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Surveys

Payments for agrobiodiversity conservation services for sustained on-farm utilization of plant and animal genetic resources

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ABSTRACT

This paper discusses the potential application of Payment for Ecosystem Services-like schemes to tackle market failures associated with the public good characteristics of agrobiodiversity conservation services. So called payments for agrobiodiversity conservation services (PACS) would increase the private benefits from utilizing local plant and animal genetic resources on-farm through voluntary reward mechanisms, so as to sustain their on-farm conservation. Theoretical and applied insights about PACS are discussed and attention drawn to some of the challenges to be overcome in implementing PACS. In particular, these relate to the identification of potential buyers, the complex institutional setting in which PACS might operate and the articulation of a meaningful conservation goal based on a safe minimum standard approach. The latter is urgently needed, so as to ensure that additional agrobiodiversity services are generated. Relative to a fixed pricing approach, PACS schemes that seek to overcome information asymmetries through the use of conservation auctions may be associated with significant efficiency gains. However, potential trade-offs between ecological effectiveness, economic efficiency, and social equity considerations need to be carefully evaluated.

1. Introduction

Despite their crucial role in contributing to the sustainability of agricultural practices through the provision of agrobiodiversity conservation services, many plant and animal genetic resources (PAGR) are increasingly being lost from agricultural landscapes worldwide (FAO, 2007a, 2009; Hajjar et al., 2008; Perrings et al., 2006).[1] Such loss is of global concern despite the existence of *ex-situ* gene banks with growing collections of germplasm (FAO, 2009). This is because key elements of genetic resources cannot be captured and stored off-site, including aspects related to their embodiment of ecological relationships such as gene flow between different populations and species, co-evolutionary adaptation and selection to predation and disease, and systems of agricultural knowledge and practice associated with genetic diversity (Altieri and Merrick, 1987; Brush, 1989). Consequently, in recent years, *in-situ* agrobiodiversity conservation is being seen as a complementary strategy to *ex-situ* conservation (Maxted et al., 2002), with the former also being mandated by the Convention on Biological Diversity (CBD).

A range of demand (e.g., availability of complementary inputs, access to insurance mechanisms and non-farm incomes) and supply factors (e.g. increased reliance on commercial farming systems, out-migration, and erosion of traditional customs and seed exchange/breeding networks) are leading to a loss of traditional crop species or varieties (also known as landraces) and indigenous livestock breeds (both henceforth referred to as 'local' PAGR) from farms (Bellon, 2004; Kontoleon et al., 2009). Furthermore, economic incentives are biased towards a few, financially profitable, high-yielding, often improved ones (henceforth called 'improved' PAGR), in part as a result of markets not capturing the public good values of the services provided by genetic resources conservation (Drucker et al., 2001; Gruère et al., 2009).

Direct payments may prove to be most effective in conserving that which benefits wider society (Ferraro, 2001; Ferraro and Simpson, 2002). These include payment for ecosystem services (PES) which build on compensation flows from the beneficiaries of an ecosystem service to the providers of that service. Although PES have been hailed as a promising solution for conservation dilemmas in many different contexts, they have mostly been applied to conserve forests and their associated ecosystems (e.g., Engel et al., 2008; Landell-Mills and Porras, 2002; Muradian et al., 2010; Wunder et al., 2008). Developed countries have for some time provided payments to farmers to change

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[1] In this context, agrobiodiversity is understood to encompass all diversity within and among plant and animal species found in domesticated systems.

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agricultural practices towards more biodiversity- and ecosystem-friendly practices, as for example in the EU (Kleijn and Sutherland, 2003), which in many ways resemble the idea of PES. Examples of such types of PES in agricultural landscapes of developing countries are less numerous,[2] even though gaining increasing attention in the literature (Lipper et al., 2009; Pagiola et al., 2007).

Here we call attention to what can be termed as 'payments for agrobiodiversity conservation services' (PACS). PACS may be understood as a sub-category of agriculture-related PES that focuses on socially valuable and threatened local PAGR. The consideration of PES for the promotion of PAGR is limited. Examples include the EU support payments for threatened livestock breeds under Regulations 1257/99 and 1750/99, and a GEF-funded project in Ethiopia,[3] both of which are PES-like although not described as such. The GEF project scheme paid farmers for conserving traditional varieties and provided compensation based on an incremental cost approach, in this case related to the yield gaps between traditional and improved varieties. Wale (2008) draws on experiences from this project in order to analyze the financial opportunity costs of conserving traditional sorghum varieties. A similar methodology is used by Fuwa and Sajise (2009) in the context of incentive mechanisms for the conservation of rice varieties in the Philippines.

Apart from such limited examples, we are unaware of any further consideration of PES-like programs in the context of PAGR and of any conceptual treatment of this important and potentially emerging topic, especially in developing countries. This paper aims at filling this research gap by discussing theoretical and applied insights about PACS to shed light on the potential of PACS to serve as a least-cost and pro-poor PAGR conservation incentive scheme, especially in the context of poor rural communities in developing countries where most threatened and valuable local PAGR can still be found.

The next section introduces some theoretical considerations about the replacement of local PAGR by more commercial ones, a major cause of agrobiodiversity loss. Section 3 elaborates on the potential PES-like solution to the underprovision of agrobiodiversity conservation services, addressing the issues of identifying service buyers and potential institutional challenges in the design and implementation of PACS. Section 4 discusses how to meaningfully define agrobiodiversity conservation goals and Section 5 provides some experimental insights from an emerging PACS initiative from the Andes. Lastly we present the main conclusions and identify key questions for future research.

2. A Conceptual Framework for the Loss of Agrobiodiversity

The erosion of agrobiodiversity may be seen in terms of the replacement of the diverse existing pool of local PAGR with a smaller range of specialized improved ones — with such replacement taking place as part of a process of development through intensification, i.e. the manipulation of inputs and outputs in order to increase agricultural growth. The implications of this replacement process and the degree to which it is economically optimal can be conceptually discussed. Local PAGR may be expected to perform better than improved PAGR in marginal production environments, which have only slightly been modified by external inputs (Bellon, 2006; Cavatassi et al., 2011). With agricultural intensification, improved PAGR (developed for productive traits under modified environments) become more productive because of their higher responsiveness to external inputs, especially in areas which are favored in terms of agronomic potential and market access (Bellon, 2006). Here we follow the ideas of Drucker and Rodriguez (2009).

As can be seen in Fig. 1, the local PAGR would outperform the improved PAGR in terms of financial gross margin up to a given level of production system intensity, I* — where the term 'intensity' is used in a broad sense and includes, *inter alia*, factors related to access to markets and extension services. According to the market profitability functions represented by the continuous lines, after I*(0) is reached, farmers face increasing financial incentives to replace the local PAGR with improved ones. The magnitude of such incentives is determined by the distance between the two curves, i.e. the financial opportunity cost (foregone benefits at current market prices) associated with the utilization of PAGR. However, there are a number of reasons which suggest that I*(0) is to the left of the socially optimal replacement point, as may, for instance, be represented by I*(S):

[1] Significant non-market and/or public good values associated with conservation services are ignored. This is particularly likely to be relevant in the case of agrobiodiversity, as this tend to be associated with impure public goods characteristics, involving a private production value component that is directly linked to farmers' decisions and a public genetic information value component not necessarily accrued by individual farmers (Heisey et al., 1997; Smale et al., 2004). The private good characteristics are not only limited to direct use values associated with production outputs but also include the private benefits associated with using agrobiodiversity to minimise risks related to external shocks, such as climatic events and pest and diseases (e.g. Di Falco and Chavas, 2009). However, at the landscape level, the use of agrobiodiversity also plays a public good role in supporting agroecosystem resilience (Hajjar et al., 2008; Heisey et al., 1997), maintaining socio-cultural traditions, local identities and traditional knowledge (e.g. Nautiyal et al., 2008), as well as the maintenance of evolutionary processes, gene flow and global option values (e.g. Bellon, 2009). Inadequate accounting of such non-market and public good values can be associated with both market and global appropriation failures.

[2] An overestimation of the performance of improved PAGR has occurred. Among other reasons, the latter may result from market failures associated with inadequate accounting of external costs and benefits, such as those related to environmental impacts.

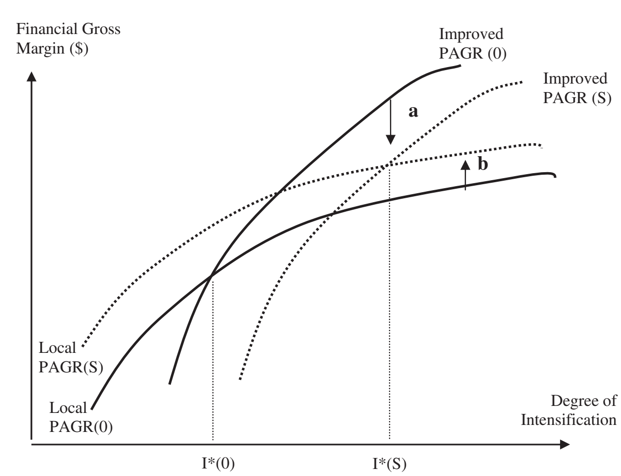

Fig. 1. Economics of agrobiodiversity loss: replacement of local PAGR by improved PAGR. Adapted from Drucker and Rodriguez (2009).

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[2] For instance: China's Grain for Green program which promotes reforestation in order to reduce soil erosion; the introduction of natural vegetation contour strips in the Philippines; integrating short-term improved fallow systems into smallholder agricultural systems in Kenya and Zambia; shade-grown coffee cultivation in Bolivia; windbreaks in Costa Rica; and the Silvopastoral Ecosystem Management Project in Colombia, Costa Rica and Nicaragua (see FAO, 2007b).

[3] Project entitled: "A Dynamic Farmer-Based Approach to the Conservation of African Plant Genetic Resources" (see http://www.gefonline.org/projectDetails.cfm?projID=351 for further details).

[3] Important intervention failures exist that increase the financial profitability of improved PAGR. These policy distortions can take many forms, including free availability of improved seeds, capital subsidies for inputs such as fertilizer or pesticides, free or subsidized support services, or subsidized market prices.

In the presence of market, intervention and global appropriation failures the financial incentives are likely to not be in accordance with the economic values (including non-market benefits and costs), so that the socially optimal replacement point may well be to the right of I*(0) resulting in the provision of agrobiodiversity conservation services at a level that is less than socially optimal (Heisey et al., 1997; Pascual and Perrings, 2007). While the precise distance between I*(0) and I*(S) is determined by the relative elasticities of the local and improved PAGR curves, it is possible to draw some general conclusions from this simple analytical model.

Firstly, to the left of I*(0) farmers may be assumed to have financial incentives not to replace local PAGR and thus conserve that what provides high economic values. Secondly, beyond I*(S), conversion of local PAGR by improved PAGR would be financially and economically justified. And thirdly, a replacement that takes place between I*(0) and I*(S) is associated with a sub-optimal loss of local PAGR, insofar as while the replacement appears financially desirable from a private/farmer perspective, it cannot be economically (socially) justified. This is because the additional loss of non-market values outweighs the benefits of the replacement.

As shown in Fig. 1, policy interventions to reach the optimal replacement point and thus optimal level of agrobiodiversity conservation services, would include: (*a*) accounting for negative externalities and removal of subsidies (in order to address [2] and [3] above), which would shift the curve for improved PAGR downwards to the right (dotted line); and (*b*) where significant non-market and public values of local PAGR exist (as per [1] above), further mechanisms need to be put in place to permit the 'capture' of the total economic values associated with local PAGR so as to shift the curve for local PAGR upwards to the left (dotted line). Such mechanisms could include niche market development for products associated with local PAGR, as well as PES-like rewards for the on-farm utilization of local PAGR, so-called PACS. The latter could also be applied in order to reach I*(S) even when not correcting for (2) and (3), or to motivate farmers conserve local PAGR at points to the right of I*(S) — e.g. for the purposes of avoiding irreversible losses by establishing a sustainability constraint, as long as they compensate farmers at least for their opportunity costs of using local PAGR.

3. The PACS Framework

PES have widely been understood as a Coasean solution to the underprovision of ecosystem services (Engel et al., 2008). Wunder's (2006, 2007) well known definition of PES stresses the voluntary nature of the transaction of a well *defined service* (or the land use necessary to secure it) between at least one *service provider* and *beneficiary*, when the provider secures service provision (*conditionality*).

This strict definition would suggest PACS to be a purely market-based solution with service beneficiaries directly and voluntarily paying farmers for the sustained on-farm utilization of local PAGR once the necessary institutions are set up. However, as discussed below, PACS may involve buyers who are not direct beneficiaries of agrobiodiversity conservation services and such programs thus need to be built in the context of relatively low levels of market development, as is the case with many of the world's government-financed PES schemes (Engel et al., 2008; Muradian et al., 2010). Moreover, there are significant institutional challenges, related to enforcement and compliance, hampering market-based transactions, which will also be discussed further below.

Accordingly, PACS can be more broadly seen as being an economic instrument to tackle market, intervention, and global appropriation failures associated with the public good characteristics of agrobiodiversity conservation services through the use of (monetary or in-kind) reward mechanisms in order to increase the private benefits from local PAGR, so as to sustain their on-farm utilization.

3.1. Matching Supply and Demand

With regard to the "defined services" criterion, PACS might be expected to focus on a particular agricultural practice, such as sustaining the on-farm utilization of local PAGR. PACS would thus have a different focus compared to that associated with more traditional PES (e.g. related to forest conservation) which tend of concentrate more on land use issues *per se*. The on-farm utilization of local PAGR in turn relates to the on-farm conservation of genetic diversity which is associated with provision of certain agrobiodiversity conservation services, such as: highly nutritious foods with unique tastes; natural insurance; the maintenance of cultural traditions, local identities and traditional knowledge; and the maintenance of evolutionary processes, gene flows, and wider option values.

The "providers" of such services are most likely to be found in less intensive agricultural systems as per the conceptual model above. Relevant communities are located in remote areas of developing countries, consisting of small-scale farmers, who manage species, varieties or breeds with unique adaptive traits (e.g. disease resistance, drought tolerance) bred over many years of domestication across a wide range of environments (Kontoleon et al., 2009; Smale, 2006).

There may be a range of service "beneficiaries" and thus potential buyers, as the demand for agrobiodiversity conservation services may be assumed to be dispersed reaching from local farmers and communities, to consumers all over the world and society in general. Yet, where these services are difficult to measure, where transaction costs associated with their exchange are high or where incentives to free ride on others exist, beneficiaries may not be willing to pay the providers, so that other agents have to act as buyers (as per Engel et al., 2008). Following Pagiola and Platais (2007), in government-financed PES a third party acts on behalf of the beneficiary, in contrast to user-financed ones where actual beneficiaries act as buyers themselves. Depending on the type of buyer and the resulting directness of transfers between service providers and the ultimate beneficiaries, significant differences in the degree of market development underlying the compensation flow may exist (as per Muradian et al., 2010).

What distinguishes agrobiodiversity conservation services from other ecosystem services are their significant direct private use values, as PAGR are linked to the production of food and fiber. It is in this context that attention has been recently drawn to the potential of existing agricultural market channels in promoting the use of threatened PAGR (Gruère et al., 2009). Local and global consumers of PAGR may pay for the on-farm utilization of local PAGR through such mechanisms as eco-labeling, certification or denomination of origin schemes when niche product markets are developed (e.g., Hermann and Bernet, 2009; Krishna et al., 2010; Rojas et al., 2009). As a note of caution, though, niche product market development may raise the financial profitability only of those local PAGR that closely match consumers' current tastes and preferences, while potentially continuing to neglect a large share of the local PAGR portfolio and their non-use values, so that such mechanisms could not correct for market failures due to the public goods characteristics of many agrobiodiversity conservation services.

In addition, private sector entities with forward or backward linkages to agriculture may be identified as an additional category of beneficiaries through potential future product development (Di Falco et al., 2008). There are also certain private industries, whose operations directly and indirectly exacerbate the replacement of traditional PAGR. Drawing on the concept of biodiversity offsets (see Madsen et al., 2010), regulatory obligations and corporate social responsibility could be used to motivate their support for investments aimed at mitigating their negative impacts.

As marginal commercial values of agrobiodiversity conservation for industry are normally not high enough to fund larger-scale on-farm conservation efforts (Swanson and Göschl, 2000) and as off-sets for adverse biodiversity impacts are only just emerging (Madsen et al., 2010), government agencies at a local, regional, national or even international level may be required at present to take on the role of service buyers. For example, local authorities could foster the use of traditional crop varieties by buying related food products and distributing them to public facilities (e.g. school-meal programs in the state of Tamil Nadu, India). These functions may also be fulfilled by quasi-governmental entities, such as development banks and conservation agencies or NGOs that acknowledge the importance of agrobiodiversity. In these cases, programs would generally be financed through tax revenues or voluntary contributions and hence resemble a public subsidy with little or no market development being required.

3.2. Institutional Challenges

Related to the "conditionality" criterion, any PES design in general is associated with a number of generic institutional challenges (as e.g. Ferraro and Simpson, 2002; Wunder, 2006, 2007). While PACS seems to provide a theoretically straightforward solution to the problem of agrobiodiversity loss if sufficient funding could be generated, implementation of such schemes on the ground is likely to be complex even when not requiring full market development.

Firstly, PACS schemes would require the creation of new institutions in order to implement negotiation, transaction, monitoring and enforcement mechanisms. While in many circumstances, the success of these interventions would depend on the institutions underlying the management of PAGR, for example patterns of collective action, PACS schemes could also potentially lead to an undermining of these same institutions (Narloch et al., 2011). Therefore, PACS would need to start by carefully assessing the interaction of reward schemes with existing institutions.

Secondly, land tenure issues need to be considered carefully. Tenure arrangements are location-specific, shaped by historical and political factors, and in poor farming communities are often not solely based on private resource ownership (Ezaguirre and Dennis, 2007). If targeted at areas where land-use rights are weakly established, PACS could potentially provoke tenurial conflicts. For instance, more powerful farmers might oust smallholders from the land they use in order to take advantage of the rewards associated with the conservation program (as per Landell-Mills and Porras, 2002).

Thirdly, as with PES schemes generally, PACS would be expected to involve intermediaries acting as transfer agents or brokers. Although in schemes built on the direct transactions between consumers or industry and farmers, the market could play this role, in other PACS schemes intermediaries might be able to exercise a dominant role in matching service providers and beneficiaries and may even be able to influence prices (as per Kosoy and Corbera, 2010). Nevertheless, as discussed below, conservation auctions through which farmers apply for conservation contracts (Latacz-Lohmann and van der Hamsvoort, 1997) may be an effective means through which farmers can determine the payments they require and farmers would be selected based on objective efficiency and not other subjective criteria as defined by intermediaries.

Fourthly, with regard to the monitoring and enforcement of PACS contracts, institutional arrangements would need to be created that deal with baselines, verification of service delivery and sanctions in case of non-compliance. The establishment of scientifically rigorous baselines is a necessary precondition for any PES/PACS scheme (Wunder, 2007). Determining baselines requires the construction of easily understandable performance metrics, clearly associated with specific conservation services in order to allow evaluation of additionality over the contract period. In some case it may be possible to link PAGR with easily measurable and observable conservation units, such as livestock of a certain breed or land area and amount of seed associated with a certain crop landrace. But in other cases it may be difficult to clearly distinguish between similar breeds and crop species/varieties, particularly in the mixed cropping systems found in many indigenous communities around the world. Nonetheless, under such circumstances, participatory collaboration with local farmers and scientists should still allow different crop varieties and livestock breeds to be clearly identifiable and documentable.

However, as with many existing PES schemes, there are severe challenges to be faced in establishing strong scientific foundations (Kosoy and Corbera, 2010; Wunder et al., 2008). Relating the conservation of specific livestock breeds or crop species/varieties to associated levels of genetic diversity is a rather complex task (van de Wouw et al., 2009), and it is also unclear to what extent these can be directly linked to the wider provision of agrobiodiversity conservation services, such as the maintenance of evolutionary processes or cultural traditions. More research remains to be carried out before it is possible to define scientifically rigorous conservation goals, as will be discussed in the next section.

4. Defining the Conservation Goal in PACS

On-farm conservation of PAGR is subject to an evolutionary process resulting from human selection and practices (Brush, 1989; Perales et al., 2003). Accordingly, on-farm conservation does not only imply the cultivation of a certain land areas and thus the generation and conservation of seeds, but also the maintenance of seed distribution networks, local traditions and local knowledge (Bellon, 2004; Brush, 1995; Stromberg et al., 2010). As such, PACS schemes may well need to incorporate a conservation strategy aiming for the maintenance of local seed systems as a whole (comprising seed production, storage, exchange and related agricultural knowledge). As part of such a strategy, a conservation goal needs to be defined in terms of which PAGR are to be conserved and what might be considered to constitute a safe minimum standard (SMS) or population needs to be established. However, such issues have only been dealt with, at best, to a limited extent in the literature on PAGR (see Bellon et al., 2003; Drucker, 2006; Zander et al., 2009).

4.1. Prioritizing PAGR in PACS

There are fundamentally different ways of conceptualizing genetic diversity. Ecological indices assign different weights according to the relative abundance of species, whereas economic indices use weights according to their dissimilarity, accounting for the characteristic features possessed by these species (Baumgärtner, 2008). This is because these two different types of indices are based on different notions of scarcity: absolute versus relative scarcity (Baumgärtner et al., 2006).

How to measure agrobiodiversity and thus to prioritize PAGR is directly linked to the type of conservation values to be supported (Baumgärtner, 2008). If agrobiodiversity conservation is mainly seen as valuable due to its contribution to ecosystem resilience, PACS ought to be based on ecological indices, but if it is mainly due to socio-cultural and option values attached to a diverse genetic resource pool, then economic indices would be preferable. As we consider the option values attached to agrobiodiversity to be potentially large, particularly given that climate change and technological progress may bring new risks and opportunities, there is also an increasing need to appraise and prioritize those resources that are associated with important socio-cultural values for farmers but that also reflect genetic diversity of a wider portfolio, subject to the limited conservation funding available (Bellon et al., 2003; Drucker et al., 2001). In this context, Weitzman-type decision support tools can help to target certain PAGR, so that the level of diversity conserved for any given conservation budget is maximized (Weitzman, 1992, 1993, 1998).[4]

Similarly, local PAGR could be prioritized for conservation based on a range of criteria. These include the level of endangerment based on different risk factors, and dissimilarity among crop varieties and livestock breeds based on agro-morphological characteristics or genetic traits (Ruane, 2000). If critical values are reached in all or some of the indicated risk-categories, PAGR may be classified as being 'under threat' or 'at risk', with priority given to those that have unique traits or are otherwise considered to embody a high degree of dissimilarity. Nevertheless, there is still a high level of scientific uncertainty, especially associated with the definition of critical values and with determining the degree of dissimilarity between and among species/varieties and breeds (Bellon et al., 2003; Reist-Marti et al., 2003; Ruane, 2000). Moreover, the cost of establishing the baselines necessary for carrying out the prioritization task needs to be taken into account and, given the general lack of detailed national statistics related to the status and trends of specific genetic resources, such activities may be costly.

There is also a critical issue related to appropriate scales of analysis, as originally shown by Weitzman (1992, 1993). This is because a local or national-level analysis might highlight certain resources as being threatened, while ignoring large near-identical PAGR populations just across a national or international administrative border. But even under these circumstances, a global conservation strategy ought to build on a decentralized system integrating different conservation sites to support co-evolutionary processes in different socio-ecological systems, while at the same time facilitating the exchange of PAGR across regions and borders, so as to maximize the safeguarded option values from agrobiodiversity conservation (Bellon, 2009).

4.2. Defining a Safe Minimum Standard for PAGR

Once PAGR have been prioritized regarding their level of threat and their uniqueness or dissimilarity, the next challenge lies in defining how much of the prioritized resource should be conserved. A safe minimum standard (SMS) based on avoiding irreversible loss of PAGR can be considered as a partial opportunity cost approach restricting the conversion of local PAGR by improved PAGR to an extent that does not threaten the long-term *in-situ* survival of the resource, thereby avoiding maximum future losses (Drucker, 2006; Ready and Bishop, 1991).

The complexity in the application of a SMS approach lies in the difficulty of defining such a minimum PAGR population size. In the case of domesticated animals, FAO (1998) defines a livestock breed generally not to be at risk if there are 1000 breeding females and 20 males. As noted previously, in the case of crop genetic resources, the estimation of a SMS is likely not only to be based on the cultivated area,[5] but also on the amount of seeds available in local systems and their age, the number of farmers of a specific species/variety and the degree of local knowledge maintained. Additional criteria, such as geographical distribution of PAGR and associated agro-ecological factors within those locations, existing seed distribution networks or breeding infrastructure, socio-cultural traditions and market integration could also be taken into account when establishing a workable SMS (e.g. as per Reist-Marti et al., 2003).

Consequently, it appears that there are many factors and underlying dynamics that would affect the definition of a SMS for PAGR, and PACS schemes would need to draw on interdisciplinary research on socio-ecological dynamics, in order to determine scientifically justifiable conservation goals. While it is possible that such goals might be fairly modest (e.g. individual variety conservation area goals might be expressed in hectares or tens of hectares rather than hundreds or thousands of hectares), to the best of our knowledge, existing research of this type is extremely limited and more work needs to be done in this area.

5. Some Preliminary Insights About PACS Performance

In addition to the challenges outlined above with regard to PACS design, there are also some important considerations related to the potential performance of PACS in terms of how they can attain their conservation goal (ecological effectiveness) at least-cost (economic efficiency), while ideally involving a pro-poor impact (social equity). As in most PES schemes, there may be certain trade-offs between such goals, especially between economic efficiency and equity (Pascual et al., 2010), as will be illustrated through some insights from an emerging quinoa PACS scheme to conserve local quinoa varieties, currently being implemented in the Andean Altiplano (see also Narloch et al., forthcoming).

Quinoa is a cereal crop with a long history in the Andes, but quinoa diversity has recently been being undermined through the replacement of varieties by commercially favored ones (Rojas et al., 2009). It is in this context that in the agricultural production season 2010/2011 a one-off pilot scheme was launched in two sites, one in Bolivia, one in Peru, with funding coming from an international agricultural research centre and local NGOs acting as intermediary institutions. Technicians from the latter prioritized a number of local quinoa varieties based on their level of endangerment and dissimilarity for inclusion in this scheme. In 2010 approximately 20 community-based groups (CBGs) in each site were invited to take part in a conservation auction involving a one-shot bidding process for conservation contracts for these varieties. Given limited conservation funds ($4,000 per country excluding operational transaction costs), a budget-constraint based selection approach was adopted and six (ten) CBGs from Peru (Bolivia) were awarded conservation contracts starting with the planting season at the end of 2010.

5.1. Ecological Effectiveness

Given a conservation strategy based on the maintenance of the existing seed system, the conservation goal of this PACS scheme is not only expressed in terms of conservation area, but also in terms of number of participating farmers (so as to safeguard agricultural knowledge and cultural traditions) and CBGs. The latter relates to the maintenance of seed distribution networks and to risk spreading when maximizing the spatial distribution of the conservation efforts, as communities in the Altiplano are widely dispersed. However, a number of issues related to the choice of goals as well as the location of the scheme should be considered.

Firstly, the focus on sites where threatened PAGR are still being utilized might raise a concern about the scheme's additionality, i.e. whether the level of conservation services would in fact have been lower without the program. Where rewards are awarded to farmers who would in any case have carried out de-facto conservation of the targeted quinoa varieties, the program would not generate any additional conservation services. However, it might be considered unfair not to offer payments to those farmers who are the de-facto custodians of the target varieties. Of course, the problem of such strategy is that it could eventually create perverse incentives if the program is not carefully designed (as per Pagiola and Platais, 2007). For example, custodian farmers might opt to stop cultivating the target

[4] Weitzman diversity indices were originally built on aggregate measures of the pairwise dissimilarity between species, through which species would be prioritized according to the increase in diversity when adding a certain species to an arbitrarily chosen pool of species (Weitzman, 1992).

[5] For example, under the Lazio (Italy) Rural Development Progamme, a crop species/variety may be considered highly threatened if it covers less than 1% of the regional area, has a declining trend, is grown by less than 30 farmers, is not found in the market and is not listed in commercial seed catalogs (PSR Lazio, 2008).

varieties in order to be considered for receiving rewards under PACS schemes in the future.

More importantly regarding additionality, in line with one of Weitzman's (1993) original findings, it might be expected that given the potentially high contribution of some specific varieties to overall diversity (i.e. because of their high degree of dissimilarity), their continued existence may be worthwhile securing even prior to their actually becoming threatened. Threshold effects may also imply that such interventions would be more cost-effective than once much smaller and threatened population levels of the PAGR in question have been reached, and when downward population trends for the targeted varieties are likely to exist.

As in both case studies, most of the quinoa varieties that entered the program were hard to find in the targeted communities, this quinoa PACS scheme can be assumed to significantly increase the area under the threatened/at risk crop varieties as well as the number of farmers cultivating them. To what extent this approach can translate into additional agrobiodiversity conservation services over the long-term remains to be determined but will clearly depend on improving the scientific foundations related to the relationship between the conservation of certain varieties and the securing of the actual agrobiodiversity conservation services that are desired.

Secondly, other concerns about the ecological effectiveness of this program are related to leakage, i.e. the unintended side-effects that adversely affect other conservation services. PACS interventions might undermine existing rotation systems or lead to an expansion into previously non-agricultural areas. However, given the program's focus on rather small areas to be dedicated to conservation activities, these concerns seem less worrying. More serious would be the possible replacement of other threatened varieties that do not form part of the program.

Thirdly the sustainability of PACS schemes, i.e. their permanence in providing conservation services over the longer term, depends to a large extent on the duration of the flow of the payments, as farmers are unlikely to self-sustain the utilization of the target varieties, when these are underutilized as a result of other species'/varieties' higher market profitability. That said, it could be argued that this PACS scheme as a one-off initiative without secured future funding is unsustainable. Nonetheless, given that quinoa seeds can normally be stored for about five years under local conditions without losing their suitability to serve as planting material, the program could still be considered as effective as long as a new PACS initiative could be started within this time-span. Identifying potential buyers for subsequent reward systems thus proves to be a critical factor for the effectiveness of this particular PACS scheme. A further factor in favor of PACS sustainability would be where conservation goals only require relatively modest areas and farmers face relatively low opportunity costs. This could translate into relatively low levels of conservation funding being required (Drucker, 2006; Zander et al., 2009), particularly when compared to other types of agricultural subsidy, hence making permanence more likely.

Nonetheless, the program's effectiveness may also be undermined from the supply side, that is, when despite the availability of funds (demand), farmers might not be willing to enter conservation contracts. This may happen when no outside intervention is accepted, e.g., when commoditisation of their conservation effort is rejected (as per Kosoy and Corbera, 2010), or farmers are unwilling to enter into long-term conservation contracts as this might jeopardize their future livelihood options.

5.2. Economic Efficiency

Given the attainment of a given conservation goal, a program's efficiency is determined by its cost-effectiveness. Payment levels need to cover at least the *opportunity costs* of the participating farmers arising from the benefits forgone from not cultivating more financially attractive varieties (c.f Fig. 1). Communities with less-intensified farming systems, such as those in the Andean Altiplano, are expected to provide opportunities to implement relatively low-cost conservation programs. Yet opportunity costs are farm-specific, shaped by location as well as individual factors, so that the efficiency challenge lies in the ability to identify valuable services and to estimate the resulting opportunity costs appropriately. Efficiency would be maximized if farmers are not compensated in excess of their financial opportunity costs.

Most existing PES based on fixed pricing rules are considered to have overpaid farmers (FAO, 2007b).[6] By contrast, the quinoa PACS scheme is built on a conservation auction, in which CBGs define the reward required for conserving a certain land area with a certain number of farmers. Under such a competitive tender approach, farmers have an incentive to apply for conservation contracts close to their real opportunity-costs (Latacz-Lohmann and van der Hamsvoort, 1997; Stoneham et al., 2003), which might be expected to also account for any private non-market values (likely to be positive). Auctions systems include a cost-revealing mechanism and so are a suitable means to tackle the existence of information asymmetries and thus may bring substantial cost savings (Ferraro, 2008). Farmers' opportunity costs vary significantly from one CBG to another and that selecting CBGs with the most cost-effective offers can increase efficiency substantially (Narloch et al., forthcoming).

However, there remains a risk that such efficiency gains may be undermined over time if CBGs cannot continue to be attracted to submit bids for conservation in future years (e.g. where CBGs who do not win a contract become discouraged from submitting further offers) or as a result of strategic behavior associated with farmers learning from repeated auctions (Schilizzi and Latacz-Lohmann, 2007). Assuming that strategic bidding behavior can be kept to a minimum (e.g. by varying the targeted species/varieties), repeating such conservation auctions every year, would prove desirable for two reasons: Firstly, such PACS schemes would be able to acknowledge the dynamic nature of opportunity costs, with farmers able to flexibly react to changing market and climatic conditions by adjusting their bids on a year-to-year basis without entering into long-term conservation contracts. And secondly, given that bids might increasingly reflect actual levels of risk, repeated tenders could potentially also provide information similar to that of an early warning system.

Transaction costs, i.e. the one-off start-up costs for program implementation plus the permanent costs of running the scheme, might be relatively high in the case of yearly repeated conservation auctions. The annual nature of such expenses plus the additional costs of potentially involving very different CBGs from year to year might be expected to exceed transaction costs related to a PACS scheme that sets a fixed price for everyone with farmers entering into contracts for multiple years. Furthermore, where participating farmers have contracted themselves to cultivate a crop variety not planted in previous years (which may well be the case given the focus on threatened varieties), PACS schemes might face the additional cost of facilitating access to quality seeds. This was the case under the quinoa pilot PACS program, although it does bring the advantage of providing an opportunity to supply a uniform seed lot of the target variety to participating farmers.

Start-up costs also result from establishing baselines and developing conservation goals. PACS schemes may be regarded as inefficient where funds are spent for something that is abundant in other places or where conservation activities do not enhance the provision of agrobiodiversity conservation services. However, it should be kept in mind that there may well be a trade-off involved in establishing exact

[6] It should be noted that in theory prices may also be set at a level at which farmers would not be willing to take part in conservation.

baselines and rigorous goals versus the costs of doing so (e.g. in terms of verification) once their practical implementability in the field is taken into account (as per Muradian et al., 2010).

Additionally, PACS schemes would involve costs for monitoring and enforcement, although participatory PACS approaches, where the scheme involves farming communities themselves in such activities, may help to minimise such costs. Furthermore, the PACS schemes in Peru and Bolivia are implemented at a group-level rather than an individual one, so that economies of scale tend to reduce average transaction costs related to administration. Similarly, contracting a few large farmers rather than many small ones could also be a strategy to reduce transaction costs (as per Pagiola et al., 2007). However, where it is considered desirable for local seed systems to be maintained as a whole it is also likely to be desirable to attempt to maximize the number of conserving farmers and their spatial distribution (as per Stromberg et al., 2010). There may also be a trade-off between efficiency and equity related to the number of participating farmers or farmer groups (as per Wunder, 2007).

5.3. Social Equity

Many authors have highlighted the fact that PES-like interventions should have their primary emphasis on their ecological outcomes, so that socially desirable goals may need to be traded-off (Engel et al., 2008; Pagiola et al., 2005; Wunder, 2007). Nonetheless, ignoring the social dimensions of PES might create a 'PES curse' by undermining the success and legitimacy of PES. To some extent then, environmental and social goals are intertwined and there is a need to take into account equity in terms of decision-making, access and outcomes (Corbera et al., 2007; Pascual et al., 2010).

Firstly, equity in decision-making under PACS could be reached through procedural fairness where different stakeholder groups have an opportunity to participate in the design of the payment schemes, or at least their interests could be taken into account. On the one hand, the quinoa PACS scheme is a top–down approach, where farmers have to accept the rules of the game if they want to participate, so that procedural fairness is rather low. Yet on the other hand, PACS schemes generally offer voluntary participation opportunities and, through the auction mechanism, the quinoa PACS scheme also allows farmers to define their required reward levels and to choose from a list of targeted varieties.

Secondly, equity in access depends on the extent to which different farmers, and in particular the poor and disadvantaged, are targeted and thus invited to take part in the conservation auction. In the Peruvian and Bolivian sites the focus is clearly on rather marginalized rural areas, so that—globally or nationally seen—this may have a pro-poor impact. However, from a more local perspective it also needs to be evaluated in how far the most marginalized communities and the poorest farmers are targeted. In case of this group-level PACS scheme with its focus on farmer-based CBGs, the intervention actually seeks to involve farmers who can build on existing institutions of collective action. In the Andes, this may tend to involve better-off farmers (as per Munoz et al., 2007). Similarly, there is a danger that poorer farmers may not always be able to overcome entry barriers related to land tenure requirements and transaction costs (as per Grieg-Gran et al., 2005; Wunder, 2007).

Thirdly, it would be desirable for PACS schemes to support equity in outcomes with a number of fairness concepts that may be relevant in different field contexts (Pascual et al., 2010). If a pro-poor impact is most desirable, then equity is very much determined by the wealth status of participating farmers and local consumers, who may also be affected by the program (as per Grieg-Gran et al., 2005; Zilberman et al., 2008). The quinoa PACS scheme is likely to benefit rather poor farming communities through the enhancing the production of local quinoa varieties associated with high nutritious values and through providing in-kind rewards that may consist of agricultural inputs or equipment, as well as building or school materials, which are determined by CBGs themselves. At an intra-group level, equity outcomes depend on how these new assets will be distributed within the farming communities. There may be the risk that powerful farmers might be more easily able to reap the benefits resulting from the distribution of such rewards. Inter-group equity is also dependent on the distribution of rewards among those CBGs that handed in a bid-offer. In certain local contexts, it would be perceived as fair if everyone is compensated according to the conservation costs they incur, thereby favoring discriminatory pricing rules, whereas in other contexts an egalitarian distribution would be preferred (paying everyone the same regardless of their contribution or effort).

While there is much more research that needs to be undertaken to evaluate inter- and intra-group equity outcomes, it is recognized that perceived inequalities may result in local conflicts and thus undermine the robustness of community-based conservation programs (as per Pascual et al., 2010). PACS practitioners might therefore do well in designing PACS schemes in a way that facilitates participation of the most disadvantaged farmers and that does not clash with local perceptions of fairness.

6. Conclusions

This paper has discussed the potential application of PES-like schemes to tackle market failures associated with the public good characteristics of agrobiodiversity conservation services by increasing the private benefits from utilizing local plant and animal genetic resources (PAGR) on-farm through voluntary reward mechanisms. Hence, so called payments for agrobiodiversity conservation services (PACS) could potentially provide farmers with an incentive to sustain the *in-situ* conservation of threatened, local PAGR. Nonetheless, attention is paid to some generic challenges to be overcome in the implementation of such programs on the ground with regard to the identification of potential buyers of conservation services and the complex institutional settings in which PACS would have to be implemented.

Further challenges are associated with the definition of a conservation goal. It is argued that interdisciplinary research on socio-ecological dynamics is needed in order to complete prioritization exercises and establish safe minimum standards for local PAGR. As with most PES programs, PACS may need to trade-off to some extent the use of scientifically rigorous conservation indicators against those that are somewhat easier (and less costly) to implement in practice. Scientific precision in linking conservation goals with the provision of agrobiodiversity conservation services is, nevertheless, urgently needed, so as to make sure that limited resources are invested in those conservation activities that indeed lead to additional conservation services. As in other PES schemes this is also important for the generation of additional funding, as potential beneficiaries are more likely to be willing to finance such schemes where the provision of conservation services is clearly verifiable.

Related to the latter, the sustainability of PACS is a key area of concern. Programs that cannot directly involve service beneficiaries, as is the case with government-financed schemes, might have a limited life-span, unless adequate endowment funds can be established. That said, niche market development for agrobiodiversity-related products is increasingly being promoted as a means of sustainably achieving conservation through use. Such "conservation-through-development approaches" can potentially be more sustainable, as they build on existing agricultural market channels and thus could be used to generate a sustainable source of funding. But it should be noted that relying solely on market development might be a dangerous strategy for the conservation of a diverse genetic resource pool, especially as market conditions can change rapidly and generally consumers and agribusiness tend to favor a narrow suite of crop species/varieties or animal breeds. Market chain approaches may also require relatively high initial investments to generate appropriate product volumes, with such volumes being far in excess of those required to achieve modest conservation goals, and where overly successful may even displace other threatened agrobiodiverse genetic resources (leakage effect).

In this context, PACS schemes might be capable of providing a stronger and more flexible longer-term foundation for conservation activities, and may be better suited for ensuring the *in-situ* conservation of safe minimum populations of PAGR. Niche market development and PACS can thus be viewed as complementing each other. In fact, a broader conservation strategy could incorporate a mixture of incentive instruments, and as such could combine niche market development with PACS schemes built on governmental funds as well as private sector funding, such as through biodiversity offset programs.

For economic efficiency reasons, PACS might focus on farmer groups instead of individual farmers so as to lower transaction costs. We hypothesize that PACS schemes involving conservation auctions may be more efficient due to their opportunity cost revealing mechanism. Despite potentially relatively higher transaction costs and the risk of strategic bidding behavior when undertaking repeated conservation auctions, this approach would not only permit the farm-specific nature of the opportunity costs to be accounted for, but also their variability over time and hence play a role as an early warning system.

Such competitive tender-based PACS approaches coupled with discriminatory pricing rules would increase efficiency and thereby also potentially permit a larger number of farmers/communities to be rewarded within any given conservation budget. It is important to note though, that such a competitive approach might clash with idiosyncratic cultural norms and possibly lead to perceived unfairness. Existing inequities in situations where better-off households are more easily able to capture the benefits of the PACS schemes also need to be considered.

Given that generally threatened PAGR are located in disadvantaged and remote rural areas in developing countries, PACS may prove a useful part of rural development packages. Under such circumstances, PACS schemes would need to be designed in a way that takes fairness considerations on-board in order not to undermine the long-term legitimacy of such programs and thus their robustness. In addition to the existing pilot quinoa PACS scheme, more location-specific research is needed to assess such potential trade-offs between ecological, economic and social goals, and to evaluate the performance of PACS instruments. We conclude that PACS may well be considered a useful potential tool for policy-makers. Nevertheless, given the many constraints and the lack of field experience to-date, there is clearly more research to be undertaken before PACS may become established in the policy-maker's toolbox.

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