Payments for watershed service: A review of literature

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Executive Summary

Payments for ecosystem services are being developed largely as a response to the challenges and constraints that are facing regulatory mechanisms for the management of natural resources. Payments for watershed services (PWS) are a sub-set of payments for ecosystems and specifically seek to establish new relationships between water users and upstream land managers. The number of PWS-based programmes is increasing even though the area over which they operate is relatively small – the exception being the sloping lands conversion programme in China. This review of the PWS literature highlights three substantial debates: the relationship between land use and hydrological functions in watersheds, the impact on the livelihoods of land managers and especially the rural poor, and the means by which PWS programmes are being financed. In the context of future research by DFID, the review suggests three themes: methodologies and models for determining land use–water relationships; the integration of incentive and regulatory frameworks, and more robust methodologies by which development and resource management programmes and projects can be evaluated.

Acronyms and abbreviations

CBNRM	Community Based Natural Resource Management
ES	Environmental service
FRP	Forestry Research Programme
ICDPs	Integrated Conservation and Development Programmes
IIED	International Institute for Environment and Development
MA	Millennium Ecosystem Analysis
MDG	Millennium Development Goals
PES	Payments for Environmental Services
PWS	Payments for Watershed Services
RUPES	Rewarding Upland Poor for Environmental Services
SLCP	Sloping Lands Conversion Programme
UNDP	United Nations Development Programmes
UNWCED	United Nations World Commission for Environment and Development
WfW	Working for Water
WWF(MPO)	World Wildlife Fund (Macro-economics Programme Office

Contents

1. Introduction

Humankind is dependent on the earth's ecosystems and on the services provided by those ecosystems. It is only recently, however, that society in general has begun to realise that the earth's resources are finite and that the general welfare of future generations depends on wise and informed use of the environment by current generations (UNWCED, 1987). The disaggregation of ecosystems into the component 'ecosystem services[1]' is a very recent approach that emphasises the interdependence of organisms and the environments in which they are found. Describing and analysing these dependencies is exceptionally complicated due to the spatial and temporal scales at which these interactions take place (Kremen, 2005).

The fact that ecosystems have been taken for granted and that services that they provided were generally considered to be free is one of the compelling explanations for why society is currently facing so many environmental challenges (Tietenberg, 2000). The disaggregation of ecosystems into ecosystem services not only highlights the interdependency of these systems but also allows these services to be valued – albeit contentiously in many cases. Correcting market failure and developing payments for ecosystem services is one approach that is particularly favoured by economists as a solution to the abuse of ecosystems (Barbier and Swanson, 1992). Not only does it correct the impression that ecosystem services are 'not free' but markets and prices create a mechanism for settling the various trade-offs that are involved when ecosystems are disrupted (for example by the construction of a dam).

The Millennium Ecosystem Assessment estimated that 60 per cent of ecosystem services are currently degraded or are being used unsustainably (MA, 2005). In particular the status of freshwater ecosystems is perilous. Collectively they are in a worse condition than forest, grassland or coastal systems (op. cit). There are many sources and drivers of degradation. These include changes in land cover, changes in land use, the over-extraction of surface and ground water, the impact of infrastructure and the introduction and spread of alien invasive species. In addition, freshwater systems have often been deliberately used for the disposal of human, agricultural and industrial waste with the result that water pollution is a real problem in many countries[2]. Accidental toxic discharges and non-point pollution particularly from large-scale commercial agriculture also contribute to the pollution of freshwater ecosystems. It is undisputable however, that the intensification and expansion of agriculture as well as the extraction of natural resources have substantially contributed to the net gains in human welfare (UNDP, 2006). However, further loss of ecosystem services and environmental degradation will become a substantial barrier to reaching the Millennium Development Goals (MDGs) that underpin the global drive to end poverty (MA, 2005).

This part of the scoping study briefly reviews the literature on payments for watershed services. It defines payments for watershed services (section 2) and then briefly reviews the literature and emerging issues (section 3). The relationships between payments for watershed services and climate change are reviewed (section 4) and areas for further research considered (Section 5).

2. What are payments for watershed services?

The dominant paradigm of the 20th century has been to promote economic development over environmental concerns, the argument being that these would be resolved at a later stage (Adams *et al*, 2004). In the last two decades however, our understanding of complex links and feedback loops between poverty, land use change and environmental degradation has improved sufficiently to know that the two issues need to be dealt with concurrently.

While environmental issues and conservation were generally subservient to economic development, they were not totally ignored. Creating 'protected areas' largely fulfilled national

[1] Ecosystem services are the benefits that people obtain from ecosystems (MA, 2005). Not all ecosystem products and functions are therefore classed as 'services'. Generally four categories of ecosystem service are recognised: provisioning, regulating, cultural and preserving services (op. cit).

[2] In China it is estimated that 75 per cent of freshwater systems are polluted and unfit for human use (Liu, 2005)

conservation objectives. Some protected areas were deliberately created to protect catchments and watersheds while in others such protection has been an indirect benefit (Lockwood, 2006). In addition to protected areas, governments often developed highly restrictive regulatory frameworks for natural resources management – including water and watersheds (Fabricius, 2005, Landell-Mills and Porras, 2002). Although some 12 per cent of the worlds surface area is now nominally protected, the regulatory frameworks for other categories of land tenure were hard to enforce, politically unpopular and sometimes of dubious veracity (Worboys and Winkler, 2006).

There have been several iterative cycles of programmes to reconcile environment and development challenges. The integrated conservation and development programmes (ICDPs) of the 1980s and 1990s failed to achieve either their conservation or their livelihood-improvement goals (Barrett and Arcese, 1995; Simpson and Sedjo, 1996). Community-Based Natural Resource Management (CBNRM) programmes have fared somewhat better because they have transferred greater ownership to local people than ICDPs (Murphree, 2000). In some instances they have also succeeded in creating substantial benefits at both community and household level from sustainable natural resource use, particularly from forests in south Asia and wildlife in southern Africa (Roe *et al*, 2006, Borrini-Feyerabend *et al*, 2004; Child *et al*, 2004; Roe *et al*, 2000).

A perceived weakness of both ICDPs and CBNRM programmes was the absence of clear links between performance and benefits (Wunder, 2005). For example, in some southern African cases communities receiving wildlife revenues are under no contractual obligation to maintain wildlife habitat[3]. An exception is Namibia where registration of a communal land conservancy and the right to retain revenue binds the community into land use and management plans (Davis *et al*, 2007).

Payments for ecosystem services are a mechanism or tool for correcting the failure of conventional markets to value ecosystem services. This is done by internalising the costs and benefits of supplying the service (Barbier and Swanson, 1992). In practice this means that the users of ecosystem services (such as residents of urban areas) pay land managers and natural resources stewards for the services provided and the costs incurred (Gutman 2006; Pagiola, Arcenas and Platias, 2004).

The key innovation and the characteristic that differentiates PES from previous paradigms or approaches is that the payments are conditional or contingent on changes in land or resource (water, forest, etc) use by the service provider. A robust and generally accepted definition of payments for ecosystem services is:

1. a *voluntary transaction* in which
2. a *well-defined environmental service (ES)* (or a land use likely to secure that service)
3. is being purchased by at least one *ES buyer*
4. from at least one *ES provider*
5. if, and only if, the ES provider ensures the supply of the ES (i.e. there is *conditionality)*

(Source: Wunder, 2005)

Each element of the definition is important as taken together, they identify PES as a new approach, not simply an old one with a new label (Wunder, 2005). The *voluntary* nature of the transaction separates PES from the conventional command-and-control approach of many governments. *Clear definition of the environmental service* implies that the service can be measured, i.e. tonnes of carbon sequestered or turbidity levels in water, which in turn is central to enforcing conditionality. Structuring the arrangement as a relationship between a *buyer* and an ecosystem service (ES) supplier or *seller* clearly defines the principles and counters the tendency for third parties to appropriate the financial benefits. The *conditionality* criterion (contingency) serves to separate payments for ecosystem services (PES) from many other incentive-based resource management approaches. In its simplest form, it means that the payment will only be made when the providers

[3] The working assumption for many CBNRM Programmes is that communities would voluntarily accept wildlife as a land-use when its net benefits exceeded those of the alternatives (Bond, 2001).

of the service implement the agreed changes. It can be refined so that payment is scaled to performance, at least up to some maximum.

The concept has some implicit elements as well. It is assumed that the desired land use is not the preferred land use option from the perspective of the landholder (otherwise there would be no need for payments as the rational landholder would already be pursuing that option). This means that the payments have to be sufficient to compensate the landholder for the opportunity costs of foregoing the preferred land use. When uncertainty, risk and the transaction costs of negotiating and sustaining the agreement are factored in, the payment must be substantially more than just the opportunity costs if it is to be any incentive to change (Ostrom, 1998).

Since the services being bought are ones that are presumably wanted in perpetuity, the change in land use should be long-term. Indeed, short-term incentives are unlikely to lead to permanent changes in the way the land and natural resources are used because, with the prospect of an upcoming end to payments, the rational land manager can and may be disinclined to make fundamental changes in land use and will simply revert to the previous land use system. Only under a long-term agreement will land managers be willing to make the necessary structural changes that would make a return to the past unlikely.

Whereas the rigorous definition of PES provides a vision of the ideal, few projects currently achieve this (Robertson and Wunder, 2005; Wunder, 2005). This is because environment and development issues in most countries are complex, involving many concessions and trade-offs. However schemes that include incentives for land managers and in some cases markets for environmental services are developing, albeit mostly at a small scale relative to the scale of catchments and the substantial challenges involved. Many of these schemes and programmes are characterised by considerable ingenuity and creativity (Landell-Mills and Porras, 2002), as stakeholders struggle to find new ways of addressing long-standing and often seemingly intractable problems. The structure of these markets, the environmental services on offer, and the form of the payments all vary considerably. One recent review of PES schemes identified 11 different payment mechanisms, ranging from direct transactions between buyers and sellers to complex exchange-based trading schemes using options and futures (Landell-Mills and Porras, 2002). Of the 287 cases reviewed, just 17 per cent involved direct negotiations and transactions between buyers and sellers of ecosystem services (*op. cit*).

Payments for ecosystem services are being developed in complex institutional frameworks that often include both formal and informal rules and codes of conduct. Security of land tenure and the freedom to make contracts have emerged as particularly important institutional issues. Those involved in providing environmental services must have some security of tenure over the land they use, otherwise they will not have the incentive to invest in new forms of land use (Pagiola, Arcenas and Platais, 2004). For the conditionality of the arrangement to be binding, the contracts must have legal standing and can be enforced in law. This is particularly challenging in developing countries where both land tenure and contractual relationships may be governed by formal legislation and traditional or social norms.

3. State of the literature debate on payments for watershed services

Environmental services derived from watersheds are one of the four general categories of forest-linked services for which markets are emerging (Landell-Mills and Porras, 2002). These services include regulating the timing and extent of runoff; storing water; recharging aquifers; reducing salinization; controlling erosion; preventing landslides; limiting the extent of flooding in some cases; and filtering and decomposing organic material, thereby purifying the water flowing from a catchment.

The relationship between land use and most of these watershed services is complicated and often very difficult to establish (Calder, 2005). In particular, the extent to which land use and land cover affect the production of watershed services is uncertain and hotly debated. Too often, however, the debate is characterised by generalisations that do not refer to the specifics of the site in question

and by conventional wisdom relating to the links between land use and hydrological functions. However, many of these long-standing myths are so entrenched that they still form the basis of forest policy in some countries[4] (FRP 2005; Calder, 2005).

Changes in land use and the impact on the hydrological functions (particularly water quantity) of the watershed are in reality, site-specific, depending on the local climate, soils, vegetation, local topography and the underlying geology, as well as on the nature of the change in land use and associated infrastructure. Changes in land use are also generally accompanied by substantial changes in water use. For example where indigenous vegetation is cleared for settlement and agriculture, water is abstracted for agriculture, livestock and domestic purposes – thereby immediately changing the hydrological regime. Thus quantification of land use–water relationships is difficult due to multiple and linked variables. There are also significant problems associated with the scale of observation and time lags between the change in one variable and the response of another (Kiersch, 2000). These challenges have important implications for programmes involving payments for watershed services. Firstly, schemes must be developed on the basis of land use and hydrology relationships from within the watershed or catchment in question, rather than being imputed from elsewhere. Secondly, the notion of 'clear and measurable environmental services' (Wunder, 2005) may not be achievable in many watersheds.

Payments for watershed services are often constructed around a simple model where the poor live in the upper catchments, while those that live further down the catchment are wealthier. Not only is the model an over-simplification of the complexity of the distribution of wealth in a catchment, but also it is frequently wrong. However, for a payments for watershed services scheme to be an option, there must be downstream buyers of the services (Pagiola, Arcenas and Platais, 2005). In many catchments there are no buyers and therefore there is no chance to develop a private sector based PWS. Even where there is a potential buyer, the buyer's perception of the problems is important (Wunder, 2005). If large parts of the catchment are intact it might be very difficult to convince a buyer that payments are appropriate to pre-empt a problem. Conversely, where land use changes are extensive, the costs of changing land use might well be prohibitive. This suggests that there is a window of opportunity for payments for watershed services that lies somewhere between initial changes in land use and large scale conversion of the catchment (op. cit).

Recent literature on payments for watershed services has focused on three key questions: What is the hydrological evidence in support of payments for watershed services? What is the potential of PWS to contribute to poverty alleviation and enhance livelihoods? And what are the payment mechanisms and how do they differ between public and private finance?

3.1 Land use and hydrology

The hydrological case for payments for watershed protection is complex and not yet fully resolved (Aylward *et al*, 1998; Bruijnzeel, 2004; Calder, 2005; Calder *et al*, 2004; FRP, 2005). In part, there is lack of clarity about whether the target of payments is to secure the flow or quality of water, or both. It is also not always clear if the payments are being made to secure a particular environmental service (i.e. water quality) or to reduce adverse impacts on the land (i.e. excessive erosion), in which changes in water quality are proxy indicators of the effectiveness of the measures being taken. Most of the debates tend to focus on forest – non-forest scenarios (The Economist, 21 April 2005), whereas in reality most catchments comprise a mix of land classes and uses. The impact on hydrology depends on where in the landscape the land use changes are situated (Smith *et al*, 2006).

[4] A good example is the impact of the 1998 floods along the Yangtze River in China that resulted in the "grain to green" of the Sloping Lands Conversion Programme (SLCP).

The most notable PWS successes have involved reductions in "non-point source pollution[5]" in developed countries (Pires, 2003; Appleton 2002; Perrot-Maitre, 2006). For example, in the Catskills–Delaware Watershed, New York City has used a combination of legislation, monetary incentives, land purchases and conservation easements to ensure that the water flowing into the city meets Federal Water quality targets (Pires, 2003). In the Vittel catchment, France, Nestlé Waters have used a similarly diverse set of instruments to reduce nitrate levels to below 10mg/l (Perrot-Maitre, 2006).

In both cases the precise relationship between land use and water quality was incomplete but there was sufficient reason to pursue the option. Uncertainty and the lack of clear hydrological evidence can be overcome by adopting an adaptive approach to the management of the catchment and its water production: specifying a clear goal; implementing changes designed to achieve the goal; monitoring and evaluating the outcome; and adjusting the management accordingly (Holling, 1978; Westly, 2002). The search for cost-effective technological solutions itself provides new information about the processes involved, which in turn helps to clarify the land-water linkages.

New technologies have made it easier to understand the dynamics of water quantity within a catchment as well as the relationship between surface and ground water (Calder, 2005). Together with more accurate means of measuring rainfall, these tools mean that more accurate predictions of changes in land management and water quantity can be made. Nevertheless, even where long-term and accurate time-series data of water flow exists, establishing a functional link between land use and water quantity can still be problematic because of high inter-annual variation in rainfall, the non-linear relationships between variables and the longer-term climatic cycles (Porras, pers. comm.).

3.2 Payments for watershed services, livelihoods and poverty

Payments for environmental services are seen as a potential win-win situation that can improve both natural resource management and the livelihoods of rural and very often poor land managers (Landell-Mills and Porras, 2002; Pagiola, Landell-Mills *et al*, 2002).

In theory, the poor can benefit from payments for watershed services both directly and indirectly (Landell-Mills and Porras, 2002). Participating individuals and households may receive direct benefits in cash or kind, while communities may profit through the development of infrastructure – hospital, schools, roads etc. The poor can benefit through more secure land tenure, if governments make the requisite changes. Individuals and communities may benefit indirectly by being empowered to take decisions and negotiate over access to and use of resources, and by having more stable social, cultural and environmental conditions.

Most of the limited quantified evidence for the positive impacts of PWS on livelihoods and poverty comes from Latin America. In Costa Rica, survey data has shown that PWS comprised 10 per cent or more of household income in about a quarter of the cases (Ortiz, 2005). In one area, Virilla, payments amounted to 16 per cent of household income, which averaged US$820 per month (Miranda *et al*, 2003), while in another, the Osa Peninsula, the payments apparently enabled about half the beneficiaries to move out of poverty (Munoz, 2004). In Ecuador, payments for watershed services contributed about 30 per cent of all household income (Echavarria *et al*, 2004).

An implicit assumption in many PWS schemes, irrespective of scale, is that the service providers are generally poorer than those buying the services. This has a number of consequences. First, there is usually a need for an intermediary to help overcome asymmetries in knowledge, power and influence, to ensure that any agreement is equitable. Second, environmental services are

[5] It is important to note the differences between point and non-point pollution and why payments for watershed services do not contradict the important principle of 'polluter pays' . Point source pollution is from a identifiable sources – an outlet into a river (Markandya *et al*). Point source pollution can be effectively and efficiently dealt with by polluter pays mechanisms. Non-point pollution is from multiple sources such as chemical applications by farmers in a catchment. It is under these circumstances that incentives have been shown to be more effective than regulation and criminalisation.

derived from land, but the poorest groups within society are generally landless or have poorly defined tenure over the land on which they live (Grieg-Gran, 2004). Third, the poor are generally not well organised, so some institutional and organisational development is necessary before and during the establishment of a PWS scheme. Finally, this preparatory work, together with that involved in negotiating and sustaining payments, carries substantial transaction costs. These are generally compounded by complex rules and regulations, unclear science about the links between land use and the desired environmental service, the presence of other stakeholders (including government), and an absence of intermediaries (Landell-Mills and Porras, 2002).

Whether PWS can help to alleviate poverty depends on the causes of poverty in any given situation. In many cases extreme poverty results from poor governance or structural inequities (e.g. as formerly under apartheid in South Africa, though the legacy lives on). Such poverty will not be substantially alleviated through PWS. In other cases, poverty is a result of more immediate circumstances, including limited opportunities to earn income and poor connectedness to markets. The development of PWS could have an impact in these cases.

Concern has been expressed that PWS could negatively impact the poor by restricting their access to land and natural resources, or even by commoditizing water (Lovera, S, 2005; Grieg-Gran and Bishop, 2004). To date, there is scant evidence of this, with the possible exception of China (Sun, 2007). More generally, the poor may not be able to benefit directly from PWS if they do not have secure rights to the land or its natural resources, or if they have few skills.

There is a developing consensus that payments for watershed services are unlikely to benefit those trapped in extreme poverty because the barriers to their participation are too great (Wunder, 2005; IIED forthcoming). This does not mean that PWS should be discarded as a new tool for resource management. PWS facilitators may be able to assist by identifying and addressing policies that either harm the poor or perpetuate their status (van Noordwijk *et al*, 2004). Alternatively, payments for watershed services might be a new way to construct relationships between the key stakeholders around water and land use issues.

3.3 Financing mechanisms

Payments for watershed services from private sector water users to upstream land managers could form a new and sustainable source of conservation finance (WWF (MPO), 2003).

Table 1: Breakdown of the sample between national and local level initiatives (source: Porras, Grieg-Gran and Neves, forthcoming)

Category of initiative	**Number/ %**	**Examples**
National initiatives	12 (20%)	Sloping Lands Conversion Programme (SLCP) in China Working for Water (WfW) in South Africa
Local/ catchment initiatives	48 (80%)	Los Negros, Bolivia

Recent evidence suggests that payment for watershed services are being made from both public and private sources, although the proportion of local initiatives may have increased slightly over time (Table 1). Publicly funded PWS schemes have both advantages and disadvantages. The involvement of government signals the importance of the issue and endorses the approach. Further, governments are usually able to absorb more of the risk, which may be important in fledgling schemes, and are more likely to introduce the necessary policy and legislative changes if they are directly involved. This may make it easier for purely private sector initiatives to evolve later. At the same time, publicly funded schemes may hinder private sector ones, at least initially,

especially if government is underwriting some of the transaction costs and, in effect, subsidising the scheme. Publicly funded schemes are susceptible to political whim and budget constraints, and so may not have the necessary permanence (Wunder, 2005).

Payments for ecosystem services are differentiated from other conservation incentives through the notion of contingency. Payments for watershed services are designed primarily to address particular site-specific issues and therefore can be contingent. In contrast, publicly funded PWS tend to be national or regional in scope, rather than focused on specific areas, and are generally implemented as a "programme" or blueprint, usually without the specificity to make them contingent. This applies even when they are focussed on critical watersheds as in Mexico (Munoz, 2005). Publicly funded PWS are therefore unlikely to produce economically efficient solutions, which is one of the critical theoretical arguments for PWS.

4. Payments for Watershed Services and Climate Change

The principle assumption made for the purposes of this discussion is that climate change will increase the variability of rainfall in much of south Asia and Africa. In addition, countries in south Asia will have to adapt to accelerated glacial melt, medium to long-term reductions in water availability and the very real threat of rising sea levels (UNDP, 2006). In both Africa and south Asia, water for life and water for livelihoods will become scarcer and will have a massive impacts on livelihoods: potentially, significantly numbers of people will be forced into poverty (op. cit.).

The role of payments for watershed services and poverty under the given scenarios for climate change are unclear. Although payments for watershed services are a tool that has only recently been developed, there is:

- Little more than anecdotal evidence to suggest that payments for watershed services schemes have resulted in substantive and large-scale changes in land use in developing countries.

- A growing sense that payments for watershed services do not and should not be expected to directly address poverty issues.

But payments for watershed services are a tool derived from the disaggregation of water ecosystems into its components. The value of the approach is that it highlights both the complexity and inter-dependence of ecosystems, especially freshwater ecosystems.

In simple terms, climate change will make dry areas drier and wet areas wetter but with greater variability and a higher incidence of extreme events (UNDP, 2006). The paradox is that in many places, usable water will become scarcer and that innovative tools for the management of water and watersheds will be desperately needed. Payments for watershed services will not provide immediate and lasting solutions over large parts of Africa and south Asia. However, using payments for watershed services as an entry point does have some advantages. Firstly, payments for watershed services emphasise the complexity of freshwater ecosystems and the value of the services derived from them. Secondly and just as importantly, payments for watershed services provide a new way of structuring relationships between land managers and users of water. However, it is important to remember that payments for watershed services deal with land use-water issues. Many catchments in Asia and southern Africa are in crisis because of the over-abstraction of ground water and over-allocation of surface water – which are not problems that can be directly addressed through a PWS mechanism (Calder, 2005).

5. Conclusions and suggested research priorities

The importance of clean water (and sanitation) to human well-being and economic development is well understood and is reflected in the Millennium Development Goals. However, its provision has largely been seen as a supply side challenge whose constraints can be overcome with more

investment in infrastructure, whether to store, move or purify water. The core supply of water from freshwater ecosystems has been abused and its perilous status is well documented in the Millennium Ecosystem Assessment (MA, 2005).

Payments for watershed services are a subset of a wider group of 'payments for ecosystem services'. These incentive based mechanisms are being investigated and developed as an alternative to regulatory mechanisms which, for several reasons, have had limited impacts especially in developing countries with weak regulatory frameworks and competing demands for scarce resources. Payments for watershed services are intuitively appealing given the multiple, complex and linked challenges of poverty, freshwater ecosystems and climate change.

Early initiatives to operationalise payments for watershed services have raised a number of challenges. These include the complexity of land use-water relationships, limited willingness to pay for watershed services, and marginal (if any) impacts on the livelihoods of poor people living in the upper watersheds (IIED, forthcoming). There is a strong argument that what is needed is not more research, but more attempts to develop working models from which others can learn (Asquith, 2007).

Currently there are a small number of projects and/or programmes that are 'field testing' payments for watershed services. They include the RUPES initiatives in Africa and Asia and the feasibility studies being conducted by an alliance of CARE, IIED and WWF (NL). IIED has recently completed a three year action-learning project in six countries and regions (IIED, 2003 and IIED, forthcoming). The Katoomba Group supported by Forest Trends is another key stakeholder that provides information and limited support to a diverse set of stakeholders who are engaged in payments and markets for ecosystem services.

Given the understanding that payments for watershed services are not a universal panacea, three areas for further research emerge:

- **Hydrology: tools and techniques for establishing cause and effect relationships**: As a science, hydrology has evolved substantially since the early field level experiments (Calder, 2005). Remote sensing, geographical information systems and models are now the key tools and have transformed the approach of hydrologists (op. cit). As emphasised, the land use–water relationships within a watershed or catchment are extremely complex and characterised by non-linear relationships. The predictive capacity of models often breaks down as catchments tend towards 'hydrological closure' (Batchelor, pers. comm.). Further investment in tools, methods and particularly models that reflect the non-linear relationships and that facilitate the cost-effective and timely analysis of land use and water relationships would contribute to a better understanding of the ecosystem services provided, even if it did not lead directly to implementation of payment mechanisms.

- **Governance of watersheds:** Regulation and government control of natural resources, including land and water, is typically seen as the only effective solution to environmental challenges (Anderson and Leal, 1991). Incentive based approaches are the antidote to what has largely been perceived as limited success of regulation and control. Too often however, regulation and incentives are portrayed as opposite ends of the spectrum, such that a choice needs to be made between them. Recent experience with incentive led approaches to land use and conservation (i.e. ICDPs, CBNRM and now PES) suggest that they are a way forward. However, incentives can only be created within a regulatory (institutional) framework. Thus the second suggested research theme is to consider the interface between incentive led and regulatory approaches to land use and natural resource management, with special reference to freshwater ecosystems.

- **Robust analysis**: Typically, investment in resource management and development programmes are made on the basis of limited, subjective analysis and even anecdotal evidence (Ferraro and Pattanayak, 2006). To maximise the returns on investment from these activities will require much stronger analysis of pilot initiatives (opp. cit.). This suggests that a

third area of research should be the robust analysis of ongoing initiatives into payment for watershed services.

Payments for watershed services are a relatively recent innovation. There are a number of action-learning or action-research type projects that are trying to operationalise PWS in a range of different circumstances. Direct references within the literature to research needs and approaches are rare. One comment that has already been noted is that more working models are required rather than research per se (see Asquith, 2007).

This analysis however has identified three potential and very different strands of investigation i.e. hydrological modelling, governance and monitoring and evaluation methodologies all of which fall would advance operationalising payments for watershed services with important benefits for freshwater ecosystem services.

Information technology allows more and more sophisticated models to be created while data can often be obtained remotely. Many models exist but few accurately represent the changes in hydrology as catchments move to 'closure.' More accurate and dynamic tools will only be developed in collaboration between developed and developing country hydrologists and modellers. While the challenge is substantial, it is essential that the tools developed are both accurate and can be used by scientists in developing countries.

The challenge of governance, especially creating the synergistic mix of incentives and legislation can really only be achieved *in-situ*, through action-learning type projects or programmes. Ideally, these need to involve several countries, have a strong learning component and a time-frame that explicitly recognises the challenges of making substantive policy changes. Ideally, these types of programmes should be regionally based. Because skills, especially in sub-Saharan Africa are scarce, technical support from selected northern-based organisations is probably required.

Over and above these two different approaches to research there are a number of guiding principles that need to be considered by DFID and NERC when formulating their new ecosystem services, poverty and climate change research strategy. Firstly, links between the research and policy are often weak and/or difficult to prove. To increase the chances of adoption, the research must be considered relevant within the region and the selected countries. Secondly, the users of the research outputs need to be clearly identified and known in advance. Finally, while aspects of the work might need specialists, this type of work generally requires a multi-disciplinary approach.

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