., static choice or inter-temporal choice), (iii) the spatial scale of change (e.g., field-level or operated farm level). These choices are affected by both external/exogenous conditions (e.g., markets and policy environment), and by internal/endogenous conditions (e.g., farmers' aspirations and expectations) (Brush et al, 1992).

2.1. Hierarchical levels (the micro-, meso- and macro-economy)

First consider the effect on of the institutional environment (H2) on farmers' decisions (H1) that impact on-farm biodiversity (L1) (Relationship H1~H2~L1 in Figure 1). Farmers adapt to institutional constraints. Such institutions can be located at the micro- meso- and macro-scales. Microeconomic institutions (H1) involve the household, family farm or agri-business. For instance, in the case of the household if there is intra-household gender discrimination, the plant species to be conserved may be determined by gender dominance. In many African drylands, for example, Dasgupta (2000) notes that women favor planting for fuelwood and men for fruit trees, because it is the women who tend to collect fuelwood, while men control cash income generated by selling fruit in the market. This explains why, even as the sources of fuelwood continue to recede in many African countries, fruit trees are often planted.

At the meso-economy (H2) level, institutions operate. This includes local/ regional markets as well as local or region-specific policies that operate at the landscape level (H3). The availability of formal land, credit or insurance institutions, for example, may determine whether farmers choose higher or lower levels of crop genetic diversity (Smale and Drucker, forthcoming). An example of meso-economic institutions that strongly affect farmers' decisions (H2~H1) is the agri-environmental policy box of the European Union (Kleijn and Sutherland, 2003).

Beyond local and regional institutions, the macro-economic environment (H4) includes institutions and policies that operate at the national scale, as well as supranational institutions that operate in the international arena. For instance, policies affecting the volatility of exchange rates of local currencies may work against the conservation of plant species that are valuable to food security and in favour of those yielding higher short-run financial returns i.e. H4~H1 (Barbier, 2000). Institutions that affect farm-level decisions by indirectly changing the context in which these households operate (e.g. creation of markets, infrastructure, etc.), include the intergovernmental organizations, such as the World Bank, the International Monetary Fund, the United Nations Development Programme, and international agreements that regulate trade in agricultural products, such as the General Agreement on Tariffs and Trade, the Sanitary and Phytosanitary Agreement, and the International Plant protection Convention. In some cases they affect agrobiodiversity by limiting the choice of management strategy or technology. In others they work by encouraging the diffusion of new technologies or by dispersing new crop varieties, pest-control agents, pests and pathogens, i.e. H4~H2~H1 (Perrings, 2005b).

2.2. Decentralised farm decisions and landscape effects: forward and backward biodiversity linkages

Farmers' private (decentralised) decisions affect on-farm biodiversity both directly through the mix of planned productive biota (crops, trees and animals), i.e., H1~L1, and indirectly through the effect of land clearance and the use of herbicides and pesticides on habitat and non-cultivated species. Both affect the mix of species and communities, and the range of services derived from them. The control of *destructive biota*, such as weeds, insect pests, microbial pathogens and so on, compromises ecosystem services that potentially benefit both farmers and consumers (S1). (Swift and Anderson, 1993; Altieri, 1999). Where on-farm biodiversity supports the productivity of crops by, for instance, directly enhancing yields (Tscharntke et al, 2005) or substituting for the use of purchased capital inputs such as pesticides, it has direct use value (S1~V1). This is common among small-scale farmers in developing countries, and is related to their lack of access to credit for the purchase capital inputs. An often cited example is that of Mexican shifting cultivation systems (or 'milpas') where maize/squash/bean polycultures yield more and are more stable than monocultures (Altieri, 2004; Altieri and Nicholls, 2005). One reason for this is the role of biodiversity in pest and disease regulation, soil formation and nutrient recycling (Altieri, 2004). Where this maintains farmers' income streams (V1) it is a sustainable strategy.

Different crop mixes at plot level and diverse individual agricultural management strategies create a mosaic of agro-biodiversity at the landscape level. The agroecological landscape is effectively shaped by uncoordinated decentralised behaviour by individual farmers (H1~H3) (Lambin et al, 2003). The ecological-economic problem is to identify the mosaic of connected habitats that best supports both farm production (S1~V1) and the production of valued off-farm ecosystem services. The latter can be negatively affected by the aggregated though uncoordinated impact of farmers on habitats (H1~H3~L2). The most common effect is for the amalgamation of agricultural fields to produce homogeneous farmed landscapes leaving only a fragmented non-crop habitats (Bélanger and Grenier, 2002; Tscharntke et al, 2005). The net result is the extirpation of many off-farm species and a reduction in the abundance of others (Robinson and Sutherland 2002; Benton et al. 2002). This is the '*forward linkage*' between farm decisions and landscape level agrobiodiversity. There are clear forward (or downstream) effects/linkages from on-farm biodiversity management to the level of the off-farm biodiversity stock (H1~L2).

There is also increasing evidence of the positive effect of off-farm biodiversity on farm productivity and stability (S2'). This '*backward'* (or upstream) effect is associated with off-farm landscape level generalist species that provide pollination and biological control services against pests and invasive species. This is an indirect value inasmuch as it provides financial savings to or increases the productivity of the farmer. The recent ecological literature offers some examples of this. Kremen et al (2002) show that more intensive agricultural land management relative to less intensive systems, such as organic farming, increases the cost of pollination to the farmer. In another study, Ricketts et al (2004) estimate the economic cost of the reduction of pollination services originating from off-farm forest habitats to coffee production in a single Costa Rican farm to be in the order of USD60,000/year. Similarly, the loss of off-farm biodiversity as provider of biological control against pests and invasive species is seen as increasing the cost of pest and disease control to the farmer (e.g.,, Symondson et al. 2002), while at the same time habitat fragmentation increases the invasibility (i.e, the risk of invasion by unwanted off-farm species) of agroecosystems (Östman et al 2001; 2003; Perrings, 2005a; Zavaleta and Hulvey, 2004). Furthermore, transboundary landscape effects also operate. There a many examples of biodiversity at regional scales affecting the resilience of local systems. The best known example, insectivorous birds migrating from Latin America to Canada regulate the growth of forest plantations in Canada by controlling budworms. The result is that landscape fragmentation in Mexico, for example, negatively affects bird populations that migrate to Canadian boreal forests, so reducing control over budworms and compromising the economic productivity of forests.

The forward-backward biodiversity linkages at the landscape level are of course, mediated by complex ecological and economic interactions. Our framework offers a stylized version of these linkages. In practice, farmers' decentralised decisions are both adaptative and reflexive in agroecosystems.[3]

2.3. A longer term view of off-farm biodiversity value

The longer-term sustainability of welfare enhancing ecosystem services (S1+S2') depends largely on the effect of farm decisions on biodiversity at the landscape level (Tscharntke et al, 2005). One reason for this lies in their insurance value (S2~V2) (Loreau et al. 2002). Recent studies of Italian rain-fed cereal production, for example, show that high levels of crop-genetic diversity stabilize both yields and incomes (Di Falco and Perrings, 2005; Di Falco and Chavas, forthcoming). Similarly, ecologists argue that over small scales (e.g. the crop-field level) an increase in on-farm species richness and the diversity of overlapping functional groups of species enhances the level of functional diversity, which in turn increases ecological stability (Tilman et al., 1996) and resilience (sensu Holling 1996). Resilience refers to the size of perturbation that is required to transform a system from one state to a different state, and is frequently increasing in the number of species that are apparently 'redundant' under one set of environmental conditions, but that perform important functions under different environmental conditions (Peterson et al, 1998).

In the case of agroecosystems as integrated human (economic) and natural (ecological) systems, resilience can be interpreted, following Carpenter et al (2001), as (i) the amount of disturbance that the system can absorb and still remain within the same state or domain of attraction; (ii) the degree to which the system is capable of self-organization – versus the lack of organization, or

[3] The circular flow depicted by the direction of the dotted arrows in Figure 1 reflects the adaptative and reflexible property of microeconomic decisions in co-evolutionary agroecosystems.

organization forced by external factors and (iii) the degree to which the system can build and increase the capacity for learning and adaptation. This also implies that a given concentration of activities may lock the agricultural system into a particular technology (e.g. intensive agriculture) or set of inter-dependent preferences by consumers (e.g., cheaper food becomes ‘fashionable’). At one level this makes the system more stable in the sense that there is less variation in producer or consumer behavior following minor shocks, but it may also reduce the capacity of that system to absorb greater environmental or economic. By eliminating options, a reduction in agrobiodiversity may also lock farmers into particular agricultural technologies (Perrings, 1998). By maintaining agrobiodiversity, it may be possible to maintain the agricultural system’s capacity to respond to short-run shocks and stresses in a constructive and creative way. Insurance value is thus linked to the option value of on-farm biodiversity (Swanson, 1999), and is reflected in efforts to maintain both in-situ and ex-situ genetic resource conservation (Fowler and Hodgkin, 2004).

Off-farm biodiversity also provides ecosystem regulatory services that are linked to the productivity and stability of farm production. Such services include recycling of nutrients, control of local microclimate, regulation of hydrological processes, regulation of the abundance of undesirable organisms, and detoxification of noxious chemicals (Altieri, 1999). These ecosystem services are also subsumed within S2 and S2’. Thus, from an economic perspective, off-farm biodiversity is relevant not only as provider of insurance (long term backward linkage, S2) but also as provider of other productivity enhancing services (short term backward linkage, S2’). To the individual farmer, however, the insurance effect will not generally be enough to justify conservation. Given the availability of artificial capital inputs (e.g., fertilizers, improved seeds, etc.), the short run insurance value of biodiversity is reduced.

2.4. Wider societal benefits of agrobiodiversity

Besides biodiversity’s effect on productivity and stability, off-farm farm biodiversity can provide recreational benefits to society (S3). For instance, the knowledge that emblematic butterflies abound under biodiversity-rich farming systems (Feber *et al.*, 1995), or that small mammals thrive in field margins may be a source of satisfaction and hence value (V3) to the wider community (Cobb et al, 1999). Those who attach symbolic, cultural or aesthetic value to landscape biodiversity are often urban dwellers. The framework presented here implies that there are multiple uses of agrobiodiversity, involving simultaneous on-farm (S1) and off-farm benefits (S2 and S3). The policy and land use implications are thus far-reaching (Walker, 1999).

3. 'Getting the price right' through agrobiodiversity valuation

The problem of agrobiodiversity loss can be seen as an investment problem involving choices made in the context of a certain set of preferences, 'value systems', moral strictures, endowments, information, technological possibilities, and social, cultural and institutional conditions. The economic problem lies in the fact that the decentralised decisions of farmers are currently biased against agrobiodiversity conservation, since the markets within which farmers operate do not reflect the full opportunity cost of biodiversity loss. Since markets do not provide the right information about how 'scarce' biodiversity is (by the price signalling), hence it is under-provided by individual land users. In this sense, markets fail to induce the socially optimal level of investment in biodiversity conservation. Hence there is a need to 'get the prices right' - i.e. to ensure that they reflect the real cost of agrobiodiversity loss. In this context, the main challenge is that biodiversity is not a localised private good, but a public good[4] often of global concern.

The problem here is that even if the ecosystem services supported by agro-biodiversity (S1+S2+S3) are known, the economic value (V1+V2+V3) of these services may not be taken into account by individual land users (H1). There is often a gap between the social value of agro-biodiversity and the value signalled by markets or institutions (H2). If the size of the gap can be calculated, incentive mechanisms can be devised to encourage individual farmers to behave 'as if' they perceived the social value of agro-biodiversity.

We have already suggested that this value is linked to role of agro-biodiversity in securing the integrity in terms of the productivity, stability and resilience of the agroecosystem as a complex adaptive system. Two current approaches to the value of biodiversity that relate to this are: (a) the valuation of the distance between species (e.g., Weitzman, 1993; Polasky and Solow, 1995;

[4] A good is catalogued as public (to different degree) if it does not exhibit rivalry and excludability characteristics. Biodiversity is non-rival as one individual's use of biodiversity does not affect another individual's use of it. In other words, both individuals can be equally satisfied simultaneously by the fact that biodiversity is conserved. It is non-excludable because it is often not possibly to exclude or prevent someone from benefiting from its conservation. These characteristics are enough for biodiversity not to be provided by individuals in sufficient levels to maximise their joint (or social) welfare.

Brock and Xepapadeas, 2003) (b) the valuation of stability and resilience (e.g. Folke et al, 1996; Perrings, 1998; Di Falco and Perrings, 2003; 2005).

The value of agro-biodiversity in this latter approach is derived from the value of the ecosystem services it supports over a range of social and environmental conditions. While the non-marketed societal value of S1 and S2'-type services can be captured by the use of production function approaches (Freeman, 1993), S3 services provided by biodiversity may be better captured by stated preference valuation methods (Bateman et al., 2003; Haab and McConnel, 2003). Capturing insurance value (S2) is a more complicated endeavor. While the economic methods for analyzing the value of a portfolio of assets are well developed, the challenge that remains is the integration of information derived from ecology at the relevant scales so that such empirical observations can be readily used by economists. This is also most relevant when assessing the role of backward biodiversity linkages (S2') and their effects on productivity and stability in the supply of foods and fibers.

Economists have long been aware that biodiversity has an 'indirect' value through the provision of regulating ecosystem services (Barbier, 1989), but there have been few attempts to estimate this value for particular systems. Similarly, while there has been recognition of the value of biodiversity in underpinning support services - 'primary value' (Turner and Pearce, 1993) or 'infrastructure value' (Costanza et al. 1997) – there have been few attempts to estimate this value.

Part of the reason for this is that the value of biodiversity in agroecosystems should capture the complementary relationships between on-and off-farm biodiversity, and hence the forward and backward linkages referred to earlier. Thus, special attention should be paid to (i) the functional role of species in their crop- and non-crop habitats, (ii) the biotic and abiotic components of agroecosystem structures that support the provision of ecological services by agrobiodiversity and finally, (iii) the contribution of such ecological functions to human welfare. The challenge is to translate such ecological interdependencies into tangible ecological services and thus value from an anthropocentric point of view.

Part of the difficulty is to account for the range of ecological interactions between species. This has been described as the 'contributory value' of species (Norton, 1986). It captures the idea that each species contributes to the survival of other species. Another way of expressing the same thing is that some species have the status of 'intermediate inputs' in that they support more directly utility-yielding species (Crocker and Tschirhart 1992). This implies that any single on-farm or off-farm associated species (even if seemingly redundant) may contribute to species diversity, and so to the long-run productivity and stability of agriculture. The cost of species deletion is thus the cost of the alternative ways of securing the same outcome. In general, the smaller the diversity of cultivated species, the greater the expenditure required on pesticides, fertilizers, irrigation, and so on (Perrings et al, 1995).

Once we think about biodiversity in functional terms, the implications for its social value (and hence the social incentive to conserve it) are profound. For instance, if the costs to society of agro-biodiversity loss mostly lie in the depletion of the gene pool, the value of biodiversity to any one country is small. No one country has much incentive to conserve it. This is the typical free rider problem at a global scale. But if the main costs of biodiversity loss lie in the loss of resilience of the affected ecosystems, biodiversity has value to all countries individually. Each country has an incentive to conserve it (Perrings and Gadgil, 2003).

What matters is not just the direct role of species in human consumption (of foods, fuels, fibers pharmaceuticals and so on) but the role of agro-biodiversity in maintaining ecosystem services. The total value of a multifunctional agricultural landscape is thus S1+S2+S3. It follows that economists need to be aware of the scientific advances regarding the interaction between on-farm and off-farm species populations and communities that can support productivity and stability of crop yields and other valued services. Ecology also needs to be aware that agrobiodiversity conservation may be better understood by acknowledging that land is a scarce resource allocated by humans according to their needs, objectives and constraints. Farmers themselves play the role of 'keystone' species by managing agro-biodiversity (Boyce, 2005). In addition, at the landscape level, ecology can help identify how mosaics of different degrees of semi-natural areas and habitats are linked, given their different degrees of connectivity. It can also help evaluate the potential for the dispersal and movement of organisms, in turn influencing species richness and its scaling relations (van Noordwijk et al, 2004). Economics can effectively use such information to assess how individual farmers' decisions create spatial (positive or negative) spill-over effects or externalities.

Some agroecologists are increasingly targeting their scientific effort towards putting biodiversity at the centre stage of land-use in agricultural landscapes, thus reflecting the overarching aim of an ecologically centered agricultural sustainability approach (Altieri, 1999, 2004). Economists are more focused on the value of the integrated system, including agrobiodiversity. Given that ecosystem services stem from the abiotic and biotic stocks of ecosystems, agro-ecological sustainability implies something about the aggregate value of such stocks. Since this is sensitive to the degree to which other forms of capital can substitute for such stocks, it is important to understand just which ecosystem services can be substituted, and at what cost. There is thus a necessity to build bridges between ecology and economics to foster an integrated agrobiodiversity science that can better inform policy.

4. The policy question: incentive mechanisms for agrobiodiversity conservation

There are important reasons to devise and implement incentive mechanisms for agro-biodiversity conservation. Such incentives should address the forward and backward agrobiodiversity linkages and thus work at the landscape level. If incentive mechanisms are to be used at the landscape level, however, they may affect the livelihoods of large numbers of people. This adds a further layer of responsibility to public agencies to be aware of the distributional implications of alternative mechanisms.

There are many ways to intervene to enhance the provision of biodiversity. These can be categorised into two main groups: (i) moral suasion, regulation and planning, e.g. by preventing specific land management practices or by designating agroecological (no take) zones resembling nature reserves and parks, and (ii) market creation for agrobiodiversity conservation given that market signals drive decentralised land use decisions. In what follows we focus on the second approach.

According to the Millennium Ecosystem Assesment (2005), encouraging market based mechanisms is necessary to conserve biodiversity. The idea is that market creation can help increase the opportunity cost to local land users of agricultural practices that negatively affect agro-biodiversity. Markets can take different forms. Firms and NGOs can already purchase land use rights, such as logging in forested regions, and then decide not to extract wood but to conserve the land for its biodiversity. In agricultural landscapes ‘use’ rights include rights of access to particular biological resources (e.g. game or fish), biological resources derived from the existence of biodiversity (e.g., non timber forest products), or other goods and services that may be associated with biodiversity (e.g., organic agricultural products). These rights are currently being extended to enable contractual arrangements between farmers and off-farm users of ecosystem services that are affected by actual farm management (e.g. between upstream landowners and those benefiting from watershed services downstream). ‘Payments for Environmental Services’ (PES) are rapidly gaining support, although their effectiveness has yet to be generally validated (van Noordwijk et al, 2005).

As in other areas, such markets for agro-biodiversity conservation may be ineffective unless participants are (i) prepared to transact, (ii) aware of prices, (iii) able to easily identify and find each other. Even in cases where there may be willingness to participate, if there are relatively few participants (e.g., by being geographically dispersed), the establishment and operation of markets can involve significant transaction costs so reducing their effectiveness.

A variant of such contractual mechanisms is the approach based on *direct compensation payments* (DCP). This idea is based on the ‘*provider gets principle*’. While at the short-run DCPs[5] or rewards may be effective, its effectiveness is put into question if the change in decentralised behaviour needs to be sustained into the future, as this would require ongoing financial commitments to maintain the link between investment and conservation objectives (Ferraro and Kiss, 2002; Swart, 2003).

A more interesting example is that of *transferable development rights* (TDRs). While TDRs are not designed to target specific habitat types, they can theoretically be applied to agricultural landscapes. They extend the longstanding agro-ecological zoning schemes, which aim to direct development to areas of high agricultural potential and to restrict land use in ecologically significant and sensitive areas. However, such zoning programs do not allow for any substitutability between plots in meeting conservation goals. By providing a market-like alternative to the command-and-control approach of pure agroecological zoning, flexibility in achieving conservation goals is introduced. The main advantage by TDRs is that it can, in principle, it can encourage conservation on lands with low agricultural opportunity costs, while providing appropriate incentives to the affected landholders (Panayotou, 1994; Chomitz, 1999).

[5] Integrated conservation-development projects (ICDPs) is also an indirect incentive designed to allow local land users to derive a stream of income by capturing international willingness to pay for biodiversity conservation. However, such programs have in practice rarely been integrated into ongoing incentives for conservation (van Noordwijk et al, 2005).

Two types of TDR programs exist: the single and dual zoning programs. The former are similar to permit systems such as those used in transferable fishing quotas or pollution control. After the initial allocation of quotas, anyone within the program area may buy or sell the permits. An application of this type of TDRs have been used, for instance to control soil degradation through erosion in the Lake Tahoe Basin (Johnston and Madison 1997). Dual zone systems instead designate both sending and receiving areas. For instance, new land use restrictions are imposed on the sending (agro-ecologically more sensitive) zone and assignment of TDRs compensates for this. Usually, tight restrictions are also imposed on the receiving zone so as to increase the demand for TDRs.

For agro-biodiversity conservation, the effectiveness of the TDR scheme relies on whether the objective is to conserve certain habitats within the landscape due to having unique biodiversity characteristics, or if larger tracks of contiguous habitats are necessary in order to better conserve off-farm biodiversity. It follows that when the landscape is highly homogeneous, and the goal is to conserve a specified ‘amount’ of habitat within the landscape, regardless of its configuration, a single zone system may be more appropriate (Chomitz, 1999). However, as Chomitz (1999) also notes, the relatively small scale of existing rural TDR programs are possibly due to the political barriers to implementing these systems. As with any tradable permit scheme, the initial allocation of permits is a sensitive issue that may have large distributional consequences. It should also be pointed out that while TDRs are often praised as being a lower cost alternative conservation measure, setting up TDRs may involve substantial administrative and legal (monitoring and enforcement) costs.

In all cases, market creation depends on the provision of good and accurate information. If it is not possible, or very costly, to convey clear and credible information about the nature of the services derived from biodiversity, then consumers’ perceptions may be distorted. One clear example is that of organically produced food markets. These markets require clear certification schemes that consumers can rely on. Organic certification agencies provide the information needed for consumers to distinguish between conventionally produced products and organic products (associated with higher levels of agrobiodiversity). These need to be monitored, and the associated costs are not trivial (OECD, 2004).

Moreover, it may be naïve to champion market creation for biodiversity conservation if the institutions supporting it are feeble due to unstable political conditions, or if farmers are simply unable to adapt their management methods. In general, if markets for agrobiodiversity are created without proper institutional back-up, the social costs of market creation may be greater than the benefits, and the biodiversity outcome may be worse rather than better (Barrett and Lybbert, 2000). One example directly linked to on-site support for the cultivation of landraces is provided by Birol et al (2005), who show that the development of food markets without proper institutional infrastructure may have contributed to abandonment of landraces used in home gardens by poor Hungarian farmers.

In a first-best world, the social cost of biodiversity loss should be internalized by markets. However in a second-best world, the level of uncertainty about the consequences of biodiversity change makes this somewhat problematic (Tomich et al, 2004). Most initiatives thus pragmatically focus on the 'rules of use' in managing agrobiodiversity and development objectives, whilst ensuring that institutions are developed that keep future options open. Specifically, they seek to develop flexible and open institutions allowing multi-scale governance systems that can mitigate the worst effects of intensification in agroecosystems, without foreclosing future (de)intensification options.

This is clearly a challenge for agroecosystems that are (i) already biodiversity poor, (ii) are characterized by narrow and conflicting objectives between conservationists and agriculturalists, (ii) are heavily dependent on the use of artificial capital such as fertilizers and pesticides, and (iii) have short-term rather than long-term goals (Perrings, 1998; Brown 2003; Lambin et al, 2003). They are also problematic in systems that are both spatially and temporally heterogeneous. The short-term costs of agrobiodiversity conservation may be local, but the potential long-term benefits may accrue internationally. Spatial 'mismatches', where the boundaries of management do not coincide with those of the ecologically relevant units, make it difficult to transmit the incentive signals from the macro- to the meso- to the micro-scale (Opschoor, 1996; 1999).

One clear example of institutional mismatch is the perverse agricultural production subsidies, tax breaks and price controls that make a biodiversity-based agriculture uncompetitive. At the beginning of this century, subsidies paid to the agricultural sectors of OECD countries averaged over $324 billion annually (about one third the global value of agricultural products in 2000). A significant proportion of these led directly to overproduction and overuse of fertilizers and pesticides in OECD economies, and to to the financial uncompetitiveness of biodiversity rich agricultural systems in developing economies. Correcting for such policy or institutional failures should be the first policy priority even if removing perverse incentives may not automatically guarantee that their effects will reverse. Subsidy removal needs to be complemented by other incentive mechanisms (direct or indirect). For instance, perverse subsidies may be transferred to direct payments to providers of the non-marketed biodiversity services or used to convert the overhead costs of setting up direct (e.g. DCP) or/and indirect incentive schemes (e.g., PES and TDR), that may otherwise not be put in place. In any case, it needs to be recognised that there is a strong inertia and strong vested interests favouring the status quo (Walker, 1999).

5. Conclusions

We close with two observations. The first is that the importance of interdisciplinary research on biodiversity in both traditional and modern agro-ecosystems is recognized as a prerequisite for the development of more effective agro-biodiversity conservation regimes (Bawa et al. 2004; Jackson et al, 2005). In order to evaluate the social consequences of agricultural practices that cause the local extirpation of species, the fragmentation of habitats or the change in the relative abundance of species, we need to understand both the role of biodiversity in agroecosystem functioning and processes, the way that changes in functioning and processes affect ecosystem services, and the impact of changes in services on the production of goods and services that are directly valued by people on- and off-agricultural landscapes.

The sustainability of agricultural landscapes potentially involves a continuum of existing farm management systems from modern, intensive, mechanized, high-input, high-output systems at one end to traditional, extensive, labor-intensive, low-input, low-output systems at the at the other. Since the unit of analysis is the landscape, it is possible that the most effective strategy involves an extreme combination of highly intensive agriculture combined with wilderness areas. The alternative to intensification frequently involves encroachment on ever more marginal land and the destruction and fragmentation of ever more scarce habitat. But intensification that ignores the costs of a change in the mix of species in the system may be even more harmful. The point is, though, that this is an empirical question and that the research needed to identify the optimal mosaic has yet to be done.

The second observation is that in a sector where the impact on biodiversity is in the hands of billions of independent land-holders, management of agro-biodiversity by direct centralized control is not an option. What is important is that independent decision-makers take into account the true social costs and benefits of their actions. For example, farmers who maintain production of drought or disease resistant crops or livestock confer social benefits (in terms of averting expenditures on famine relief) that are seldom reflected in the prices they receive. Whether this implies taxation of the high risk components or subsidy of the low risk components depends on local circumstances and the international trading regime. In other words, the effectiveness of alternative mechanisms for changing farmers' decisions is also an empirical question. While it may be possible to identify the social opportunity cost of alternative farm management strategies, the best method for inducing socially optimal behavior depends on understanding not just the responsiveness of farmers and consumers (the relevant elasticities) but also the role of the social, cultural and institutional environment.

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Figure 1. A stylized framework of the linkages between agrobiodiversity levels, ecological services and economic values in agroecosystems.