UNIVERSITY OF THE PHILIPPINES LOS BAÑOS

Master of Science in Environmental Science

DAVID M. WILSON

AN ASSESSMENT OF THE POTENTIAL FOR PAYMENT FOR ECOSYSTEM SERVICES TO SUPPORT THE SUSTAINABLE MANAGEMENT OF GABAYAN WATERSHED, BOHOL, PHILIPPINES

RODEL D. LASCO, Ph.D.

Date __________________________

This thesis can be made available to the general public	**YES**
This thesis can be accessed only after consultation with the author and thesis adviser	**NO**
This thesis can be accessed only by those bound by confidentiality agreement	**NO**

____

DAVID M. WILSON

____

RODEL D. LASCO, Ph.D.

AN ASSESSMENT OF THE POTENTIAL FOR PAYMENT FOR ECOSYSTEM SERVICES TO SUPPORT THE SUSTAINABLE MANAGEMENT OF GABAYAN WATERSHED, BOHOL, PHILIPPINES

DAVID M. WILSON

**SUBMITTED TO THE FACULTY OF THE GRADUATE SCHOOL
UNIVERSITY OF THE PHILIPPINES LOS BAÑOS
IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE
DEGREE OF**

**MASTER OF SCIENCE
(Environmental Science)**

APRIL 2014

BIOGRAPHICAL SKETCH

The first son of Norman and Debbie Wilson, David Martin Wilson was born on February 21st 1980 at the Bradford Royal Infirmary, Yorkshire, UK. After finishing primary education at Crossley Hall School and secondary education at Rhodesway upper school, from 1999 – 2003 he attended the University of Sheffield graduating with a 2:1 bachelor of arts degree in archaeology and prehistory with honours. After graduating he travelled and volunteered extensively in Latin America, returning to the UK in 2006 where he spent over with over 7 years as an environmental programme manager at a leading London authority delivering various food security, energy efficiency and most recently carbon management and reduction projects.

In 2011 he took a sabbatical to work as a volunteer developing a carbon forestry project hosted by marginalised agricultural communities in rural Nicaragua. This experience inspired him to pursue a change in career and in 2012 he relocated to the Philippines to pursue graduate studies at the University of the Philippines Los Banos specialising in ecosystem restoration and community based resource management. He is the recipient of an associate graduate fellowship from the World Agroforestry Centre (ICRAF), Philippines which enabled him to pursue this research.

DAVID M. WILSON

ACKNOWLEDGEMENT

Firstly, my deepest thanks to Dr Rodel D. Lasco without whom this research would not have been possible. The financial and logistical support offered by ICRAF Philippines was crucial but more than that, your door was always open to me no matter how small the issue and how busy you were. Your body of work on natural resource management in the Philippines and PES in particular were the inspiration for this research and your dedication to the socio-ecological challenges of the Philippines and of the world continue to motivate me now.

To Dr Marge Calderon and Dr Vicky Espaldon, my thanks for your advice and guidance from the outset and your willingness to meet with me at short notice. Both your bodies of work greatly influenced this research.

Thanks also to the support staff at the ICRAF Los Baños office for making travel arrangements and ensuring the smooth passage of each field visit and to other researchers for sharing their ideas and experience which have enriched this research especially Laya Espaldon for connecting me to the research community in Bohol. To Geremil Cordero for your support in Bohol and going the extra mile.

I reserve some of my deepest gratitude for those members of the Carood Watershed communities and LGUs in the Gabayan watershed and Carood basin for their openness, willingness to cooperate and support for this research in the field. Your generosity and warmth will stay with me forever. Thanks also to Sally Kelling for wading waste deep in the rivers of the Gabayan watershed without complaining!

To my family who supported me in this endeavour from the other side of the world – thanks for your understanding. Finally, for her endless patience, unfaltering support and belief in me my thanks and love to my wife Jody Aked.

I dedicate this work to my unborn child – I hope in some small way it can contribute to making the world you will inherit, a better place.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

FIGURE		**PAGE**

LIST OF MAPS

LIST OF APPENDICES

ABSTRACT

WILSON, DAVID M., University of the Philippine Los Baños, April 2014. **An Assessment of The Potential For Payment For Ecosystem Services To Support The Sustainable Management Of Gabayan Watershed, Bohol, Philippines**

Major Professor: **RODEL D. LASCO Ph.D.**

The Gabayan watershed is a heavily degraded multi-use landscape covering over 5,000 hectares in eastern Bohol, Philippines. The principal livelihood activities of subsistence agriculture - particularly rice and maize production - as well as livestock management and aquaculture, are closely bound to the ecosystem services provided by the watershed. The degraded nature of the watershed, which has been largely deforested and replaced with extensive agricultural and grasslands, has led to alternate flooding and drought episodes, an accelerated level of soil erosion as well as downstream sedimentation, all of which impact the livelihoods of local communities.

Alternative land-use practices which continue to offer livelihood benefits are required to tackle these environmental problems bur remain nascent and technical capacity low. Incentivising these land use practices using a Payment for Ecosystem Services (PES) mechanism has been identified by local stakeholders as a potential solution and this study employs interdisciplinary techniques from participatory mapping to hydrological modelling to determine whether PES is a viable solution in the Gabayan watershed. Through a combination of scientific, policymaker and local ecological knowledge (MEK, PEK and LEK) the most important ecosystem services are identified, quantified and mapped. A series of simulated scenarios determine the relationship between land management practices and ecosystem services and a set of indicators for determining the viability of a PES scheme is offered. Finally, the architecture of a potential PES scheme in the Gabayan watershed is proposed.

CHAPTER I

INTRODUCTION

Why This Research, Why Now?

The links between human wellbeing and the goods and services provided by a range of ecosystems is well established and generally accepted, particularly since the publication of the Millennium Ecosystem Assessment in 2005 (MA 2005). Similarly, the relationship between economic activities particularly industrial, agricultural and natural resource management practices which result in land use change and the degradation of those same ecosystems is increasingly evidenced and understood. What is less well understood is how the ecosystem goods and services (ecosystem services from here on for brevity) are affected, how they respond to such stresses and what this means for societies and communities which rely on them either to meet day-to-day subsistence needs or less tangibly in their intrinsic or cultural values.

Water in particular is a critically important resource upon which most organisms rely for their very existence. It is also highly un-substitutable and its availability varies spatially and temporally. Water is also often considered a common resource and is open access potentially leading to ‘freeriding’ and over extraction issues which in turn drive pressures associated with its unavailability. Therefore, governance of water as a resource, its management and extraction is a common source of conflict, especially in times and areas of increasing water stress. These areas, according to WRI (2012) are increasing and when climate change projections are considered may be further exacerbated.

As with most environmental issues, access to water and the availability of the associated services and benefits it provides (nutrient transfer, irrigation, drinking water, recreation) is placed under further threat when we consider it through the increasingly powerful lens of global climate change. As mentioned, water availability varies temporally and spatially and the impacts of climate change on the hydrological cycle follow this same pattern. Intensification of the hydrological cycle in combination with other factors such as urbanisation, lack of infrastructure and poor land use practices has already begun to manifest in severe flooding in some parts of the globe. At the same time, many areas of the world are experiencing drought conditions which exceed any normal seasonal variation. The resulting reduction in agricultural productivity, infrastructure damage and loss of human life associated with both these extremes are compelling reasons to ensure that any research accounts for these phenomena.

Clearly then interventions to address these wide ranging and somewhat daunting societal challenges are required. Interventions that lead to the more sustainable management of existing resources and are able to tread the fine and often blurred line between environmental-societal or human-ecological trade-offs need to be prioritised. One such intervention which has been the subject of much debate, excitement and scepticism in equal measure amongst development, environmental and economic scholars and practitioners is payment for ecosystem services (PES). Considered as a conceptually neat and relatively simple measure in which the resource manager or steward is compensated for making changes to land use which positively affect the flow of ecosystem services to a beneficiary, in practice it is anything but. As we will learn, the growing body of literature on this subject has almost as many failed schemes or those functioning sub-optimally as it do successes which deliver benefits to all actors involved, with priority given to the poor. This research will therefore explore whether PES could be an effective intervention in the sustainable management of Gabayan watershed, part of the Carood basin in eastern Bohol, Philippines or whether it is actually an unwelcome distraction from other, more appropriate measures.

Research Problem and Rationale

Many ecosystem services, particularly water, are considered open access or common and are extracted, exploited and enjoyed by societies without attachment of any monetary value or the need to pay for such services or compensate those communities who may be responsible for their continued supply (Brauman et al. 2007; Fisher et al. 2010; Dasgupta 1996). They can be considered as external to the traditional economic system and this can lead to over-exploitation to the point of a collapse in ecosystem function. Internalising these externalities then, becomes of critical importance if ecosystems and the services they provide are to be conserved, restored or rehabilitated.

Watershed services such as soil stabilisation and erosion control, flood attenuation, provision of quality water and the timing of the arrival of that water can all be affected by the prevailing land use. The relationship between vegetative cover and watershed function is site specific, complex and not simply linear i.e. more trees ≠ reduced floods or a guaranteed supply of water in the dry season. Heuristics and literature however tell us that upland communities and the way they manage the land in the headwaters of a watershed can have a significant impact (positive or negative depending on the context and downstream requirements) on watershed function and related ecosystem services and flow.

A recently released World Resource Institute tool, Aqueduct (WRI n.d.), shows the increase in water stress around the world. This tool also overlays the IPCC AR4 projected climate change predictions from relating to hydrology and temperature variability which shows that by 2025 under an A1B scenario, Bohol will be at slight to moderate risk from increased water stress. At the same time, communities and local government in the Gabayan watershed are already reporting alternating drought and flood events particularly in the municipalities of Alicia, Candijay and Mabini.

Land use activities in the Gabayan watershed vary from the headlands to the outlet with the major tributaries traversing multi-use landscapes which have been subject to wide spread deforestation and the proliferation of cogonal grass lands which are seasonally burnt as pasture for grazing livestock. This has further degraded the soil and led to land becoming underutilised creating pressure on existing arable land and in turn resulting in increased resource management conflicts within and between different zones of the watershed. Furthermore, the removal of vegetation in the upland and midstream zones is believed to be the reason for an observed intensification of soil erosion and siltation of irrigation channels and destabilisation of river banks in the downstream zones.

Thus far, these observations are largely anecdotal but what is certain is a change in function of the watershed and the resulting services due to human activity. What is less certain is to what extent and what the impacts are and could be if interventions are not made.

The larger Carood Basin of which the Gabayan watershed is a part has been under some form of formal management since 2003 with the establishment of a multi-stakeholder management council. However, perennial problems with insufficient funding, incoherent governance and inadequate capacity has meant that many of the environmental and social problems in the area covered by the watershed (some of which have been discussed here), persist. More recently, attempts have been made to re-invigorate the council with the drafting of a refreshed strategy, log frame and in 2010, its acceptance as a member of the International Model Forest Network. This renewed impetus includes the consideration of watershed wide interventions which may deliver some of the goals agreed by the members in the strategy. PES has emerged as one such option which has provincial and regional level political support and which is gaining some momentum. This led to the commissioning of a willingness to pay survey in 2012, which broadly stated that a representative sample of community members would be willing to pay for the provision of services flowing from a well-managed watershed. The stage, it seems, is set.

However, operationalizing PES is a challenge, particularly as there is an apparent lack of recent data relating to the current function of the watershed. This study will therefore aim to provide a baseline against which the effects of any PES scheme can be measured and to what extent changes in land use practices deliver the targeted services. There is also a need to better understand the perceptions of the local stakeholders – beneficiaries and stewards of the ecosystem services – and to create a space for negotiation over the land use changes to be adopted and any compensation for so doing.

This research will therefore work with the Carood Watershed Model Forest Management Council (CWMFC) and the communities it represents to identify, characterise and unpack some of the complex underlying issues, interdependencies and relationships which exist between communities, watersheds and the ecosystem services they provide. Different land use activities and vegetative cover scenarios will be modelled to determine the effects on the identified ecosystem system services which could be water provision, quality, quantity and timing. Crucially, this study will aim to provide a scientific (social and biophysical) basis for decisions to be made as to whether or not to pursue PES as an intervention.

Research Assumptions

The environmental problems relating to the Gabayan watershed are currently based on anecdotal evidence and have not been quantified. There is also an assumption that these problems are priority issues for those people affected. The nature of ecosystem services means that a change in one can positively or negatively affect another. Downstream communities may be benefiting from an increased abundance of water for irrigation with some seasonal flooding but the former may outweigh the latter in their own internal cost-benefit analysis.

Furthermore, hydrological services provided are often unidirectional, that is to say they flow away from the upland communities via surface and subsurface routes and are provided to downstream users. Therefore, there is little incentive for upland communities to adopt land-use practices which ensure the continued supply of these services; instead they may opt for activities which provide the most value to them. However, intrinsic values such as bequest and inter-generational values may also be part of their decision making and PES can change these motivations in a phenomenon known as 'crowding out'. The overall assumption is that these communities are maximising the utility value of their land, whether that protects and maintains hydrological ecosystem services or not.

Conceptual Framework

Figure 1 represents the conceptual framework for this research. A DPSIR (Driver, Pressure, State, Impact, Response) model has been selected to illustrate the research conceptual framework. The DPSIR model in this sense is used to indicate the interrelationship between the different components and how these can produce, increase or decrease ecological functions and services flowing from the environmental 'domain' to the human one (David Niemeijer & Groot 2008).

The model identifies the drivers of the reported environmental problems which are anthropogenic in nature and how these lead to pressures on the ecosystem under study. In turn these can lead to a change in state of the ecosystem function which results in impacts which are both environmental and social in nature. These impacts can further drive pressures in a positive feedback. Responses are human in nature and address drivers as well as some pressures directly. There is also an interaction (represented by a two-way arrow) with the impacts as these are likely to be the reasons driving the need for a response and that this will need to be iterative over time. The dotted line between the human and environmental domains is an attempt to show that the boundaries are permeable.

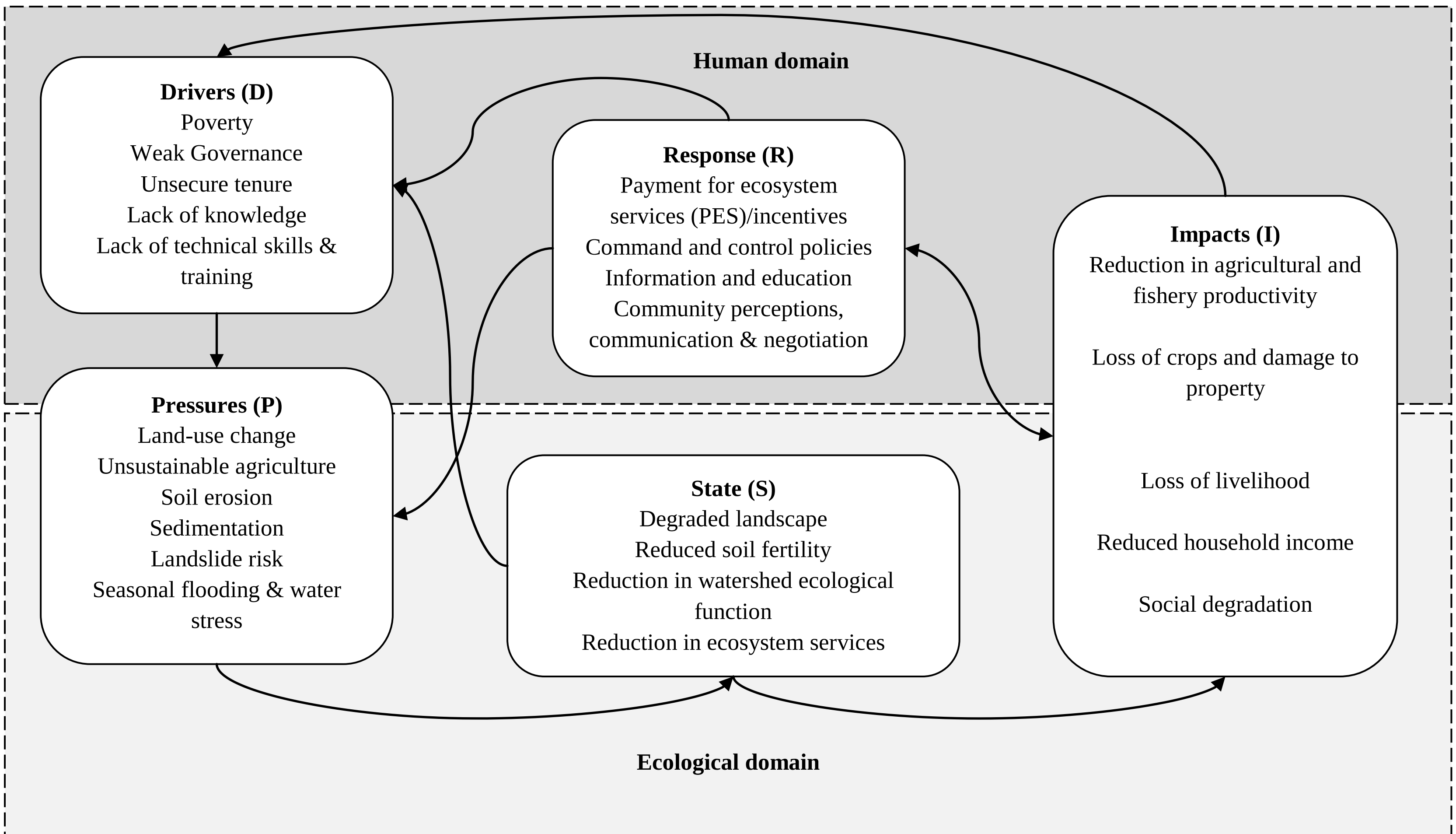


Figure 1. Conceptual framework

PES is the intervention under study in the research and is shown as a response in the model. However, an understanding of the social drivers, pressures which these generate on the watershed ecosystem and the impacts they create are crucial to understanding if and how PES could be a viable intervention. This is why command and control measures have been included as a response as this may be the ultimate policy recommendation. For any intervention, baseline information and education as well as the mediation of different community perceptions will need to be understood.

Figure 2 represents an attempt to situate this conceptual model in the real world setting in which the research will take place. Three communities or zones within the landscape are represented (up-, mid- and downstream). The conditions within each of these zones are described to provide an initial insight into the different problems and perceptions which may need to be negotiated. The broken lines between the communities represents a simplification of disrupted ecosystem services moving through the landscape which are further broken as it reaches the downstream area as the midstream can be considered as a sink area. The dash-dot-dash lines demonstrate the lack of communication and discord between the communities. The lower left portion of the figure broadly represents the status quo in which ecosystem services and watershed function are degraded. The upper portion of the image represents the conditions which would see the restoration of ecosystem services and watershed function (represented as solid arrows) through mediation and negotiation of payments based on inter-community communication and good baseline information i.e. the focus of this research (the circled area).

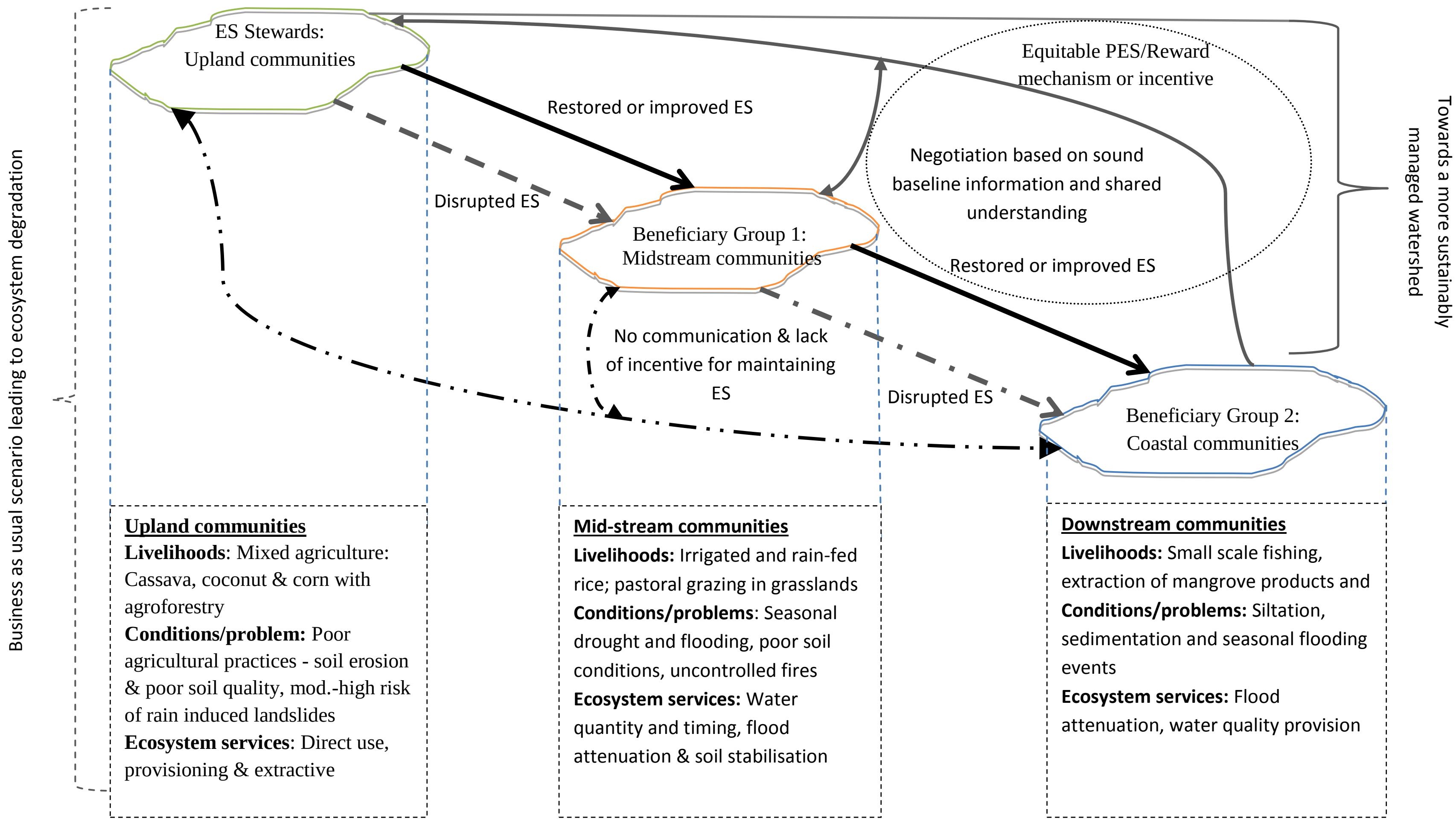


Figure 2. Spatially adapted conceptual overview of the research study in Gabayan watershed

Research Aim, Objectives and Questions

The overall aim of this study is to test whether a payment for ecosystem services mechanism is an appropriate mechanism to support the sustainable management of Gabayan watershed.

In order to make this assessment and meet this aim, the following specific research objectives are targeted:

1. To identify, characterise and map ecosystem services and the stewards and the beneficiaries of those services within the Gabayan watershed;
2. To determine the relationship between land use practices and the identified ecosystem services;
3. To determine whether a PES mechanism is a suitable intervention that will promote watershed rehabilitation Gabayan watershed.

Table 1. Summary of research questions

OBJECTIVE	RESEARCH QUESTIONS	METHODOLOGICAL COMPONENT (Table 9)
Objective 1	What are the main ecosystem services?	B, C, D, E
	Who and where in the landscape are the stewards and beneficiaries of these ecosystem services?	A, B, C, D
Objective 2	How do current land-use practices affect the provision of the ecosystem services?	B, C, E
	How would different land-use scenarios affect the provision of these services?	D
Objective 3	Is PES viable in the Gabayan watershed?	E

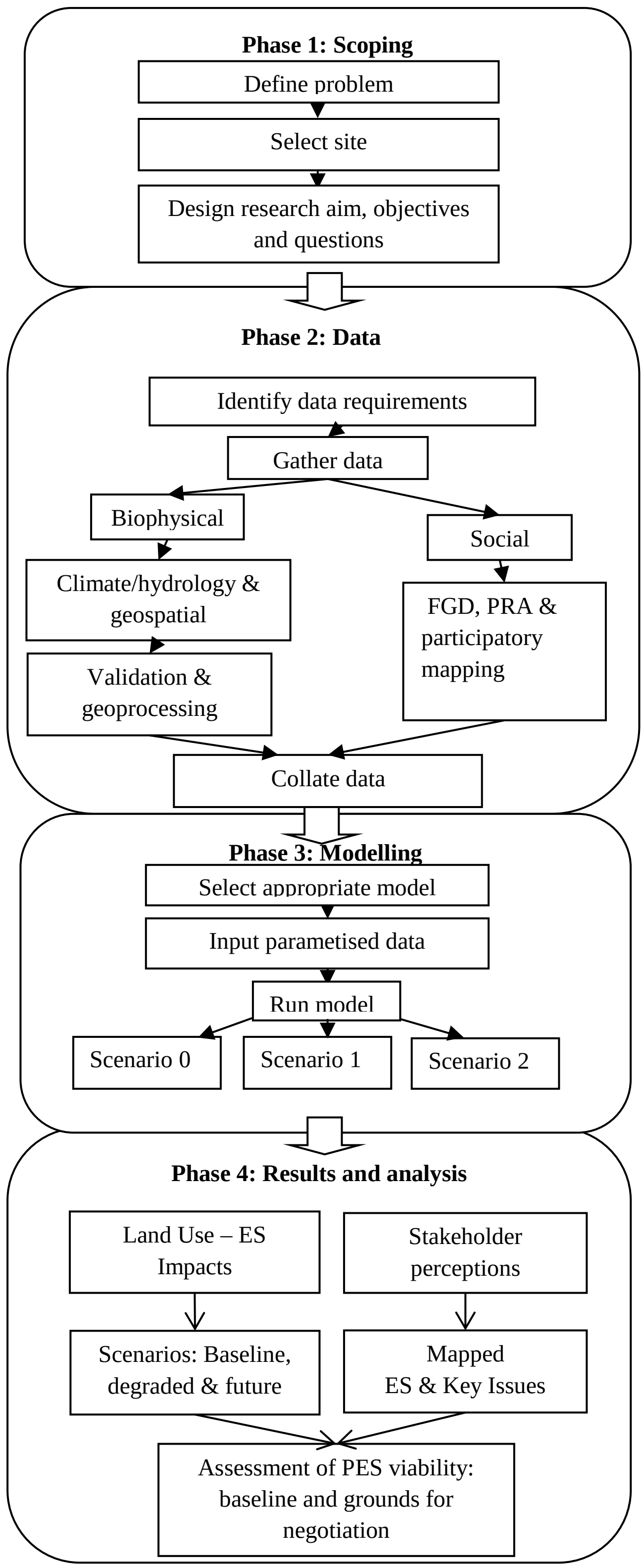


Figure 3. Research design framework.

Figure 3 provides an overview of the different phases of the research designed to address each of the objectives.

Research Scope and Limitations

Figure 4 represents a hypothetical framework for negotiating Payment for Ecosystem Services between a range of actors and includes some of the considerations for each. The ecosystem service stewards will have motivations and limitations which affect their willingness to accept payment or reward. At the same time the ecosystem service beneficiary will have motivations and limitations which affect their willingness to pay. If a PES scheme or mechanism is to be considered then these potentially conflicting motivations and limitations will need to be mediated and resolved in a constructed market or space for negotiation. This may be done directly between stewards and beneficiaries and will require predetermined conditions for success or alternatively negotiated indirectly via intermediaries. This process should be iterative, transparent and revisited regularly if the scheme is to be delivered equitably and managed sustainably. This research study aims to support the negotiation process in the 'market' area of the figure and will specifically contribute to the aspects underlined and in italics. The research study is not designed to conduct an economic valuation of the ecosystem services but as a Negotiation Support System (van Noordwijk 2005) providing data to support establishment of the market.

It is important to point out some of the limitations with this study when considering the outputs of the simulations and results presented here. Firstly, and perhaps most importantly the lack of robust observed data for the watershed for any of the model output parameters poses challenges in accurately validating the model outputs. Secondly, the agroforestry systems modelled here have been included based on literature, local priorities according to the watershed management council and the modellers' own ecological knowledge and not in close consultation with the farmers who manage the land. Ideally, agroforestry systems would be co-designed and tailored to the skills, needs and preferences of local farmers. Thirdly, the climatic data used as an input into the model was taken from only one climate station for the whole watershed and not interpolated which would be desirable in order to have a more spatially sensitive simulation (Srinivasan et al. 2012). While additional data was sought in order to spatially interpolate the rainfall and other climatic variables, this was not available and this should be kept in mind when considering the analysis of the results as orographic factors may not be represented. However, the relatively small size of the watershed (<100km2) means that any impact on the results should not be too significant. In addition, due to time limitations beyond the control of the researcher for example the terrible 7.2 magnitude earthquake which struck Bohol and limited field access at crucial stages as well as the indirect impacts of Super Typhoon Yolanda (the research site was without electricity for some time thereafter), some fieldwork components were not completed. Validation of the participatory mapping exercises and a final presentation to local stakeholders were not possible although this does not materially affect the results.

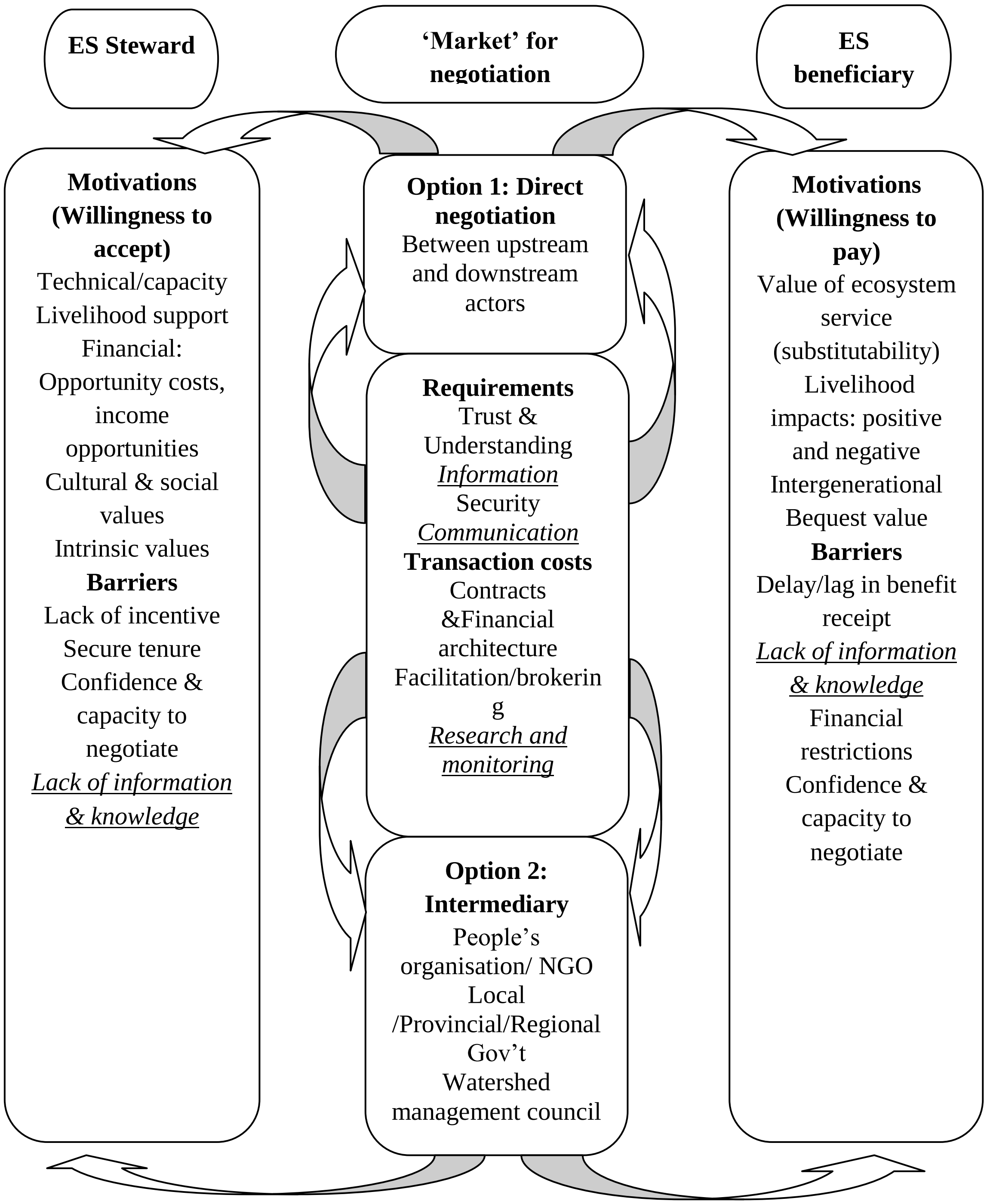


Figure 4. Generalised PES framework.

CHAPTER II

REVIEW OF LITERATURE: CONCEPTS AND CURRENT DISCOURSE

Ecosystem Goods and Services

For the purposes of this thesis, ecosystem goods and services are defined as those benefits derived by human society from the function of ecosystems which is in turn reliant on the status and quantity of natural capital to borrow that of the Millennium Ecosystem Assessment (MA 2005). According to Farley and Costanza (2010), "ecosystem services are essential, non-substitutable and poorly understood". It is therefore of great concern that the overall trend in ecosystem goods and services and the natural capital that provides them is one of decline through anthropogenic activities (Farley & Costanza 2010).

The MA (2005) is considered as a seminal publication in the discourse linking ecosystem services with human wellbeing. The MA categorised such goods and services into four major groups: provisioning, supporting, regulating and cultural which in combination support or contribute to the constituents of wellbeing: security, health, functioning social relations and the basic material for a good life. In this way, ecosystem services and the benefits they provide are fundamental to the welfare and continued existence of human society. As well as these useful definitions and characterisations the MA also provided stiff challenges to scientists and policy makers. Of the 24 ecosystem services considered in the assessment, 60% were found to be either used unsustainably or degraded. As well as comprehensive summary of the state of the world's ecosystems, the MA was a call to action.

Ecosystems and the functions and processes which lead to the production of goods and services are inherently complex, poorly understood and ill defined (Wallace 2007). Ecosystems are constantly evolving, often on temporal and spatial scales discordant with that of human societies. Ecosystems are complex and there is no simple, linear causal link between the activities of human actors and the effect on them over time (Folke 2006). Attempts to make distinctions between goods and services provide further insight into their complexity when attempting to internalise them into an orthodox economic system. Farley and Costanza (2010) define ecosystem goods as 'stock-flow' resources, those more tangible readily market based resources (such as timber for construction) and whose quantity is reduced through use. On the other hand, they define ecosystem services as 'fund-services' which are the emergent product of complex interactions within and between the aforementioned 'stock-flow' resources but which cannot be stockpiled (Farley & Costanza 2010). These distinctions are useful if only to highlight the complexity of ecosystem services but also offer some operational clarity when designing and implementing interventions of schemes (such as PES) which target the maintenance, restoration or enhancement of such complex systems using economic instruments.

More recently, there have been a number of attempts to accurately quantify and map ecosystem services and the flow of those services within a landscape between recipients and providers of those services (Troy & Wilson 2006; Bagstad et al. 2012; Primmer & Furman 2012; Potschin & Haines-Young 2011). Accurate quantification and spatial mapping of ecosystem services is both highly desirable and at the same time technically challenging as a result of the dynamic and complex nature of ecosystems, full of emergent properties, feedbacks and what Folke (2006) terms ‘surprises’. This has somewhat limited attempts to develop accurate indicators for ecosystem services which would in turn allow for appropriate interventions to guarantee or restore their provision. The adoption of a ‘beneficiary based approach’ (Nahlik et al. 2012; Bagstad et al. 2012) which seeks to identify well defined end users of a service could provide a useful operational solution to this problem.

Furthermore, prioritisation or enhancement of the provision of an ecosystem good or service which produces human benefits in one location may in turn reduce the access to another location and scale (Elmqvist et al. 2011; Vira et al. 2012; Turner et al. 2003; Brauman et al. 2007). As we shall see in the following discussion, this is particularly relevant for watershed services.

Valuation of Ecosystem Services

Conceptually, the valuation of ecosystem services or at least the acknowledgment of the value provided by nature and existence of natural capital has been discussed and debated for almost 50 years (Krutilla 1967). It was recognised that ecosystems and the services they provide were being depleted at a rate which was unsustainable and beyond which continued human development could be threatened – environmental limits were being reached. One of the main issues highlighted in this early work was the absence of the goods and services provided by nature, whether direct provisioning services or perhaps less tangible (though arguably no less important), intrinsic cultural or aesthetic value within the economic market.

However, such early acknowledgements did not immediately lead to the internalisation of environmental externalities into an orthodox economic paradigm (Vatn & Bromley 1997). Academic discourse on the subject of economics and the environment re-emerged with vigour in the 1990's (Dasgupta 1996; Sachs & Warner 1995; Arrow et al. 1995) and included early attempts to ascribe a monetary value to nature and ecosystem services to include the value they provide to the economic decisions which ultimately affect their continue flow and provision (Costanza et al. 1997; Balmford et al. 2002). These valuations were inferred at a global scale using national or regional level data and up-scaling to provide a total economic valuation of the goods and services provided at the biosphere level of between $16 and $54 trillion per year with a benefit cost ratio of conserving these functions of 100:1. Inevitably such significant sums raised the attention of conservationists, economists and decision makers but also drew criticism for the coarse nature of the data. This provided a further challenge for ecological and environmental economists to develop increasingly accurate tools and indicators for measuring the value of ecosystem services.

This was followed by an intensification of the debate around how best to capture the value of nature so as to avoid the continued depletion of resources through perennial undervaluation and invisibility within the economy (Fenech et al. 2003; Turner et al. 2003; Costanza 2003; Farber et al. 2002). These refinements of methods and techniques have led to more recent attempts to institutionalise the inclusion of ecosystem services in economic valuation via natural capital accounting. This gained significant traction with the publication of The Economics of Ecosystems and Biodiversity (TEEB 2010). This builds on the comprehensive and consensus building MA (2005) but begins to offer more practical and operational definitions of ecosystem service valuation, underpinned by a deeper understanding of the role and function of ecosystems and biodiversity in generating economic value and societal wellbeing (Elmqvist et al. 2010; Groot et al. 2010).

Whilst there is broad consensus amongst ecological and environmental economists of the importance of valuing natural capital and ecosystem services (Nahlik et al. 2012), there is increasing debate over the most accurate, appropriate and often highly technical methods to do so (Salles 2011; Baiocchi 2012; Abson & Termansen 2011; Sagoff 2011; Wilson & Hoehn 2006). Identifying reliable indicators of ecological function and the resulting flow of goods and services, beneficial to human society is a challenging pursuit and has so far yielded few universally accepted and deployed operational outputs.

At a local, project level, valuation techniques which draw on behavioural economics in order to reveal the hidden or unseen value of a given ecosystem service based on the preference of the potential beneficiary are often used. Total Economic Valuation is one such approach commonly used to determine both the use and non-use value of a targeted good or service. However, in most cases because of the previously discussed complexity, the TEV approach fails to capture the full value of the interdependent functions of an ecosystem and the services it produces (Turner et al. 2003)

Payment for Ecosystem Services (PES)

Definition of PES

Payments for Ecosystem Services (PES) projects have been operational around the world at various scales and in different settings for almost 20 years. There is a growing body of evidence and appraisals of such mechanisms and the benefits they provide to stewards (sellers) and beneficiaries (buyers) of the services as well as the restoration and conservation of the ecosystem and the biodiversity it supports (Engel et al. 2008; Wunder et al. 2008; Tacconi et al. 2010; Tacconi 2012).

An accepted and often cited definition of PES is that offered by Wunder (2005) in which "a well-defined ES (or land use likely to secure that service) is being 'bought' by a (minimum one) ES buyer from a (minimum one) ES provide, if and only if the ES provider secures ES provision (conditionality)"(Wunder 2005). In the intervening years and with the operationalising of an increasing number of PES schemes, it is becoming clear that this definition is perhaps too narrow to accommodate 'real world' practices (Tacconi 2012). Muradian et al (2010) offer an alternative framework for considering PES in a broader more flexible way which allows for the inclusion of PES and 'PES' like schemes situated in a wide range of socio-political contexts and with different levels of government involvement. They identify three elements which define a scheme: the use and importance of some kind of economic incentive; how directly the economic incentive is transferred and the level of intermediary involvement and; how clearly defined the good or services is – it's level of commodification (Muradian et al. 2010).

For the purposes of this study, we shall consider the operational definition of PES as an incentive mechanism to ensure the restoration or enhancement of an ecosystem service provided by a steward and received by a beneficiary, usually associated with specific land-use or resource management practices, with or without the support of a third party. PES offers managers of the natural resources that provide these services, financial rewards on the condition that they are maintained or enhanced (Haskett & Gutman 2010; Wunder et al. 2008).

Theoretical Economic Foundations

The theoretical economic underpinnings of Payment of Ecosystem services are not universally agreed upon. Coase's *The problem of social cost* (Coase 1960) which advanced the Coase Theorem, is often considered to provide the theoretical basis for PES although recent discussions have challenged this view (Tacconi 2012). Coase directly challenged the Pigouvian principle of 'polluter-pays' for environmental damage caused, administered under an institutional (often Government led) command and control mechanism and instead suggested that a more satisfactory or efficient (in an economic sense at least) outcome for all concerned may be arrived via negotiations between the parties concerned. Coase Theorem however, is premised on the following conditions: secure property rights are allocated to the two parties (polluter and the victim or receiver of the pollution); that each party is well informed, behaving rationally and able to negotiate and; the absence of transaction costs. This theoretical foundation is undermined in practice given the context in which many PES schemes take place. In particular the requirement of secure tenure is often not met in rural developing countries in particular and where transaction costs associated with establishing a scheme and arranging contracts may not only be present but also high (Tacconi 2012; Muradian et al. 2010).

An alternative theoretical foundation for PES is the application of the Kaldor-Hicks principle which builds on Pareto's Efficiency wherein the allocation of resources in which no one can be made better off without making another person worse off. A Pareto improvement is therefore an allocation of resources which makes one person better off without making any other person worse off. The Kaldor-Hicks theory acknowledges that in reality, most decisions or allocations will not meet the Pareto efficiency and therefore as long as the payment of compensation is possible when a decision that makes one person better off and one person worse off, then that allocation is Kaldor Hicks efficient. If we relate this theory to PES in practice, this suggests that the compensation (payment or reward) must be less than or equal to the value of the ecosystem service to the beneficiary and more than the opportunity cost faced by the ecosystem service provider in changing their practices to ensure those services continue to flow (Tacconi 2012; Fisher et al. 2010).

The general principle of PES is that a resource steward may be involved in activities which are of direct benefit to them but that compromise the continued provision of an ecosystem service which is relied upon by another resource user who may not be co-located. As a specific example, let us take a farmer in the upper reaches of a watershed and assume that instead of conserving remaining forests, they are removing them for the purposes of agricultural expansion. This will affect a number of ecosystem services associated with higher vegetative cover and relied upon by users or beneficiaries (rural farmers for example) including: water quality (likely decrease), quantity (possible increase) and timing (quicker peak flow release and lower dry season flows); flood attenuation (likely reduced), erosion control (more vigorous erosion) and soil stabilisation (less stable soil leading to sedimentation). The activities of the upland farmers, therefore is producing a negative externality, in this case of a unidirectional nature, affecting downstream communities.

The rationale for a PES mechanism is therefore for the downstream service beneficiaries to engage upland farmers involved in those degrading activities in a form of economic transaction (payment or reward) which incentivises them to alter their practices and ensure the continued provision of the ecosystem services. To satisfy both parties (the provider and the beneficiary) any payment must be less than or equal to the value of the ecosystem service provided and greater than or equal to the foregone benefits to the provider in adopting new practices (opportunity costs). This should be negotiated (possibly via an intermediary) in a voluntary manner and result in net benefits for both parties involved.

PES Design Considerations: Some Basic Requirements

Whether we prefer Wunder's (2005) slightly restrictive definition or broader, more pragmatic one, both identify certain criteria that should be met if a PES scheme is to be successful, regardless of ecological and environmental economic tensions as to their values as true market-based schemes (Muradian et al. 2010; Tacconi 2012). What do we mean when we say a successful scheme? Is it to purely achieve efficiency in an economic sense, as close to Pareto or Kaldor-Hicks' efficiency as possible or should overall equity and total societal benefits be the goal? This study adopts a pragmatic approach to this question of success, emphasising the latter. However, a number of design elements drawn from literature are discussed below which should at least be considered, although in reality may not be wholly realised, when targeting a socially equitable PES scheme.

Conditionality. As we have discussed in previous sections, ecosystem services are provided by the complex interactions between biotic and abiotic components of an ecosystem which produces an emergent good or service. These biophysical interactions can be further altered by the activities, decisions and behaviours of human agents. This inherent complexity makes accurate measurement of the quantity and flow of a given services a continuing research challenge (Bagstad et al. 2012; Müller & Burkhard 2012; Wallace 2007). The quantification of ecosystem services or an appropriate proxy however, is considered by some as crucial to the development of a PES scheme. In reality, the measurement and quantification of actual services can be challenging particularly when considering less tangible supporting and regulating services. Therefore, proxies or indicators such as land use practices themselves may be used instead. For beneficiaries of services or ‘buyers’ to be reassured that the service will continue to be provided and indeed to be convinced that the service is under threat in the first instance requires a baseline to be set against which changes can be measured. This will allow the future monitoring of the identified service (or proxy) which may in turn determine the size and timing of the payment (Tacconi 2012).

Lasco et al. (2008) offer a useful way to conceptualise the level of monitoring required which draws on case studies in the Philippines and uses the IPCC’s tiered approach to calculating carbon emissions. Tier 1 is based on ecological principles (e.g. more vegetative cover reduces soil erosion); Tier 2 attempts to model the ecosystem services using best available secondary data and Tier 3 uses observed data which is monitored as part of the scheme. However, others still suggest that the difficulty in accurately measuring and monitoring ecosystem services, pre and post intervention means that conditionality in the strictest sense should not be the target and indeed can have counterproductive results in the long term such as the ‘crowding out’ of more intrinsic behaviours (Farley & Costanza 2010). Either way, the reality is that many functioning PES schemes do not have robust monitoring regimes suggesting that conditionality is desirable rather than an imperative (Muradian et al. 2010).

Clearly defined property rights: To be able to ensure equitable distribution of any resulting ecosystem service payments, property rights should be clarified (Farley &

Costanza 2010; Porras et al. 2008; Wunder 2005). This is especially true for those stewards responsible for the sustainable management of resources or land which promotes the flow of ecosystem services. In many cases, unsustainable agricultural practices stem from the lack of clear and secure property and tenure rights in the first place. Upland farmers for example may be occupying government owned forest lands which are semi-open access and poorly policed under existing command and control instruments. If property rights are not secure under these circumstances then there may be no incentive for farmers to invest in the sustainable management of agricultural land currently under their care which could in turn lead to intensification of practices (more inorganic inputs for example) as land degrades or even expansion into surrounding forests, changing land-use and precipitating a further change in ecosystem function thus affecting related services.

Transparently and voluntarily negotiated: If PES has been targeted as a resource management intervention, then most likely command and control mechanisms are either deemed inappropriate or have failed. The basis of developing a PES mechanism should be voluntarily on behalf of both the steward and the beneficiary. It is of particular relevance for stewards however as it is most likely their practices which will need to change in order to continue with ES provision. This may in turn have an impact on either their livelihood directly (although this should be met through PES) or on their ability to practice the foregone land use practices (Tacconi 2012). In a voluntary scheme, beneficiaries can chose whether or not they participate in the scheme by opting in or out.

However, this could create inequitable outcomes if the ES is considered common pool (as may be the case with water). It will be difficult to exclude them from extracting water for example even if they are non-participants in a scheme leading to problems of free riding. Furthermore, some schemes involve the addition of user fees to the existing bills or fees of consumers who may not even be aware of them (Kosoy et al. 2007) . Can this be considered voluntary engagement?

Transparency should be considered as part of any PES scheme design. If two parties (steward and beneficiary) are to enter into a voluntary contract then this process should be open with as much information as possible provided to both parties to allow for an equitable and sustainable agreement to be established. This transparency should begin in the scoping and design phase, through an ecosystem service assessment (to establish and monitor conditionality) and into negotiations over who should pay whom, how much, when and under what circumstances.

As we have discussed, PES schemes seek to induce changes in land use practices by a manager or steward in one location which will improve or maintain the flow of services to beneficiaries by offering incentives. This will naturally involve negotiation or mediation at some level to arrive at a mutually beneficial agreement over who is paying how much and for what. Indeed PES schemes have been shown in some cases to provide an incentive in tackling existing conflicts relating to natural resource access (Kosoy et al. 2007). These negotiations may take place directly between the stewards and beneficiaries but are more likely to involve some sort of intermediary or honest broker which could be governmental or non-governmental. Vignola et al (2012) provide a technical framework for approaching these negotiations which seeks to identify and reconcile often competing and differing perspectives on which ecosystem services are most important, how they can be enhanced or preserved and who is responsible for ensuring this (Vignola et al. 2012).

Transaction and opportunity costs: Even if all the necessary conditions are met for a potentially successful PES scheme, establishing one doesn't come without costs. Any costs which are not direct payments can be considered transaction costs and may include but are not limited to costs of negotiation; legal costs (e.g. establishing contracts); technical costs of transitioning to alternative land use activities (e.g. intensive annual crops to agroforestry); establishing a baseline scenario and on-going monitoring and any costs relating to the administration of payments of reward mechanisms (Wunder et al. 2008). Meeting the opportunity costs borne by stewards making changes to land use practices must be met but should not be considered as fixed costs. Farmers and resources users will be subject to market forces such as fluctuation in prices of goods, policy interventions and introduction or removal or subsidies to give a few examples. Therefore a PES scheme must be flexible enough to be able to recognise and meet these costs if it is to continue to deliver the benefits it promises (Fisher et al. 2010).

Bundling of services: If combined (bundled or stacked) PES has the potential to deliver wider environmental and social co-benefits (Deal et al. 2012). However, when multiple services are offered within the same area this may lead to an increased risk of free-riding (Engel et al. 2008). Being able to identify opportunities for bundling ecosystem services of different types, at an appropriate scale and with demonstrable benefits is important but remains challenging to achieve (Wendland et al. 2010).

PES Financing Typologies: User-Financed Versus Government-Financed.

A review of the growing body of literature relating to operational PES schemes from around the world demonstrates a wide range of payment, compensation and reward mechanisms both financial and non-financial or in-kind (Wunder et al. 2008; Haskett & Gutman 2010; FONAFIFO et al. 2012). Wunder et al. (2008) make a distinction between user-financed and government-financed schemes. User-financed schemes are those in which buyers of the service are using their own finances or resources to make payments or rewards and who are able to opt out of the scheme at any point. These schemes are considered to be more efficient and closely aligned to the definition of PES offered by Wunder (2005) and indeed nearer to the conditions of Coase Theorem.

Government-financed schemes on the other hand are used as a catch all term to refer to schemes which are either financed or managed by a third party which could be governmental or non-governmental. This may be done on behalf of the ultimate beneficiaries of the service or indeed in order to secure multiple benefits, say from the protection of a forested area through supporting agroforestry activities providing carbon sequestration, biodiversity and livelihood benefits. Another characteristic of government financed schemes is scale – they are often much larger than user financed schemes both spatially and in the number of services being provided with user financed schemes often focused on just one (Wunder et al. 2008). Whilst these schemes may not be considered PES in pure economic or Coasean sense (they are sometimes described as ‘PES like’), they are often able to deliver economies of scale which keep transaction costs low and therefore may actually be more sustainable (Engel et al. 2008). In addition, government agencies, particularly at the local level may have an important role to play in the mobilisation of communities, communicating important messages (Cremaschi et al. 2013) Where common goods such as water services are concerned such institutions may be able to reduce the risk of free-riding, motivated by a desire to fulfil their social contract with all services users.

Payments themselves can be made in cash or in kind via technical assistance or provision of infrastructure, tools, seeds etc. or a combination of all these. Wunder et al (2008) in their review of a number of schemes of varying scale and typology found that payments were also more likely to be differentiated, that is based on actual performance of the seller measured against some baseline, in user-financed schemes than in government-financed schemes which tend to offer a flat fee. This also suggests that conditionality criteria are not as stringently applied in government-financed schemes.

PES Actors: Buyers, Sellers and Intermediaries

The main actors involved in any PES scheme are the buyers, the sellers and in some if not most cases, intermediaries (Engel et al. 2008). Buyers of ecosystems services are actors who derive some value from the continued or enhanced provision of a given service and who either pay a seller directly or through a user fee or tax to ensure its provision. However, in some cases the buyers of the services provided are not necessarily the actors who will receive direct benefit from those services but instead a third party, often either governmental or a non-government organisation (NGO). To make this distinction, when discussing those actors who benefit directly from the services provided we prefer the term beneficiary as opposed to buyers which has purely financial connotations.

Sellers of ecosystem services are those actors who are able to influence the provision of ecosystem services directly or whose activities and land-use practices may indirectly affect the provision of such services. In a sense they are the safeguards of these services or ecological functions. As we have discussed, not all PES arrangements involved actual financial transactions, therefore the term ‘seller’ does not always seem appropriate. Instead we use the term steward to reflect the role of the actor who will alter or moderate activities, particular relating to land-use in order to guarantee the provision of the targeted service.

The role of government and institutions whilst contrary to the pure environmental economic definition of PES, in practice is often critical in the success or otherwise of a scheme. In the case of Costa Rica, often cited as a country leading the way in PES with a national level, institutionalised scheme (Pagamientos por Servicios Ambientales – PSA), original aspirations of a reduced role for government over time have not been realised almost two decades later (Matulis 2013). Governments, local, regional and national clearly have an important role to play.

Whether the role is that of honest broker between actors, communicator of the benefits or more directly as a buyer of the services on behalf of actual beneficiaries and in some cases even regulators of a hybrid-mandatory scheme, governments or other forms of institutions have a hand in determining the outcome of PES schemes (Pirard 2012). This insight is the result of reviews of existing schemes and challenges the purely economic definition of PES and suggests a pragmatic approach with government as a stakeholder in schemes, most especially at the local level (Cremaschi et al. 2013; Vatn 2009). Moreover, government involvement may deliver savings in transaction costs, particularly those relating to information sharing and knowledge gathering and possibly others, such as financial administration and monitoring.

Human-Ecosystem Interactions and Pro-Poor PES

It has been argued that PES schemes are designed explicitly to preserve, restore or enhance ecosystem services and not to assist with meeting development or 'pro-poor' aspirations (Engel & Palmer 2008). However, many PES schemes take place in developing countries and in settings which involve communities of stewards and beneficiaries with high incidences of poverty. *De facto* then, any entity wishing to establish PES in these settings even with conservation as an explicit goal will need to at least consider the impacts on those communities involved and in not doing so risks failure of the scheme and worst still, negatively impacting participating communities.

PES schemes that include complementary activities such as investment in capacity building and training in sustainable agricultural practices including agroforestry for example, to assist in the transition to new practices which secure livelihood and conservation goals may prove more successful in the long run (Tacconi 2012; Pirard et al. 2010). However, the role of PES in supporting livelihoods is poorly understood and often not the focus of a PES scheme more concerned with delivering the ecosystem services or land management activities which precipitate them (Milder et al. 2010). Assessing whether the beneficiaries and stewards are deriving net benefit from the scheme is often overlooked or not explicitly targeted from the outset or monitored effectively over time in the same way that carbon sequestered or water flow is for example (Tacconi et al. 2010).

In some cases, PES may even serve to exclude poorer communities from the scheme and thus the potential benefits either because they are unable to pay in the case of beneficiaries, or they do not meet certain criteria such as holding secure tenure or lack the technical knowledge to shift to alternative land-use practices, in the case of stewards (Muradian et al. 2010). This is cruelly ironic as it is often poor rural communities which are dependent on often open-access resources and ecosystem services in order to meet subsistence needs (Bulte et al. 2008). Thankfully, there is some evidence to suggests that if carefully designed, PES schemes may have benefits for the poorer members of a community but that this involves an understanding of local power structures which may be prevalent (Pagiola et al. 2005; Pagiola et al. 2010).

Moreover, whether PES is viewed as an instrument aimed purely at maintaining ecosystem function or as a rural development tool for addressing often embedded socio-economic issues, people are at the heart of the scheme. Therefore a deep understanding of the potential social impacts, (positive and negative) and community dynamics is essential if a scheme is to avoid creating greater social ills and deliver tangible benefits (Robards et al. 2011; Bremer et al. 2014). A small but important body of literature relating to how humans interact with ecosystems and how such interactions affect functioning and services attempts to explore this issue (Folke 2006; Holling 2001; Ostrom & Cox 2010). Socio-ecological systems (SES) as an approach seeks to explore the complex networks and interactions that link human society and the environment and may prove useful in designing more effective PES schemes which deliver benefits at both a societal and ecological level (Yin & Zhao 2012; Huntsinger & Oviedo 2014). Recent attempts have also been made at adopting a quantitative approach to SES which allows for the spatial mapping of such interactions, particularly between communities, the natural resources upon which they rely (Bodin & Tengö 2012). Such approaches contribute to an expanding box of tools which can be used to address the question of conditionality and appropriateness of a scheme in a scientifically rigorous manner and could be combined with early mentioned efforts at quantifying ecosystem services and mapping their flow.

Land Use and PES: A Role For Agroforestry?

Land-use conversion, including opening access for agricultural expansion, infrastructure and clearance through legal and illegal logging, remains one of the key drivers of deforestation and land degradation (FAO 2010). Often these activities are considered to be more financially rewarding than keeping forests in-tact and at the community level at least are driven by complex socio- economic decisions aligned to livelihood activities such as subsistence farming, opening of pasture lands and charcoal manufacturing to name but a few (Angelsen 2007; Lambin & Meyfroidt 2010).

PES schemes are often applied in situations where the benefits of ecosystem services are external to the managers of a given ecosystem or the land therein. Under these circumstances, managers of the land often have little incentive to ensure the continued flow of -those services through sustainable land management practices. Therefore, land use decisions which affect the flow of these services may be taken based on maximising the utility to the manager or owner of the land and not with the provision of ecosystem services in mind (Engel et al. 2008). It follows then, that if land managers are to be incentivised to make changes to land use practices which ensure the flow of these services to beneficiaries, then trade-offs between the two groups will be required.

In order to make equitable decisions about those trade-offs an understanding of the flows and interactions of for example, how regulating services affect provisioning services is required (Elmqvist et al. 2011). This can also be considered at multiple scales, for example, the global benefits received through the planting of trees to sequester carbon may have local detrimental impacts for communities in a watershed which now yields less water because of loss to the trees (Vira et al. 2012).

In many PES schemes however, the relationships between the targeted ecosystem service and the land use activities which influence their provision are poorly understood (Wunder et al. 2008; Muradian et al. 2010). This is particularly true in the case of watershed services where myths and 'logical' assumptions are made about how forest cover will affect water provision and avoid landslide risk for example. The relationship between land use and vegetative cover and the resulting effects on water quantity are debated and extremely site specific. A study by Bruijnzeel (2004) focused on the effects of land use on hydrological functions in tropical south-east Asia perhaps provides a useful heuristic: water flow increases as forest cover decreases. However the timing of these flows may be disrupted with higher discharge during storm events and lower flows during summer or drier periods. Vegetative cover was found to have a significant impact on soil stability, erosion and in turn sediment yield, although provides little protection against larger land slide risks which are determined by underlying geology (Bruijnzeel 2004).

In other settings, there is some evidence to suggest that it is possible to incentivise transitions to more sustainable land use activities through PES like schemes, especially when designed to incorporate or moderate existing land-use practices as opposed to prohibiting them (Pagiola et al. 2007). For example, a PES scheme may encourage the adoption of land use practices which conserve and protect forests as part of an improved agricultural regime but which still allow for productive rather than protected land use activities i.e. agroforestry in multi-use landscapes.

The role of agroforestry (discussed here as the incorporation of trees and woody perennials into multifunctional, agro-ecosystems) in supporting and restoring environmental services, while at the same time enhancing (or at least not reducing) the livelihood opportunities of small holder farmers in developing countries, is becoming increasingly well understood and documented (Puhlin & Lasco 2008; Mbow et al. 2014; Mbow et al. 2013; Carsan et al. 2014; R. D. Lasco et al. 2014; Jose 2009). In particular these studies highlight the role of agroforestry at a landscape scale delivering multifunctional benefits which complement instead of conflicting with existing agro-ecosystems. Schemes which have included agroforestry elements into their design have been shown to deliver household level economic benefits as well as additional benefits including increased resilience to climate and market related shocks (Hegde & Bull 2011; van Noordwijk et al. 2011; Garrity 2004; Santos Martin & van Noordwijk 2011). Furthermore agroforestry techniques such as alley cropping and contour planting may provide other benefits such as soil stability and improving soil structure and fertility (Delgado & Canters 2011; Gómez-Delgado et al. 2011). Adoption of agroforestry however comes with challenges such as the technical capacity, training and capital investment required for a transition to a perhaps unfamiliar land use activity. PES practitioners may be able to address these challenges using the funds raised from beneficiaries and institute more sustainable practices which may even outlive the formal scheme itself.

PES and Watershed Management

All organisms depend on water in some form for survival on our ‘blue planet’. For human society, fresh water is an essential good used for drinking, washing, cooking, irrigating and in many cultures is considered a universal human right or a gift from God to which all should have access. Watersheds, as the name suggests have a crucial role in the regulating the quantity, quality and timing of water extracted either directly from rivers fed by surface run off or from groundwater. A well forested watershed can provide a range of ecosystem services some of which are highlighted in Table 2 (Pattanayak 2004; van Noordwijk 2005). As well as these provisioning functions, healthy, stable watersheds provide what Bagstad et al. (2012) term *preventative services* such as flood attenuation (at least at a local level) and regulating services such as soil stabilisation and sediment transfer regulation.

A watershed is defined by Brooks et al. (1991) as “any topographical area that can collect water and is drained by a river system with an outlet” (Brooks et al. 1991). Implicit in this definition is the movement of water through the landscape from source to outlet. This is an elementary observation but a crucial one when considering the related ecosystem service flows. Degradation of watersheds and the services they provide can be attributed to a number of human induced drivers including deforestation and removal of natural vegetation; inappropriate and intensive agricultural practices; unregulated and intensive land use and land use change as well as a number of indirect drivers including lack of secure tenure; poverty and livelihood insecurity; conflicting or perverse institutional incentives and a perennial undervaluing of associated goods and services.

Such goods and services are often considered as common pool resources and in many cases are rival (use by one actor, say, extracting water for irrigation can limit availability for another) and non-excludable i.e. difficult to regulate or control access at the landscape level (Fisher et al. 2010). In certain circumstances, they may also be considered as club goods wherein only those (perhaps members of an irrigation co-operative diverting water for their crops) who hold rights, either property or resource access will benefit (Engel et al. 2008). These characteristics are important to remember when considering the establishment and design of a PES scheme as a shared understanding and negotiation will be required between actors linked by a service flow, separated by time and space. In this sense, determining scale, defining boundaries and understanding relationships (or lack thereof) between steward and beneficiary becomes of utmost importance (Fisher et al. 2010).

Some of the most often cited problems relating to the degradation of watersheds through land use change reducing or altering ecological function include, soil degradation and loss of fertility, increased peak flows or storm events leading to localised flash flooding, increased sedimentation creating problems for irrigation and hydro-electric schemes and a reduction in water availability during drier months i.e. reduced low flow (Bruijnzeel 2004; Tomich et al. 2004). Whether command and control measures or incentive mechanisms are most appropriate in addressing these problems will be extremely site specific and need to be carefully considered given the social setting and political economy of a given watershed (Tomich et al. 2004).

Table 2. Watershed ecosystem goods and services and their benefits to human society

ES DOMAIN	SPECIFIC ECOSYSTEM SERVICES	BENEFITS FOR HUMAN WELLBEING
Provisioning	• Water for irrigation and domestic use (including drinking) • Food source: aquatic biodiversity	• Livelihoods – farming and aquaculture • Meeting daily needs
Regulating	• Flood attenuation • Soil stabilisation • Regulation of sedimentation	• Protection and prevention of damage to property and livelihoods
Supporting	• Nutrient cycling • Soil formation	• Enhancement and protection productivity
Cultural	• Recreation, indigenous people's culture closely linked to	• Intrinsic value and contribution to spiritual wellbeing

Undoubtedly though, PES schemes are often selected as appropriate interventions to restore or maintain watershed functions and services (van Noordwijk 2005). Indeed the literature points to PES schemes relating to watershed services being amongst the most common around the world (Porras et al. 2008). This is further reflected in the increasingly large market for watershed services at the international level with estimates currently at $8.17 billion, most of which is generated from schemes in the US and China (Bennett et al. 2013).

PES in the Philippines

Payment for Ecosystems Services (PES) schemes which promote the protection and enhancement of ecosystem services (ES) and goods are already operational in the Philippines (Lasco & Villamor 2010; Cremaschi et al. 2013). Indeed there is evidence of PES like schemes operating in the Philippines as early as 1996 (Soriaga & Annawi 2010) albeit with limited success. Since the beginning of the 21st century however, a number of schemes have become operational mainly relating to the provision of watershed related services and carbon sequestration (Lopez et al. 2011; Lasco & Villamor 2010; Villamor & Lasco 2009). These schemes have been arguably more successful than earlier attempts but are not without their problems (Cremaschi et al. 2013). Recent attempts to assess the suitability of PES schemes have adopted interdisciplinary approaches including hydrological modelling and natural resource economics which demonstrate that people within watersheds value the services they provide and would be willing to pay for their continued provision (Calderon et al. 2013)

Schemes relating to the provision of watershed services are the most common form of PES in the Philippines although there are an increasing number of projects relating to the provision of carbon sequestration services associated with reforestation and forest conservation which could be considered PES like schemes (Lopez et al. 2011; Lopez RC, Mirasol FS 2011; Lopez RC, Ibañez JC 2011; Bennagen et al. n.d.). A recent review by Cremaschi et al. (2013) of four watershed PES schemes in the Philippines cited a number of issues which limit their efficiency including: lack of technical capacity to accurately relate land-use practices to ecosystem services output and therefore meet conditionality requirements; high costs of monitoring a scheme and lack of clarity around the institutional framework which governs the scheme. The authors found that local government intermediaries played a pivotal role in the success (or not) of a scheme, especially in disseminating information and that other actors such as NGOs were crucial in ensuring social values and benefits were realised.

Table 3 provides a summary of a selection of the types of PES schemes in the Philippines including both watershed and carbon forestry projects. Larger scale carbon forestry CDM, REDD+ and voluntary market projects have not been included here but are emerging in the Philippines (Lasco et al. 2013).

Table 3. A selection of PES schemes in the Philippines

LOCATION	REWARD/PAYMENT	ECOSYSTEM SERVICES	REFERENCE
Bakun Watershed, Benguet	Mandatory taxes paid by a hydro-electric	Water quantity and sediment regulation	(Villamor & Lasco 2009)
Maasin watershed	In-kind: labour wages and technical support/capacity building	Water quantity	(Arocena-Francisco 2003; Salas 2004)
Baticulan watershed	Php 0.75/cu. Added to domestic water bills	Water quantity	(Lasco & Villamor 2010)
No Fire Bonus scheme, CAR	Provision of infrastructure	Fire regulation and biodiversity	(Soriaga & Annawi 2010)
Sibuyan Island	Payment from a collected water levy	Soil stability and sediment regulation	(Lasco & Villamor 2010)
Quirino Forest Carbon Project	In-kind technical support with carbon payments to come	Carbon sequestration, biodiversity protection	(Lopez et al. 2011)

Synthesis: An Operational Framework for PES

Drawing on a wide and well established body of literature, previous sections have discussed in detail the conceptual underpinnings of payment for ecosystem services from an ecological and economic perspective including some alternative definitions. The different actors commonly involved in PES have also been presented along with some of the common typologies and design features including payment or reward mechanisms and different schemes from around the world, including the Philippines. The intimate, complex relationship between human societies, ecosystems and the services they provide has been highlighted and in particular the role land-use and management activities have in affecting such services. This served to demonstrate the need for trade-offs between communities in a landscape setting and the need for negotiation and mediation to determine who pays who, how much and for what.

But what does all this rich information mean and how can we relate the learning to this study? What perhaps comes through most clearly from this review of literature is that PES is not a static, homogenous intervention but rather a diverse set of tools which have been deployed in many different socio-economic, political and ecological settings. It seems that an understanding of the conditions and the socio-ecological systems is required which is tailored to the ecosystem and considers the various perspectives of different stakeholders.

As already stated, the subject of this research is a watershed in the Philippines. The literature shows that PES schemes relating to watershed services are some of the most common around the world, with the Philippines no exception. The range of services offered are many and may relate to agricultural productivity, fish stocks, disaster reduction, domestic water quality, tourism and livelihoods. These are hefty issues and care will need to be taken in negotiating the inherently complex trade-offs.

To summarise, three key learning points from the literature which are of particular relevance for this research are listed below:

1. Identification of relevant ecosystem services under threat, how these can be maintained or improved and how this can be measured;
2. The role of land-use activities in influencing the provision of ecosystem services and what trade-offs will be required by whom;
3. Who the beneficiaries and stewards are and their ability and willingness of to participate, communicate, negotiate and mediate potentially conflicting perspectives. This is conceptualised as a question: *i.e. who will pay who, how much and for what?*

Research Methodology Literature

A number of options arose from the literature regarding ecosystem service assessments but the most appropriate was deemed to be ICRAF's Rapid Hydrological Appraisal (RHA). The RHA approach was designed as part of the wider Rewarding Upland Poor for the Environmental Services (van Noordwijk 2005) which aims to facilitate the negotiation of equitable PES mechanisms across Asia. The RHA component aims to address the first three (Scoping, Awareness and Identifying Partners) of seven steps identified by the RUPES programme, to implement an effective PES scheme. RHA is considered as a Negotiation Support System (Jeanes et al. 2006) providing a sound research basis for communication and negotiation between relevant stakeholders – beneficiaries, stewards and intermediaries. Overall, the tool is specifically designed to support decision making at a watershed or sub-basin level and determine whether a PES scheme is appropriate given the local circumstances.

This methodology acknowledges and gives equal weight to three broad and overlapping knowledge domains: Local Ecological Knowledge (LEK), Policymakers Ecological Knowledge (PEK) and Modellers Ecological Knowledge (MEK). The LEK domain combines cultural and religious traditions, available, technology, politics, identity and gender in shaping perceptions of ecosystem services. PEK is shaped by current public debate, economic development, planning and management roles and national legislation and the power dynamics with LEK. Bio-geophysical science approaches including ecological modelling, (agro) forestry sciences and a systematic, objective approach are the features of MEK (van Noordwijk et al. 2013) . The potential for a viable PES scheme in the local context are thus considered through these analytical lenses which are presented in Figure 5 below. Once we have elicited the perceptions across each of these domains as far as possible and using the methods described in subsequent sections, we must interpret the results and responses to determine whether there is adequate common ground within them to make a PES viable.

Given the stated aims and objectives of this study, RHA has been identified as a suitable suite of tools to be deployed at the study site. A number of such studies have been deployed in South East Asia (Lusiana et al. 2008b; Lusiana et al. 2008a, Khasanah et al. 2010) including a more limited number of studies in the Philippines (Lasco, Cruz, et al. 2010) although in this case RHA was part of a wider research aim looking at the impacts of climate change in a watershed.

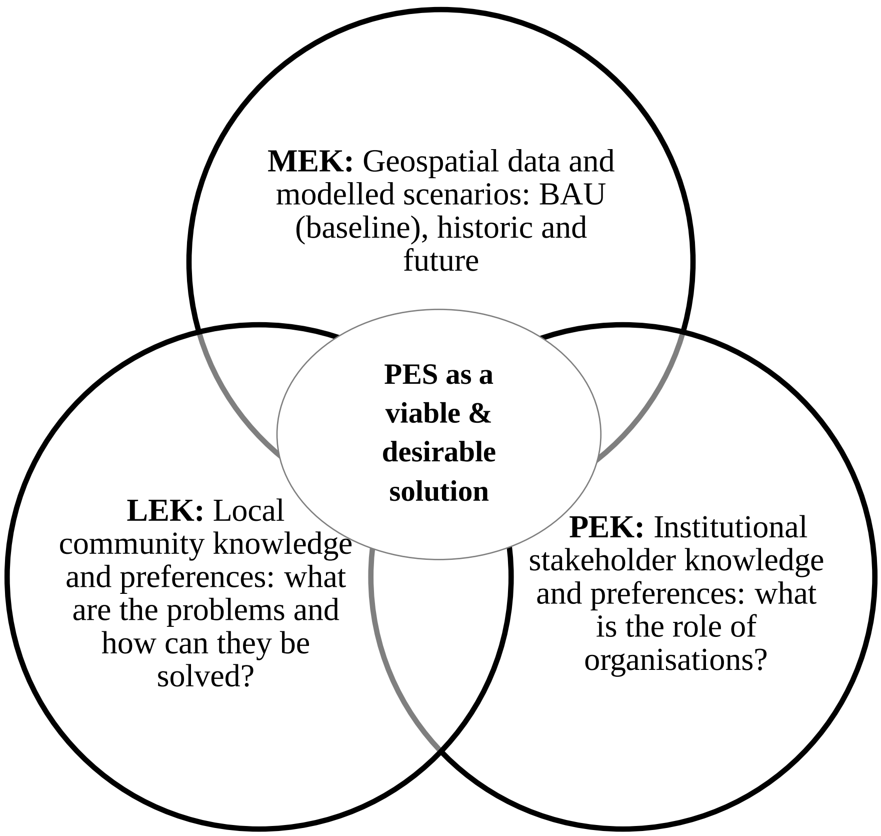


Figure 5. Analytical lenses combining biophysical and social observations

However, the scale of earlier studies both temporally and spatially is much greater, requiring resources and time beyond the scope of this research. Therefore, the suite of tools and methods has been adapted to better suit the circumstances of the site. Employment of these tools will enable practitioners and stakeholders to pinpoint the interventions and practices which will best support the continued provision of the ecosystem services most important for the sustainable management of the Gabayan watershed in providing social and environmental benefits.

CHAPTER III

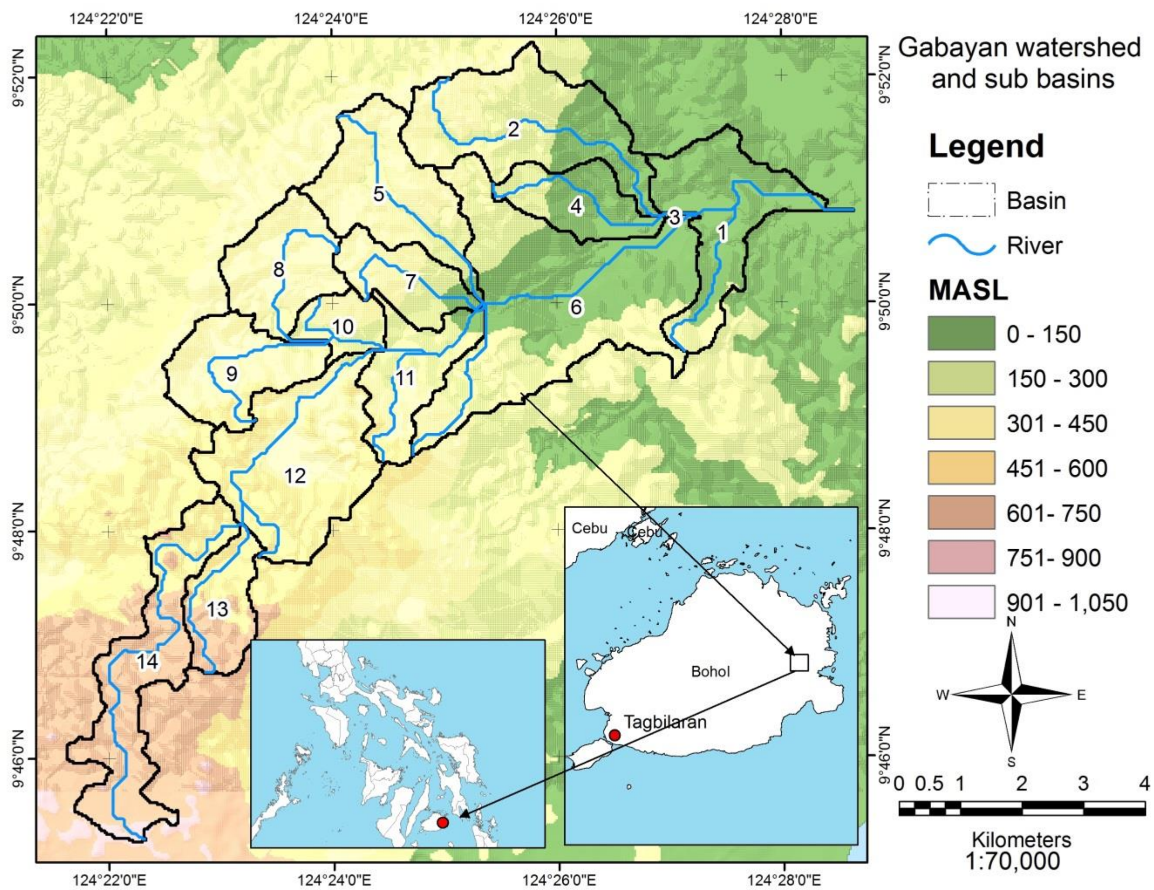
DESCRIPTION OF THE STUDY SITE

Location

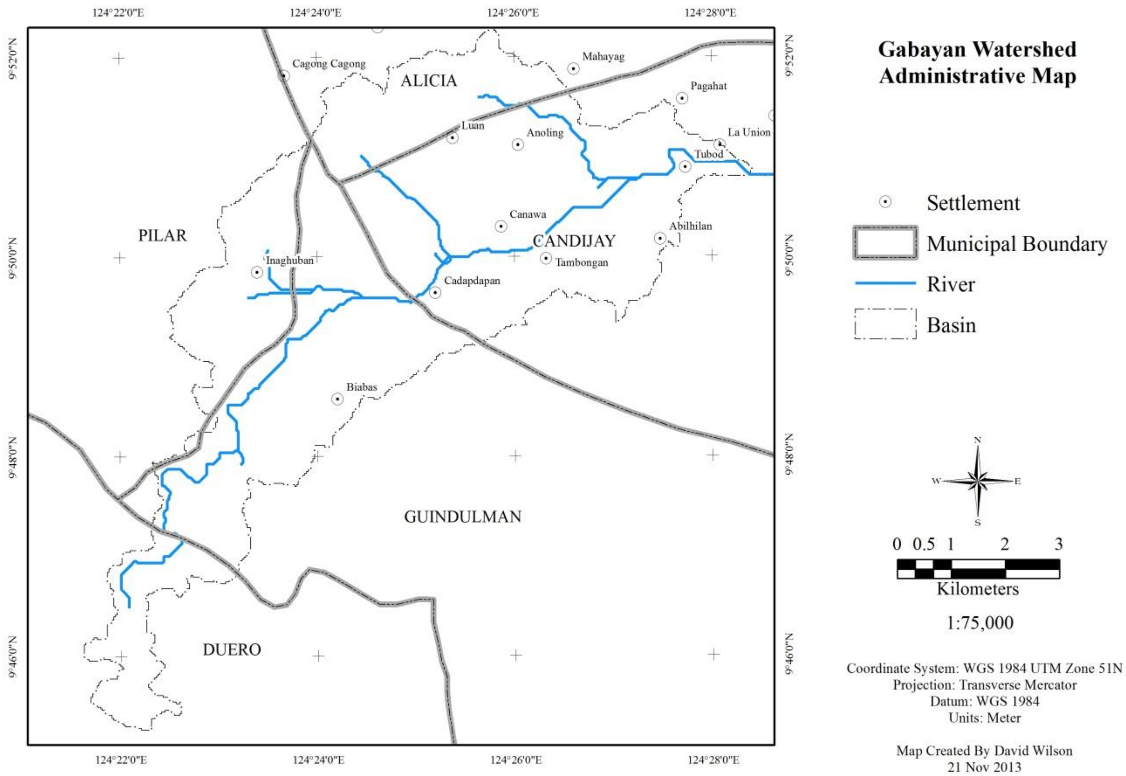
With a total area of 20,749 hectares, the Carood basin is considered as the 5th largest watershed in Bohol. The area covered by the watershed incorporates parts of 6 municipalities including Alicia, Candijay, Ubay, Mabini, Pilar, and Guindulman and is home to 64, 962 residents. Carood Watershed lies in the eastern part of Bohol with geographical coordinates of 9° 48' 00" latitude and 124° 22' 30" to 124° 31' 20" longitude. Two major river systems namely Gabayan and Carood drain to Cogtong Bay. Gabayan sub watershed has a total area of 51.52 km^2 (5152 hectares) and drains the Gabayan River through Candijay to Cogtong Bay.

Micro and Macro Study Sites

This study is situated in the Carood basin. However, given its size and complexity as well as a lack of robust observed data at that scale a micro site, that of the Gabayan watershed (Map 1) has been selected both for practical reasons but also as a representative landscape. Some research activities will be conducted at the macro level although more fine grained analysis and data gathering will focus on the micro site. This makes sense both spatially and politically. The Gabayan river has it headwaters in Pilar and Guindulman and runs through the municipalities of Candijay and a small part of Alicia and these four municipalities will be the focus of this study. Candijay has been one of the worst affected municipalities in terms of flooding and has a full range of land use activities (natural and plantation forests, agroforestry, rice and vegetable production, grasslands and mangroves). Although the Carood watershed is not a homogenous landscape it is anticipated that results and recommendations will be readily scalable to the watershed level for the benefit of decision makers.



Map 1. Gabayan watershed showing delineated sub basins, drainage network and topography



Map 2. Administrative map of the Gabayan watershed

Table 4 describes the main features of the Gabayan watershed which is over 5,000 hectares in total area with a relief of 790m and a drainage density of 0.47km/km^{-2} and a dendritic drainage pattern. The watershed has steeply sloping upland areas which are where most of the forest remnants are located. The dominant soil type in the study area is Ubay clay loam (31% clay/39%Silt/40%Sand) according to the FAO's digital soils map of the world which is slightly acidic (pH 5.9). Topography is generally characterized as moderately rolling, hilly and to steeply sloping terrain with an average slope of 17.1%. Such characteristics have resulted in a relatively thin soil cover (common in almost all areas of Bohol), bedrocks cropping out even at valley areas and coastal zones. Steep slopes, high precipitation and frequent, extremely heavy rainfall over short period due to typhoon exacerbate already serious soil erosion in some areas. Soil erosion and associated loss in productivity and degraded water resources are serious threats in upland areas in the Philippines (Asio et al. 2009). In a recent study conducted by the Australian Centre for International Agricultural Research (ACIAR) demonstrated that activities which have the highest impact on agriculture sustainability in the upland farming in Bohol are up and down cultivation on sloping lands, use of nutrient depleting crops such as corn and cassava and extensive cultivation along these areas. Over most of the hilly portion and ridges there is very little top soil cover (ACIAR 2012).

Table 4. Gabayan watershed profile

CHARACTERISTIC	DESCRIPTION
Catchment Area	52.05km2 (5205 ha)
Elevation Range (Relief)	7m – 797m (790m)
Drainage Density (Total Length of Stream/Area)	18.182/38.05 = 0.47km/km^{-2}
Drainage Pattern	Dendritic
Mean Annual Rainfall	1656mm (25 year time series data)
Soil Texture (dominant)	Oxisol: Clay loam (31%clay/59%Silt/40%Sand),pH 5.9
Main Vegetative Cover	Forest fragments, annual agriculture, grassland

Land use activities in the Gabayan watershed vary from the headlands to the outlet with the major tributaries traversing multi-use landscapes which have been subject to wide spread deforestation and the proliferation of annual agriculture and cogonal grass lands (*imperata cylindrica)* which are seasonally burnt as pasture for grazing livestock. This has further degraded the soil and led to land becoming underutilised creating pressure on existing arable land and in turn resulting in increased resource management conflicts within and between different zones of the watershed. Furthermore, the removal of vegetation in the upland and midstream zones is believed to be the reason for a locally observed intensification of soil erosion, siltation of irrigation channels and destabilisation of river banks in the downstream zones. Thus far, these observations are largely anecdotal but there appears to be a change in function of the watershed and the resulting services due to human activity.

Reason for Selection

Neither the Carood Basin nor Gabayan watershed have been declared a critical watershed and consequently receives no additional central government finance to support sustainable management. Despite, and perhaps because of this, Carood basin has been the subject of a number of development interventions, social and scientific studies in the last 10 years. However, whilst some progress has been made, these interventions have so far failed to realise a sustainable management system which ensures the conservation and rehabilitation of the watershed to continue to provide the ecosystem services which support livelihoods for the local communities. These activities undertaken by local, provincial and regional government agencies and Non-Governmental Organisations (NGOs) as well as a number of long-term volunteers have generated a rich but disparate repository of data.

The Carood Watershed Management Council (CWMC) which was formally established by then Governor Erico. B. Aumentado in 2003 and is a multi-stakeholder body which includes representatives from the six Local Government Units (LGU), People's Organisations (PO), Non – Government Organisations (NGOs), government agencies and the academe. The council is active, meeting quarterly and its community level and government stakeholders members are somewhat engaged. Furthermore, PES has been identified by the watershed management council as one potential way to address some of the prevailing environmental and social issues in Carood and provide funds to support the long-term management activities defined in their strategy and log frame. More recently, the Carood watershed has been accepted as a member of the International Model Forest Network[1] which may provide this study and any learning drawn from its conclusions, with a more global reach. In 2012 a Willingness to Pay survey was conducted in the watershed which provided an indication that local communities could be willing to participate in a PES scheme as long as the cost did not exceed 20Php per month per household.

Demographic Information and Local Economy

According to the CWMC, the Carood watershed is home to around 65,000 people. Full population information for each of the six municipalities within the area is provided in

[1]The International Model Forest Network (IMFN) is a global community of practice whose members and supporters work toward the common goal of the sustainable management of forest-based landscapes through the Model Forest approach. Three aspects central to a Model Forest are a large landscape, broad partnerships and a commitment to sustainability: http://www.imfn.net/

Table 5. Please note however that the focus of this study is on four of the six municipalities, Candijay, Alicia, Guindulman and Pilar so this information should be taken as indicative only. The population growth rate according to a 2007 census has decreased from 2.95% for the period 1995 – 2000 to 1.06 for the period 2000 – 2007 (PPDO, 2010).

Table 5. Population in the four municipalities within Gabayan watershed

MUNICIPALITY	PEOPLE	HH
Alicia	23422	4564
Candijay	31183	5951
Guindulman	32355	6598
Pilar	27276	5045
Total	208924	41263

(Data source: Bohol PPDO)

Levels of poverty incidence (Table 6) amongst the households with Gabayan watershed also appear to be relatively high with more than 67% of the households in Candijay living below the income threshold which means most or all of their income goes towards food security and as high as 77% (Guindulman) in other municipalities. At the provincial level 15% of households are 'Poor Hungry' and unable to meet their daily sustenance requirements.

Economic activity in the 4 municipalities is generally limited to small scale, irrigated and rainfed agriculture and aquaculture. In Candijay the primary activity is rice, corn, root crops, coconut and banana production. There is also some evidence of agroforestry and fruit orchards, particularly mango, jackfruit and cacao cultivation and also pasture lands used for grazing livestock. Pilar is known for its rice production as it has a good irrigation system supplied by two dams but the area within Carood has a high slope and is dominated by root crop and agroforestry. There is very little in the way of tourism which is mainly focused on the nearby coastal resorts of Anda.

Table 6. Poverty incidence in the six municipalities within Carood watershed

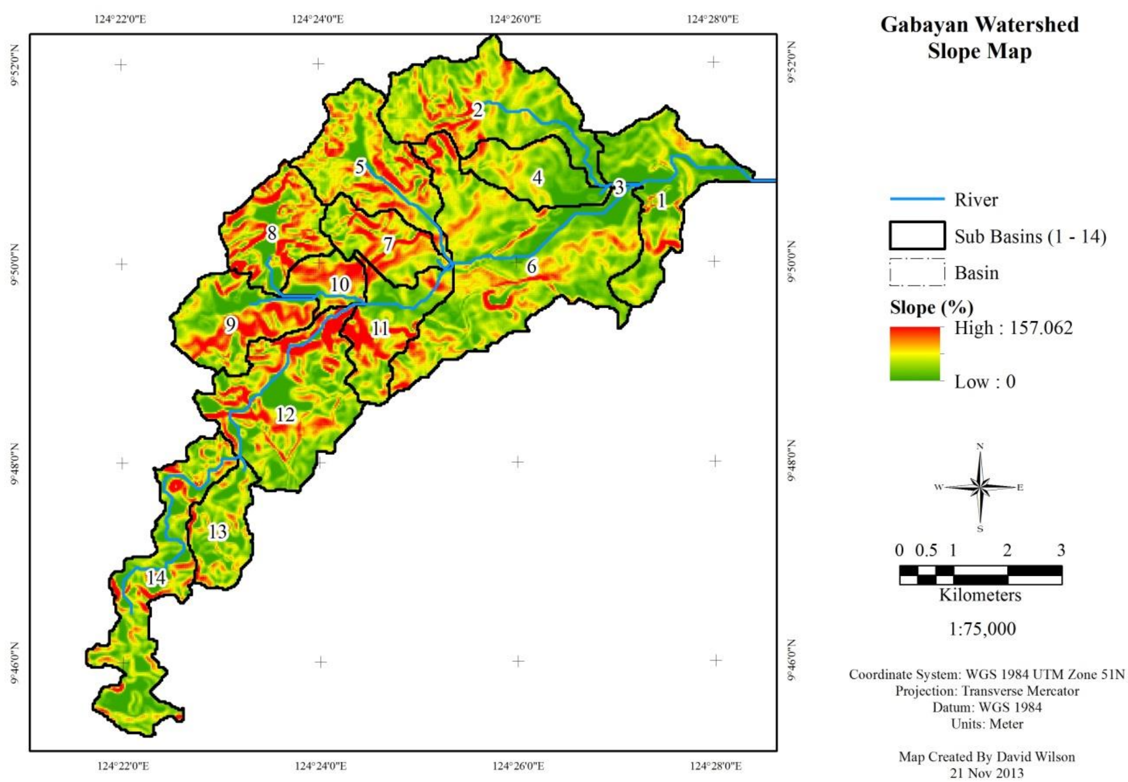
Municipality	# HH below income threshold	% of total HH
Alicia	2212	62.14
Candijay	1607	67.69
Guindulman	5108	77.42
Pilar	2221	51.4

(Data source: Bohol PPDO)

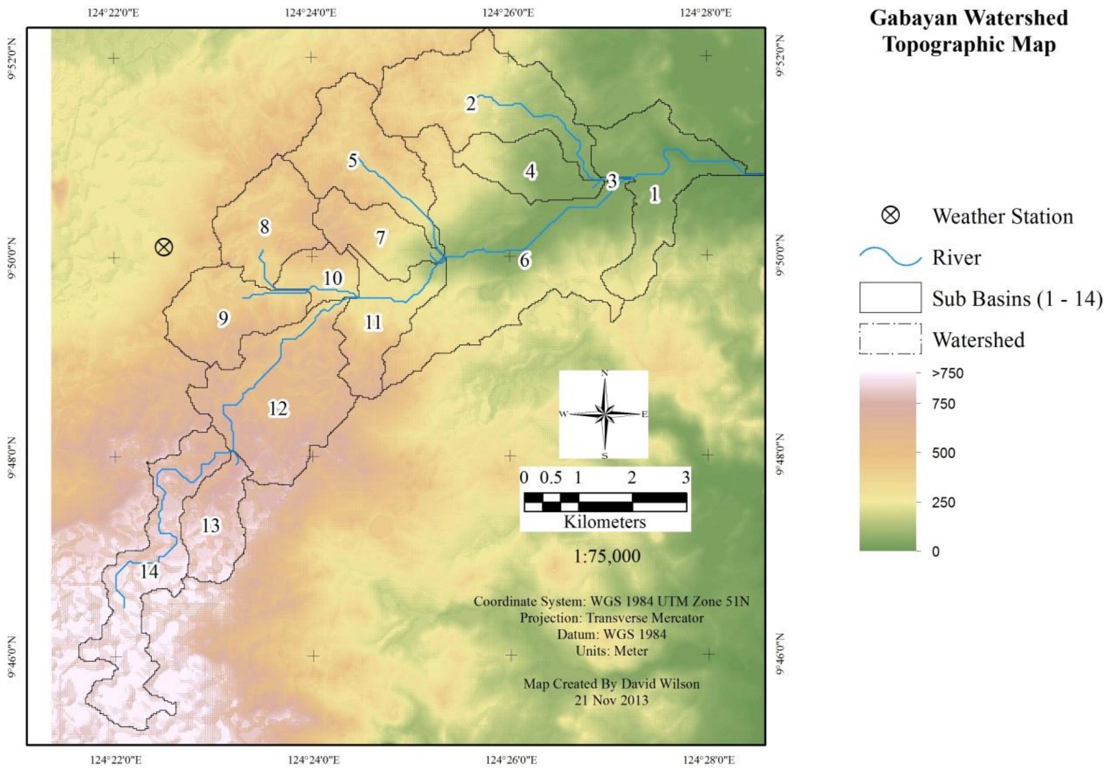
Overall, the local population are heavily reliant on agricultural activities for their livelihood security and to meet daily subsistence needs. The availability of water, in terms of quantity, quality and timing is therefore of vital importance to the local economy and provides the basis, conceptually at least for undertaking a study into how this essential ecosystem service can be protected and enhanced.

Geographical, Topographical and Watershed Features

The topography of the Gabayan watershed varies from gently sloping and undulating hills, to steep sloped areas in the uplands, especially in Pilar, Candijay and Guindulman. The lowlands, particularly in the municipality of Candijay and Alicia are dominated by agriculture and grasslands which are seasonally burnt to encourage new growth for livestock grazing.



Map 3. Slope map of the Gabayan watershed with delineated sub-basins



Map 4. Topographic map of Gabayan watershed

Climate and Climate Change Projections

Bohol is classified as a Type IV climate according to the modified Corona classification which means there is more or less even distribution of rainfall throughout the year. However, as we will discuss in the results section, time series climate data from stations within the watershed indicates that there is in fact a pronounced dry season between February and April. Furthermore, provincial downscaled projections from PAGASA based on an A1B scenario (Table 7) suggest that there may be an increase in seasonal rainfall by 2020. During the period December to January as Bohol may receive up to 9.8% more rainfall against the observed baseline (1971 – 2000) and 21.2% by 2050. This intensification of hydrological cycle is likely to have local impacts including exacerbating existing flood and flood risk. An increase in average temperature of 1.2 degrees Celsius during the period March, April, May by 2020 and 2.3 degrees Celsius by 2050 for the same season. This could represent an additional risk for Bohol and Carood, reducing water availability, increasing evapotranspiration loss and altering the growth patterns of staple crops.

Table 7. Climate change temperature and rainfall projections for Bohol, 2020 & 2050

PERIOD	CHANGE IN 2020 (2006 – 2035)				CHANGE IN 2050 (2036 – 2065)			
Season	DJF	MAM	JJA	SON	DJF	MAM	JJA	SON
Temperature (^{0}C increase)	0.9	1.2	1.2	1.0	1.8	2.3	2.3	1.9
Rainfall (%)	9.8	-7.1	4.5	6.8	21.2	-11.9	18.9	22.6

(Source: PAGASA)

Political Units, Land Use and Tenure

The majority of the land in the Gabayan watershed is considered to forestlands with the remainder classified as alienable and disposable (A&D). A & D land is mainly used for different agricultural purposes which represents the principal livelihood of the local population. Of the 2999 hectares (ha) of designated forestlands within the municipalities which make up the Gabayan watershed, just over half (1975ha) is under some form of tenurial, at least on paper. However, over one third (1304ha) remains open access with much of this is found in Pilar and Candijay. Table 8 provides an overview of the different tenure arrangements found in the Carood watershed.

Table 8. Forestland tenure arrangements in Gabayan watershed municipalities

MUNICIPALITY	FOREST LAND (HA)	CBFMA	CSC	CADC	OPEN ACCESS	TOTAL AREA WITH TENURE
Candijay	1917	1304	200	-	413	1504
Guindulman	355	-	-	355	-	355
Pilar	727	-	116	-	611	116
Total	**2999**	**1304**	**316**	**355**	**1024**	**1975**

(Source: DENR PENRO, Bohol)

Community-based Forest Management Agreements (CBFMA) cover 1304 hectares of land in the Candijay. CBFMAs are awarded to people’s organisations (POs) and communities who are actively engaged in the management of and stewardship over designated forestlands and are granted for a period of 25 years, renewable for a further 25 years. Much of these forestlands in reality do not have tree cover and indeed part of the agreement is that at least 20% of the area seceded should be maintained as or restored to forest.

Community Based Forest Management (CBFM) is one strategy identified to tackle these issues which is well established in the Philippines (Lasco, Evangelista, et al. 2010). Whilst challenges to the efficacy of this system remain, overall it is viewed by both the government and participating communities as a successful mechanism for the protection and enhancement of forest resources. In particular, the use of agroforestry within a CBFM framework has been successful in reducing the impacts of forest conversion due to shifting agriculture, at the same time providing or maintaining a livelihood for upland farmers (Puhlin & Lasco 2008).

The predecessor to the CBFM was the Integrated Forest Management (IFM) arrangement which saw Certificates of Stewardship Contracts (CSC) awarded to individual families on the basis that they would manage the land sustainably and maintain some forest cover. These contracts had the same tenure period as CBFM (25 years) but many of these are coming to an end and only 316 hectares of the Gabayan watershed are currently covered by this arrangement.

Of the remaining forest lands, 355 hectares are under a Certificate of Ancestral Domain Claim (CADC) which is held by the Eskaya community in Guindulman, an Indigenous People's group. This officially recognises the group and gives them control over natural resources and economic activities within the area of their stewardship in line with their traditions.

The range of tenure arrangements in place within the watershed in addition to the political boundaries and associated land use activities serve to highlight the complex nature of the institutional and governance landscape. This is highly relevant for a study into the potential for PES as tenure arrangements will govern who has access to and rights over different ecosystem services. This study will attempt to understand and map these different rights of access in order to understand the potential for conflict and to determine whether and how an equitable PES scheme could be realised in the Gabayan watershed.

Governance, Legislation and Institutional Setting

The Gabayan watershed is not covered by a proclamation as a critical watershed, nonetheless there are a number of relevant governance institutions and instruments which affect and the influence the management of the watershed and land use activities within its boundary. These include:

- The Clean Water Act of 2004 (RA 9275) which provides local devolution of water quality monitoring and enforcement responsibilities ;
- RA 3601 grants the National Irrigation Authority control over irrigation activities including collection of fees;
- Section 37-39 of the Revised Forestry Code (PD 705) – forest production and protection;
- Republic Act 7160 - the local government code which gives some responsibility for management of natural resources to LGUs.

CHAPTER IV

MATERIALS AND METHODS

This study will seek to identify and characterise the significant ecosystem services within the Gabayan watershed within the Carood basin in Bohol and determine whether they can be sustainably maintained or enhanced using PES as an intervention. The interaction of communities within the study area with the ecosystem service will need to be determined. Community use, extraction and conservation of ecosystem services directly or the resources and land-use practices which affect their provision will be identified and mapped. This will involve the gathering of biophysical and social data, both primary and secondary. Therefore, this study will employ an adapted version of the World Agroforestry Centre's (ICRAF) Tools of Multi-Use Landscapes – South East Asia (TUL-SEA), in particular Rapid Hydrological Appraisal (RHA) which combines a number of social and biophysical tools (Jeanes et al. 2006). RHA was designed as a tool to assess the conditions within a given watershed or catchment and whether a PES (labelled Environmental Service Rewards by ICRAF) mechanism or scheme is feasible by: identifying the main stakeholders and what their different perceptions and expectations from a scheme are; assessing the current hydrological function of the watershed and identifying the most acute environmental problems and how different land use practices contribute to these. Table 9 below provides a summary of the proposed methods in detail grouped into six distinct but overlapping research components, A – F.

Table 9. Summary of research components, methods and outputs

COMPONENT	METHOD	PURPOSE	TYPE
A. Environmental scoping and stakeholder analysis	Review of grey literature (CLUP, vulnerability assessment) Consultation with provincial agencies Secondary data collection: PPDO, PENRO, BEMO General watershed reconnaissance, observation and photographs Identify land-use patterns	Identification of ecosystem services Photographic record of study site and identified env. problems Develop list of stakeholders Develop a list of env. issues to help shape component B & C	Desk and field based
B. Policymakers Environmental Knowledge (PEK)	Inception workshop (Carood Watershed Management Council) Stakeholder baseline questionnaire Institutional stakeholder analysis and consultation with local, provincial and regional government and non-government agencies	Identify env. issues and identification of impact areas Definition of spatial focus of the study Identification of community level stakeholders and site Determination of perceptions and expectations in relation to PES Identification of key ecosystem services	Field based
C. Local Environmental Knowledge (LEK)	Participatory mapping workshops: current and past land use Preparation and use 'sketch maps' of target communities for participatory mapping Community consultation (upstream, mid-stream, downstream [coastal])	Pinpointing of env. problems (hotspots) relating to watershed functions and land-use Articulation of local community's perceptions and expectations of PES	Field based
D. Geospatial analysis and scoping	GIS data gathering and processing: Remote sensing data acquisition Digitising Digital Elevation Model (DEM) Processing Radiometric and Land-cover assessment 'Ground truthing' (GPS field work)	Watershed delineation Study area maps (physical, political, socio-economic) Initial identification of focus of study, possible stakeholders and env. problems relating to degradation watershed services and function	Desk and field based

Table 9. Continued …

COMPONENT	METHOD	PURPOSE	TYPE
E. Modellers Environmental Knowledge (MEK)	Hydrological modelling Aggregation of spatial data, land-use, watershed delineation, DEM, rainfall, soil depth & type, calibration & geology Set up and calibrate SWAT model	Watershed/sub-catchment, service flows water balance & functions Historical (with forest), current and future scenarios modelled	Post-fieldwork
F. Data analysis and communication of findings	Analysis of modelling outputs, community and institutional perceptions Value-Threat-Opportunity-Trust Assessment	Presentation of findings (Thesis) Determine future likelihoods and options (including PES)	Post fieldwork

Environmental Scoping and Stakeholder Analysis (Component A)

This component involved the gathering of available secondary data as well as reconnaissance work to better understand and conceptualise the environmental problems and ecosystem services in the Gabayan watershed and Carood basin. The aim of this component is to determine an initial list of potential environmental issues within the study site and ultimately to articulate this into a more coherent overview of the linked socio-ecological issues. The first step was desk based and involved a review of literature to identify historic environmental issues within the study area and determine the main land-use activities. This work was carried out between January 2013 and April 2013 and involved visiting both the study site and the provincial capital, Tagbilaran which is the location of the provincial government and associated functions. Both the regional and provincial DENR offices were engaged and provided useful data relating to the watershed including GIS shapefile maps and back ground reports including a vulnerability assessment and Forest Investment Plan (FIP) (DENR 2011b; DENR 2012). In order for these documents and data to be shared openly, a Memorandum of Agreement (MoA) was signed between Region VII DENR and the lead researcher which set out the terms and duration of the research.

The Bohol Provincial Planning and Development Office (PPDO) also provided a substantial amount of spatial data and shared the province's water resource management plan, the Bohol Integrated Water Supply System Master Plan (Bohol PPDO 2011). The Carood Watershed Model Forest Management Council (CWMFMC) also provided secondary data including the updated strategic management plan and log frame which includes agreed activities and outputs for the sustainable management of the watershed. In addition, representatives (Municipal Planning and Development Officers and Municipal Agriculture Officers) of Local Government Units from Alicia, Candijay, Guindulman and Pilar were approached and informally interviewed to provide additional secondary data.

Reconnaissance visits around the watershed to better understand the prevailing land use categories, agricultural practices, land management practices, watershed degradation, livelihood activities and drainage network were conducted during the same period. In an adaptation to the original RHA process and in order to save time, these tours around the watershed were combined with GPS ground truthing exercises to determine the accuracy of desk based land classification exercises discussed in later sections. A photographic record of these visits was created. The data gathered via this exercise was used to shape the design of future components.

Policymakers Environmental Knowledge – 'PEK' (Component B)

Research Inception: The experiences and knowledge of local decision makers and those individuals and agencies which influence activities and development within the watershed are essential in understanding whether a PES type scheme will be viable. Recent literature (Villamor & Lasco 2009; Cremaschi et al. 2013) suggests that local government in particular has an influential role in whether a PES scheme is sustainable.

At the April 2013 meeting of the Carood Watershed Model Forest Management Council (CWMFMC), the proposed research was introduced to the 26 council members which include Local Government Units (LGU), regional and provincial Department of Environment and Natural Resources, Bohol Island State University, Bohol Environmental Management Office and seven People's Organisations (POs) 5 from upland and midstream communities and 2 from coastal and mangrove areas. This body is elected and is broadly representative of the agencies, actors and communities who live and work in the watershed area.

Baseline Questionnaire: Following the inception meeting, questionnaires were sent to a wider group of stakeholders which requested more detailed information about the activities relating to water based ecosystem services, environmental problems in the area, perceptions on their cause and effect, severity and proposed solutions. In early July 2013 the questionnaire was distributed to stakeholders within the watershed: municipality officials – planners and agricultural officers, water district councils and co-operatives, people's organisations, DENR, BEMO, BISU, NIA, and other relevant government departments based in Tagbilaran City and locally. More than 50 questionnaires were sent out. The full questionnaire can be found in Appendix A.

These contacts were identified during consultations with council members and representatives of the regional DENR. One to one meetings were held with every organisation to inform them why the questionnaire was being distributed, to give background information on the Carood watershed where there had been limited or no previous contact, and to offer help in completing the questionnaire. This component was completed by research partners based at the field site and data shared with the lead researcher.

Local Environmental Knowledge – ‘LEK’ (Component C)

This component represents the most in depth and time consuming aspect of the field work and was designed to pinpoint the current environmental problems) relating to watershed functions and land-use and to articulation the local community’s perceptions and expectations of PES. The actual individuals, communities and organisations were identified through diversity sampling which does not involve standard sample selection using statistical means (stratified random sampling for instance) but instead will employ ‘diversity sampling’.

Diversity sampling is a new technique used specifically with participatory activities (Maxson & Guijt 2010) and suits well this study which uses the knowledge and perceptions of the local decision makers to determine which groups of people should be the focus of this component. Target groups and individuals are determined on this basis but diversity sampling allows for the addition of actors from social groups or sectors (females, elderly, youth etc.) if they are under-represented. Therefore, some positive selection bias was applied to ensure, for example there was fair gender representation amongst the small groups consulted. A full list of the participants in this component can be found in Appendix B

This approach may seem counter intuitive to orthodox social scientific rigour but since the information we are trying to elicit in this study is largely qualitative - perceptions, local knowledge and opinions relating to an environmental problem – this is not viewed as significant issue. Furthermore, the rigidity imposed by a statistical selection process would not allow for the addition of new groups or individuals based on the conversations with each stakeholder and thus the more nuanced *'you should really speak to'* and *'so-and-so knows all about that problem'* points would have been missed. Ultimately, the stakeholder selection process was conducted in coordination with the CWMFMC, with many of the members and extended networks attending 2 workshops which were conducted on 16th and 19th August 2013 at two locations in the watershed.

Workshop design: In order to identify the drivers of land use change in the watershed and better understand the type, scale and location of associated environmental problems and any perceived change (positive or negative) in ecosystem services, a workshop for local community representatives was designed. The overall objectives of these workshops were:

i. To reach a shared understanding of what a Payment for Environmental Services scheme could be in the context of the watershed;
ii. To identify and map the current environmental services within the watershed;
iii. To identify what environmental problems there are and where these are occurring;
iv. To establish how land use activities relate to these environmental services/problems and how these have changed over time;

These workshops were designed together with local partners including the DENR and Voluntary Services Overseas and were influenced by the data already gathered during component A and B. The overall aim of the workshop was to identify any linkages between current and past land use which influences the provision of ecosystem services. There are inherently both temporal and spatial aspects to this and therefore two different techniques were used to elicit the perceptions of local workshop participants which are discussed in turn below.

Participatory mapping (spatial component): The first activity with each of the selected stakeholder groups was to map out the local environmental problems using participatory mapping techniques (IFAD 2009; Garrity 1999). Participatory mapping is a tried and tested technique used in order to understand the spatial relationships between land-use activities and environmental problems situated in a given landscape and is used here largely as a diagnostic tool to elicit the knowledge of local stakeholders individually or in groups (Lynam et al. 2007). Sketch maps were prepared for the selected area using a GIS base map onto which local stakeholder's included their perceptions and opinions of the environmental problems in the area, the major land-use activities and patterns as well as any linkages they see between them and their position in the landscape. The main objectives of the mapping activity were to:

i. Locate on maps the **main environmental problems**, with participants using symbols and writing to identify what is happening where.

ii. Locate on maps the **current ecosystem services** – water storage, supply, reforestation, soil stabilisation, flood alleviation, waste issues

iii. Identify on maps all **key natural resources** – forests, mangroves, agriculture land, rivers, springs etc.

Large scale maps of the whole Carood basin were produced and provided to each group (see Appendix C). Participants were asked to draw on the maps directly and use symbols and post-it notes to represent the services, problems and natural resources in the their municipality. They were asked to do this as precisely as possible to allow the information to be compiled and transferred to GIS. Participants were also asked to correct any errors they recognized in administrative boundaries and the location of settlements which were provided as reference points. Photographs were taken to document the contents.

Current and past land use (temporal component): The purpose of this activity was to see how land use, ecosystem services (benefits) and hazards or problems have changed over time. It builds on the mapping activity, introducing a temporal aspect to the spatial information gathered. This activity used a combination of field tested participatory methods (IIAC 2008).

Each group was provided with a template with a space representing their municipality or local area with a key to a range of land use types. They were encouraged to add or alter these land uses to make it relevant for their area. The groups were then asked to shade the areas to show the amount of land currently given to each land use type as a rough percentage of the total. They were also provided with some blank pie charts; one group for environmental services and one for problems. A complete pie chart in the services group = fully available service and in the problem group = major problem. This activity was then repeated but people were asked to think as far back as possible to past land use activities (see Appendix D).

As well as being used to gather new information on existing and past land use, this activity was designed to validate information about the problems in the watershed and build on the previous spatial mapping activity. It was designed to get people to start thinking about how services and benefits (e.g. soil stability, water quality) are affected by land use activities. This is a crucial concept in designing effective PES schemes.

Geospatial Analysis and Scoping (Component D)

Initial spatial analysis is required to determine the topographic boundaries of the Gabayan watershed and therefore the area of study and involved a combination of desk based secondary data gathering and analysis as well as field based ground ‘truthing’ and validation. Spatial data is required in order to define the study site boundaries and also to locate communities and ecosystem services within the landscape. Geospatial analysis is also particularly important for the hydrology modelling exercise (Component F) as the model requires inputs derived from spatial data. Table 10 below summarises the geospatial data gathered and used in this study.

Table 10. Geospatial data retrieved for use in this study

DATA	RESOLUTION	FORMAT	SOURCE
Landsat WRS 2: Path 113 Row: 53 for 1990 & 2010	30m	GeoTiff	USGS
Aster (DEM)	30m DEM	GeoTiff	NAMRIA

The digital elevation model (DEM) was sourced from the Philippines National Mapping and Resource Information Authority (NAMRIA) national level dataset with a resolution of 30m and was pre-processed to assign the necessary projection (WGS 84 51N), fill any unwanted pixel anomalies and clipped (fitted) to the area of interest to reduce processing time during modelling. The DEM is used in the model to topographically delineate the watershed, further discretize this into sub watersheds and finally identify the stream network through the calculation of the flow direction grid and flow accumulation grid. Correct preparation of the highest resolution DEM available is therefore important for overall accuracy.

Determining the land cover of the area of interest was done using available medium resolution (30m) satellite imagery via USGS LANDSAT. Ortho-rectified images for the years 1990 and 2010 were accessed in order to show the vegetative change over time. The images were first pre-processed to allow for accurate data extraction and normalization for comparison between years. Atmospheric correction and radiance correction were conducted using the inbuilt Exelis ENVI© 5.0 functions, QUick and Calibrate Landsat. Finally, cloud masking was conducted to ensure that these pixels were excluded from the analysis. The selected images all contained <9% cloud cover and the areas of interest were largely free of cloud so this did not significantly affect the classification activity.

Once the images had been corrected and prepared, land cover data extraction could be conducted. It was decided that given the required inputs for the model, Level 1 classification would be sufficient and the following land use classes were targeted: closed canopy forest, open canopy mixed forest, grassland, mixed agriculture, water, urban, and barren. A supervised classification was conducted using ESRI© ArcGIS 10.1 and training sites identified using both local knowledge of the site and also the assistance of higher resolution satellite imagery via Google Earth and also available (but with high cloud cover) Spot 5m resolution data from NAMRIA. With the training sites finalized, a Maximum Likelihood Classification module was run on the area of interest to identify the target land cover categories. The results were then assessed using a Confusion Matrix which calculated the overall accuracy and agreement between the remote sensing exercise and the ground truthing exercise.

Modellers Environmental Knowledge – 'MEK' (Component E)

The hydrological modelling component of the study was the final component of the overall methodology and was the most technically demanding. According to ICARF's RHA tool, the Stella based model GenRiver is used. However, this requires significant data on the observed stream discharge (stream flow) which is lacking at this study site. Many of the watersheds in the Philippines lack this sort of data, particularly time series data, indeed this is a problem common to many developing tropical nations (Petheram et al. 2012) . Instead, the US Department of Agriculture's *Soil and Water Assessment Tool* (SWAT) was identified as a suitable model as it is specifically designed to predict the effect of alternative land management decisions on water, sediment and chemical yields with reasonable accuracy for un-gauged rural watersheds (Neitsch et al. 2005). The model components, data requirements and overall operational framework are described in more detail below.

Soil and water Assessment Tool (SWAT): SWAT is a quasi-distributed model which evaluates complex watersheds with varying soils, land use and management conditions over long periods of time (i.e. > 1 year). It is a continuous-time model using daily average input values, and is not designed to simulate detailed, single-event flooding. Major inputs for the model include: climatic variables, land cover data, slope, topography and soils. Major outputs from the model include channel discharge (m3 day^{-1}); evapotranspiration (mm); surface runoff (mm); sediment yield (t ha^{-1}); sediment concentration (mg kg^{-1}) and baseflow (lateral flow plus groundwater flow returning to the channel).

SWAT predicts the hydrology at each hydrological response unit (HRU) using the water balance equation, which includes daily precipitation, runoff, evapo-transpiration, percolation and return flow components. The surface runoff is estimated in the model using the Natural Resource Conservation Service Curve Number (CN), the percolation through each soil layer is predicted using storage routing techniques with crack-flow model (Neitsch et al. 2005) and the evapo-transpiration is estimated according to Penman - Monteith (Monteith 1965). The SWAT Model uses the Modified Universal Soil Loss Equations (MUSLE) to compute HRU-level soil erosion. It uses runoff energy to predict the detachment and transport sediment in the channel and the deposition using fall velocity. These calculations are made based on the soil and land cover input data with assumptions made on the corresponding type of management. The MUSLE is expressed as follows:

Equation 1: Modified Universal Soil Loss Equation

$$sed = 11.8(Q_{surf} + q_{peak} + area_{hru})^{0.56} + K_{usle} + C_{usle} + P_{usle} + LS_{usle} + CFRG$$

Where:
Sed = sediment yield
Q_{surf} = surface run off volume (mm/ha)
q_{peak} = peak run off rate (m^3/s)
$area_{hru}$ = area of hru (ha)
K_{usle} = soil erodibility factor
C_{usle} =cover factor
P_{usle} = practice factor
LS_{usle} = topographic factor
CFRG = Coarse fragment factor

Model parameterisation: The SWAT model was developed in the USA and has been widely used there and in many other countries around the world (Gassman et al. 2007; Ma et al. 2009; Licciardello et al. 2011). In order to ensure the best possible accuracy of the simulations, the default values particularly those relating to the MUSLE were adjusted based on secondary data for each crop type in the Philippines. In particular, the K_{usle}, C_{usle} and P_{usle} values were adjusted according to comprehensive studies for a wide variety of crops including agroforestry species and systems (FAO 2004; David 1988). These factors influence the hydrologic pathways at a basin scale and are especially important for accurately estimating the soil loss and transport rates within the model.

The overall operational framework for conducting simulations using the SWAT model can be found in Figure 6. Once the relevant, parametised data is uploaded to the model, it is run and the outputs used for validation and calibration purposes. The model was run initially using 10 years rainfall data from 1981 – 1991. This was done for two main reasons. Firstly, it is recommended to allow a ‘warm up’ period for the model to run efficiently, recognize the data and navigate the correct file paths. Secondly, as we discuss later small amount of observed data was available for the period 1986 – 1991 which is useful in calibrating the model in preparation for longer term simulations.

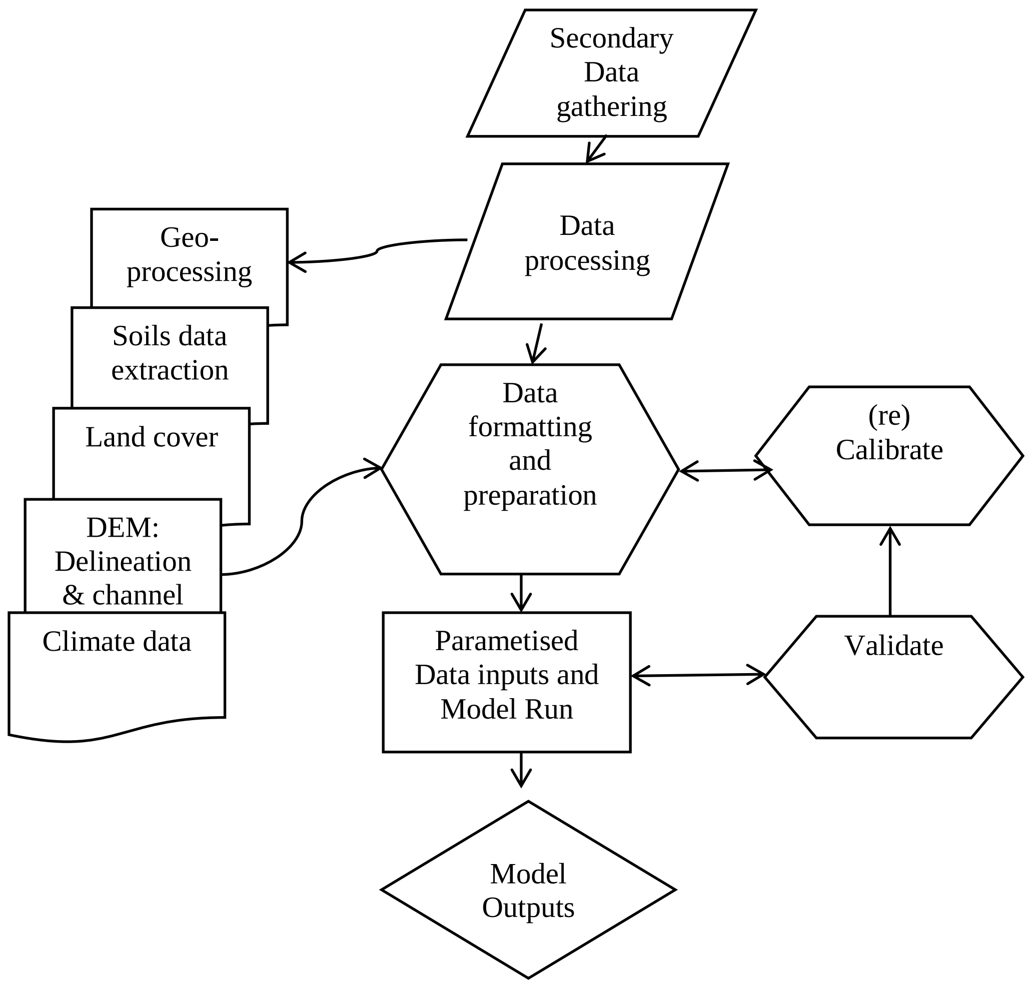


Figure 6. Operational framework for SWAT model

Model inputs: The required inputs for the model were collected from a number of sources. Many of the required parameters were derived from satellite imagery using remote sensing software and GIS in order to extract, format and prepare the necessary information. Soils data is required for the model as a parameter which greatly influences the movement and pathways of water within the watershed. Hydraulic conductivity, bulk density and texture all influence percolation, seepage and water availability in upper levels for evaporation. Soils data is therefore crucial for the model. The soils data is required a shapefile or feature dataset and digital soils information is difficult to obtain in the Philippines. Bureau of Soils and Water Management (BSWM) data is available although it is not in a format compatible to the model. The validity and accuracy of this data is also unknown. Therefore, in this case coarser resolution but more reliable data was used in the shape of the Food and Agriculture Organisation's (FAO) Digital Soils Map of the World[†]. This is a shapefile containing spatial information and associated soils information including texture, compaction, hydrology group, pH and salinity. This data is loaded to the ESRI ArcGIS SWAT interface and a look up table linking that data and the relevant soil information to the geodatabase was created.

Observed precipitation data was obtained from the Philippines Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) Ubay BES weather station just outside the watershed itself for the period 1979 - 2006. However, this data was not considered to be of high quality with many missing data sets and unusually low annual rainfall for even the driest parts of the Philippines. Therefore additional data was sought. Global, high resolution, coupled atmosphere-ocean-land surface data was retrieved via the SWAT Global Weather Data portal[‡] which draws on data collated by the CISL Research Data Archive, a US body which analysed and processed directly observed and satellite recorded climate data. This is considered reliable for the purposes of this modelling exercise and was sense checked against the PAGASA data.

[†] http://www.fao.org/nr/land/soils/digital-soil-map-of-the-world/
[‡] http://globalweather.tamu.edu/

For the SWAT model module, synthetic climate data is also required to fill any gaps in observed data and generate a synthetic data set which can be used to simulate the effects of land use change, isolated from the effects of weather i.e. holding the weather constant across different scenarios. This is generated using statistical processing of the observed data discussed above. Table 11 provides a summary of the parameters and input data used in this study.

Table 11. Data inputs for SWAT model

	DATA	**RESOLUTION**	**FORMAT**	**SOURCE**
Land cover and DEM	Landsat WRS 2: Path 113 Row: 53 for 1990 & 2010	30m	GeoTiff	USGS
	Aster (DEM)	30m DEM	GeoTiff	NAMRIA
Climate	**Data**	**Format**	**Period**	**Source**
	Precipitation	Daily (mm)	1981 - 2010	PAGASA
	Rainfall intensity	Daily (mm)	1981 - 2010	PAGASA
	Temperature	Daily (Celsius)	1981 - 2010	PAGASA
	Solar radiation	Daily (W^{-m2})	1981 - 2010	SWAT
	Wind	Daily (m^{-s})	1981 - 2010	SWAT
	RH	Daily	1981 - 2010	SWAT
Soils	**Data**	**Format**	**Period**	**Source**
	FAO Digital Soil Map of the World	ESRI Shapefile	n/a	FAO

Calibration and model performance (validation): To calibrate and validate the model, observed data is required. Unfortunately, such data for any of the model outputs for the area of interest is scarce and what data there is was considered unreliable. The only available data is monthly discharge (m^3 s^{-1}) which was collected by the Bureau of Research and Standards between 1986 and 1991. It should also be noted that this was collected based on only one observation per month and using a stream gauge method. There is therefore some concern about the validity of this data and this should be considered when assessing the overall model efficiency. Nevertheless, an attempt was made to determine the efficiency of the model by conducting statistical analysis, namely the Nash-Sutcliffe Efficiency (NSE) (Equation 2) test, and a simple linear regression to determine the coefficient of determinance (r^2). To do this, the simulated data produced from the initial model run 1986 – 1991 was compared with the observed data for the same period. The data was split into two (1986 – 1988 and 1989 – 1991) with the earlier dates used for calibration and the later years for validating model output.

Equation 2. Nash-Sutcliffe Efficiency (NSE)

$$E = 1 - \frac{\sum_{t=1}^{T} \left(Q_o^t - Q_m^t\right)^2}{\sum_{t=1}^{T} \left(Q_o^t - \overline{Q_o}\right)^2}$$

Where: Q_o is observed discharge,

Q_m is simulated discharge

Q_o^t is observed discharge at time t

Calibration of the model was conducted using the manual calibration tool which is in-built to the SWAT-ArcGIS interface. This is essentially a trial and error procedure conducted on selected parameters, in this case the surface runoff curve number (CN2), SOL_AWC and ESCO sequentially between model runs as recommended by Srinivasan et al. (2012). In addition, co-efficient values which influence the soil loss equation (C, K and P) described earlier are parameterised at this stage. This manual calibration approach has also been conducted in other studies using SWAT (Ma et al. 2009) and is preferable when little observed data is available.

A NSE value of 1 indicates a perfect match between the observed and simulated data. Any negative value indicates that for that data set, the mean would be a better predictor. Table 12 below shows the outputs from the statistical treatment. In 50% of the years in which observed data was available (1986 – 1991), the NSE output could be considered acceptable as it is a positive value with corresponding reasonable correlation (r^2) values. However, it should be noted that some authors suggest that an NSE value greater than 0.5 is required for the predictive efficiency of the model to be considered satisfactory (Srinivasan et al. 2012). In this case, given the uncertainty about the quality of the available observed data and the lack of alternative data, this was considered adequate for validation purposes.

In an attempt to further sense check the outputs of the model with other available data at the provincial level, the model output for mean annual discharge (m^3 s^{-1}) for the same period was compared with that of other watersheds in Bohol.

Table 12. Results of statistical analysis to determine model efficiency and select appropriate parameters

YEAR	NSE	R^2	RESULT
Calibration			
1986	0.2	0.59	Acceptable
1987	-3.42	0.01	Unacceptable
1988	-0.68	0.33	Unacceptable
Validation			
1989	0.43	0.45	Acceptable
1990	0.03	0.61	Acceptable
1991	-2.01	0.13	Unacceptable

The results of this comparison (Table 13) suggest that while different watershed characteristics (topography, pedology and land cover) all have a bearing on processes such as discharge, the overall output of the model is within a sensible range.

Table 13. Comparison of discharge from various watersheds in Bohol

WATERSHED	DRAINAGE AREA	MEAN ANNUAL DISCHARGE (M^3 S^{-1})	SOURCE
Gabayan	51 km^2	3.29	This study
Pamacsalan	33 km^2	1.75	National Irrigation Authority (NIA)
Cambangay	21km^2	2.04	NIA
Loboc	43 km^2	3.09	NIA

Scenario simulation: The premise of PES schemes and the hypothesis of this study is that land use change and land management practices determine the availability, timing and sustainability of ecosystem services at a watershed scale. In order to be able to investigate this in the Gabayan watershed, a number of scenarios have been designed which, when modelled using the method described above, will provide some insight into the relative changes brought about by different land uses and management practices. SWAT model simulations were therefore carried out to determine the ecosystem services associated with watershed functions based on three scenarios:

1. *Historic conditions:* A description of what the historic conditions of the sub watershed were based on 1990 satellite image i.e. > 20 years earlier. This provides a baseline scenario against which to compare current conditions;
2. *Present conditions:* A representation of what the present hydrological conditions are within the study area is based on the 2010 satellite image.
3. *Future conditions:* Simulating the possible future conditions if factors land management practices are improved under a PES scheme. This will be simulated based on conservation agriculture principles including improved tillage, crop management practices and an increase in agroforestry activities as a more sustainable land use practice.

Each of these scenarios is described in greater detail in the results section.

CHAPTER V

RESULTS

Institutional Stakeholders Questionnaire – 'PEK'

In total, 25 agencies and organisations returned the questionnaire which represents a 50% response rate. A breakdown of those organisations and agencies which responded as found in Table 14. LGUs and people's organisations were the two groups of stakeholders which provided the highest response rate.

Table 14. Agencies responding to the ecosystem services baseline questionnaire

TYPE OF ORGANISATION	RESPONSES
Central Government Department	2
Local Government (LGUs or LG agencies)	11
Peoples Organisations (including 2 water co-operatives)	9
Education Sector	2
Agriculture Sector	1
Total	25

In addition to requesting organisational details, question 1 asked respondents to define environmental services with a selection of definitions cited anonymously here:

'Carood environmental services includes land, water, minerals, forestry products, flora and fauna, caves, indigenous cultures, historical sites'

'Ecologically balance.'

'The Carood watershed gives water for agricultural, economic and domestic use and it really needs payback. Collecting environmental fees for having funds to be used for management of the watershed and its resources.'

This demonstrates that there exists some understanding of the components, role and function of a watershed which is encouraging if a PES scheme is to be operationalised. This may be associated with the recent work in the watershed to investigate the possibility of such a scheme being established.

Question 2 asked the organisation about any water based services which they currently provide (Table 15). The municipality of Candijay which, forms the majority of the watershed, provides emergency services such as responding to landslides and developing flood defences and are also consumers and suppliers of water for commercial purposes. This is significant as is could represent an incentive for the municipality to invest in or support watershed management practices which reduce the need for emergency responses.

Table 16 summarises the responses from a range of local agencies when asked to indicate what specific water infrastructure, supply, storage or distribution services they provide. Three water cooperatives, one LGU and the provincial level DENR responded with services ranging from dam maintenance for agricultural use, domestic water supply, well maintenance and also the introduction of vegetative strips for river bank stabilisation.

Table 15. Environmental services supplied, managed or received by municipalities in the watershed

MANAGEMENT OF WATER RELATED SERVICES IN GABAYAN WATERSHED	ALICIA	CANDIJAY	GUINDULMAN	PILAR
Supplier of water – including storage, treatment or distribution.		✓		
User of Water – domestic or any commercial use.		✓	✓	
Managing land for collection or storage of water.			✓	
Provide Emergency Services, e.g. water supply or flood prevention.			✓	
Future Planning for water management including flood defence.	✓	✓	✓	
Investment in water services.	✓			✓
Managing land for other watershed services.				✓
Collection or treatment of waste in watershed.		✓		✓
Provide Emergency Services – landslides, fires.		✓	✓	
Data management on other watershed services.				✓

Table 16. Providers of Water Related Services in Gabayan watershed

ORGANISATION	LAND MANAGE-MENT	WATER STORAGE	WATER TREAT-MENT	DISTRIBUTION
Alicia WDC	Storage of water from spring and deep well	Reservoir	Chlorination	Waterpumps Spring Distribution pipework
Guindulman LGU	Irrigation	n/a	n/a	Pumping
Pilar Waterworks System	n/a	n/a	n/a	Distribution of water for domestic use; Level III Water Supply
Pilar Community Water and Sanitation Service Cooperative	n/a	n/a	n/a	Distribution of water services for domestic use. Level II and III domestic water supply.
Guindulman BWASSCO	n/a	Dams	Chlorination	Pumping Leakage Control Storage Wells Distribution System
DENR	Vegetative based river stabilisation	n/a	n/a	n/a

Question 5 asked about the organisation's top five priority watershed services and also the top 5 worst environmental problems (Table 17). This was anonymised but we can see from those areas shaded in grey in the table below that water supply (mains, irrigation and well), water quality (mains), soil erosion control (stabilisation) and flood attenuation are clear priorities for the majority of organisations. In terms of environmental problems, somewhat surprisingly solid waste management is the top ranked priority issue given that many of the priority services relate to water supply. Deforestation and livelihood opportunities are also highly ranked as well as illegal logging and mangrove depletion. The inclusion of essentially land use change issues (with the exception of livelihood opportunities) is of particular interest as establishing a link between land use and land management practices and watershed services is especially important for a PES scheme.

Table 17. Priorities in Relation to Gabayan Watershed Management

WATERSHED SERVICES	NO OF ORG. NOMINATING AS TOP ISSUE	ENVIRONMENTAL PROBLEM	NO OF ORG NOMINATING AS TOP ISSUE
Mains (tap) water supply	**10**	Solid waste management	**8**
Mains (tap) water quality	**9**	Deforestation	**6**
Irrigation water supply	**8**	Livelihood opportunities	**6**
Soil stabilisation	**8**	Illegal Logging	**4**
Well water supply	**6**	Mangrove depletion	**4**
Flooding attenuation	**6**	Grassland/forest fires	**3**
Poor drainage	**5**	Intensive agriculture	**2**
Landslides	**3**	Illegal fishing	**2**
Well water quality	**2**	Sand and gravel extraction	**2**
Spring water supply	**2**	Livestock management	**1**
River water quality	**2**	Harvesting non-timber products	**1**

Table 17 Continued…

WATERSHED SERVICES	NO OF ORG. NOMINATING AS TOP ISSUE	ENVIRONMENTAL PROBLEM	NO OF ORG NOMINATING AS TOP ISSUE
Soil water salinity	**2**	Loss of biodiversity	**1**
Spring water quality	**1**	Other sources of pollution	
River water supply	**1**	Urbanisation- planning controls	
Irrigation water quality	**1**	Storms and typhoons	

Participatory Mapping and Land Use Change Through Time – 'LEK'

Participatory mapping outputs: Workshops were held on 16th and 19th of August 2013 in the watershed area and a total of 65 people excluding facilitators attended. Participants were from local communities and people's organisations with some local government representatives and other agencies present (see Appendix B). Participants spent the first half of the day indicating on scale maps where the main resource activities and environmental services and problems were in the land scape as part of the spatial component of this activity (Figure 7). During the second half of the day, they worked on more temporal aspects – indicating how land use had changed through time and also completed a ranking exercise to determine the top 5 environmental concerns in the watershed.

Figure 7. Participants at the workshops involved in mapping and land use change exercises to elicit local environmental knowledge (LEK)

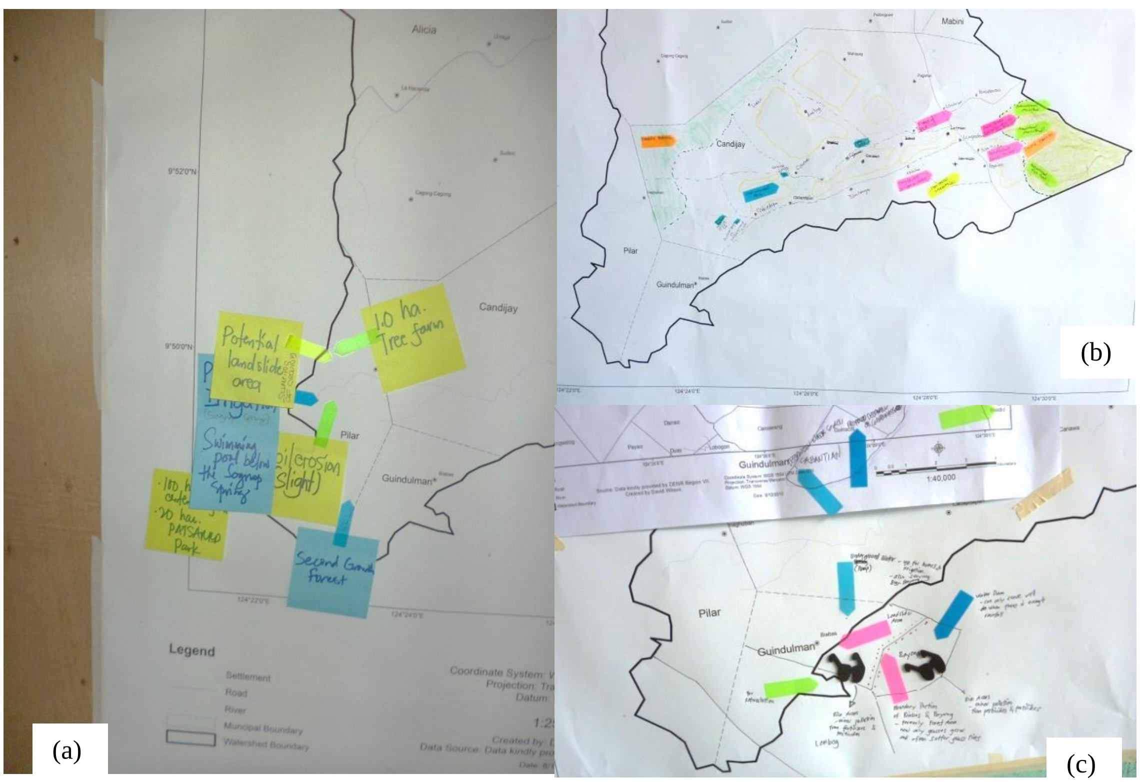
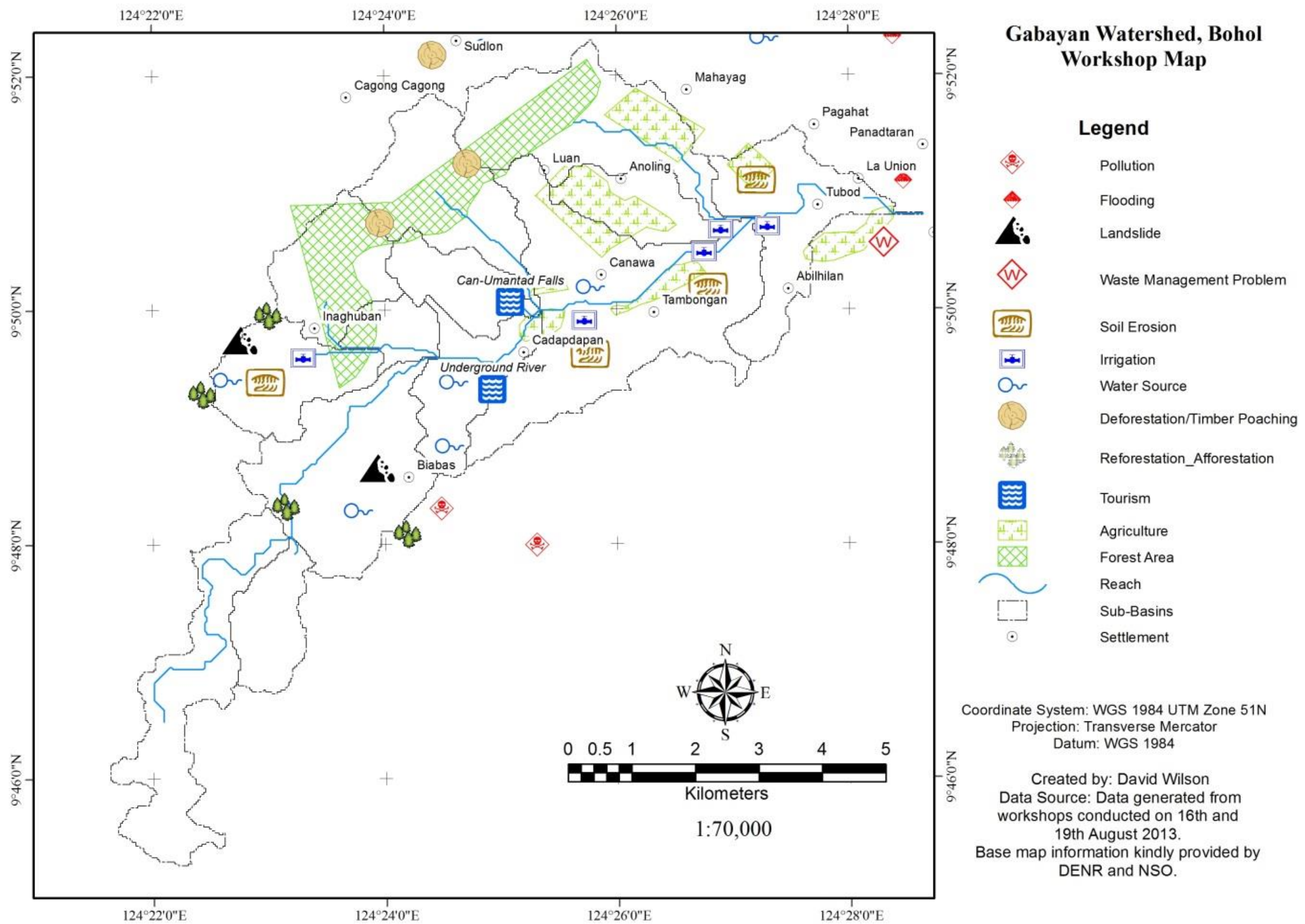


Figure 8. Outputs from participatory mapping exercise in the municipalities of (a) Pilar, (b) Guindulman and (c) Candijay

The information captured on the municipal level maps was then transferred into ArcGIS and compiled to create a watershed wide map documenting the natural resources, environmental services and problems (Map 5).

A summary of the main features of the map has also been provided in Table 18. Common problems identified appear to be flooding. In the upland areas landslide occurrence has been identified as a problem and soil erosion has been noted in a number of locations throughout the watershed. Timber poaching has been identified in the remaining areas of forest but there are also a number of locations where reforestation efforts have been observed. Notably, water often features as an environmental service in the form of springs, tourism locations (waterfalls), cultural (swimming areas); and crucially given the large areas of agriculture depicted in low land areas, as irrigation sources. This builds a rich picture of activities, resources and environmental services at the watershed scale and reveal the local knowledge of community members.



Map 5. Collated outputs from participatory mapping workshop

Table 18. Summary data extracted from mapping exercise

MUNICIPALITY (WATERSHED LOCATION)	MAIN ENVIRONMENTAL PROBLEMS	MAIN ECOSYSTEM SERVICES	KEY NATURAL RESOURCES
Alicia	• Soil Erosion • Flooding • Deforestation • Illegal soil and gravel extraction	• Tourism • Water supply	• Coffee plantation • Palm oil plantation • Reforestation • Irrigation
Candijay (Upstream – downstream)	• Timber poaching (upland) • Insufficient water for irrigation (downstream) • Flooding (downstream) • Salt water • intrusion into agriculture (downstream)Mangrove timber poaching (downstream)	• Water: springs • Tourism: Falls and underground river • Agricultural land: soil • fertility	• Springs • Forested areas
Guindulman (Upstream)	• Soil loss and landslides • Pollution from fertilisers (rice areas)	• Groundwater for domestic use	• Rainfed dam • Reforestation area
Pilar (Upstream)	• Soil erosion • Landslides	• Cultural: swimming area	• Irrigation • Second growth forest • Tree plantation

Perceived land use change outputs: Following the participatory mapping exercise which identified ecosystem services and environmental problems in the landscape, the next exercise was to establish possible links between land use practices and these phenomena. In order to do this, participants were asked to identify and quantify past and present land uses within their municipality using a template provided to them. The template was used as a representation of their municipality and also included a chart to show the availability of ecosystem services. Participants were asked to fill these up for two time periods the present and the past to see how land use had changed through time. Participants allocated a land use as a percentage proportion of the total and we were therefore able to conduct rudimentary quantitative analysis. Sample outputs from the workshop are shown in Figure 9. Even a cursory glance is enough to see that there have been significant changes in land use and the availability of ecosystem services as perceived by community members. A summary of the perceived and quantified land use changes is show in Figure 10.

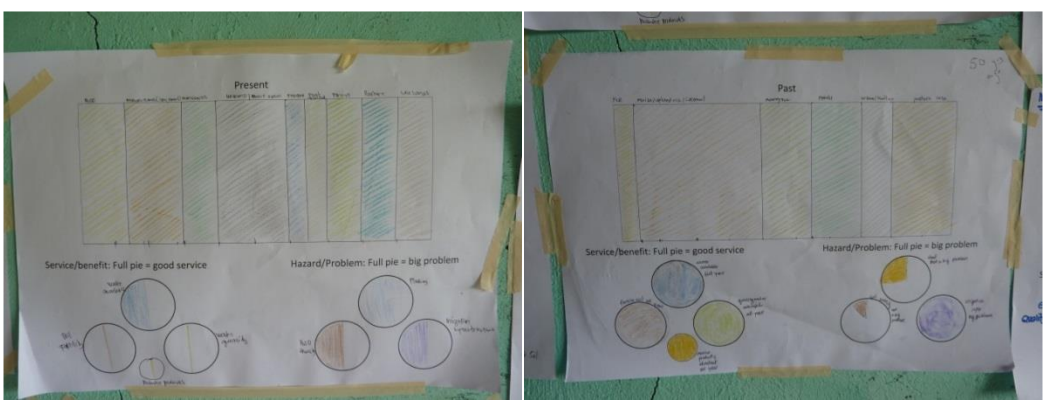


Figure 9. Sample outputs from the land use change exercise.

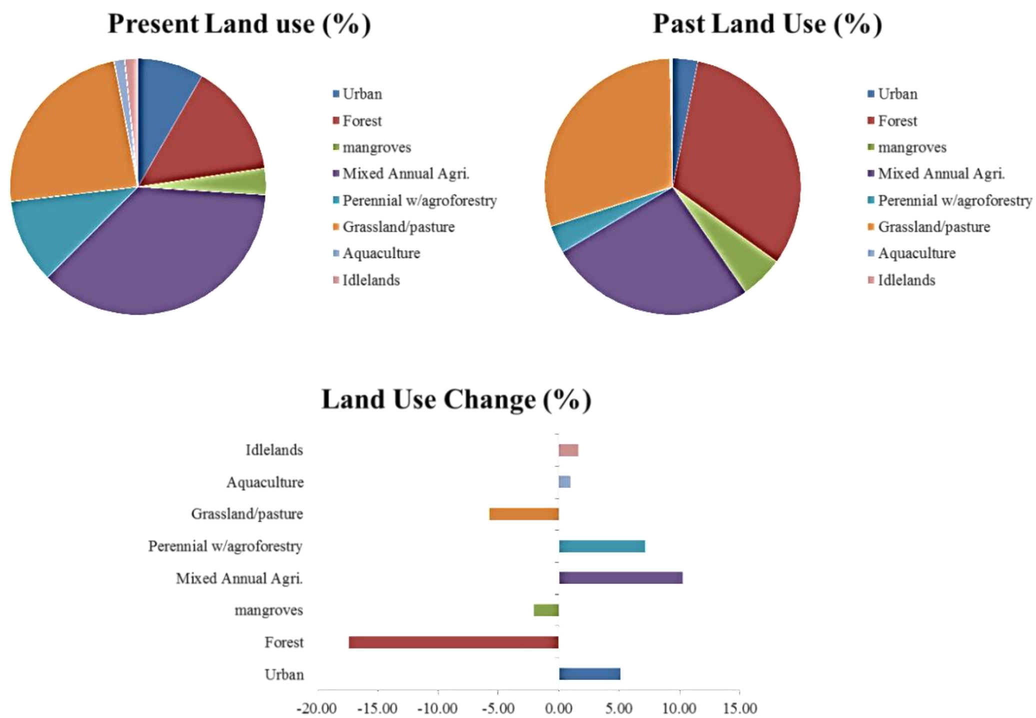


Figure 10. Summary of perceived land use change for the Gabayan watershed as quantified by community members during the mapping workshop

From the figure above we can see that community members have clearly perceived a large loss of forest cover (almost 20%) and a significant reduction in grasslands and pasture and a small reduction in mangrove areas. The largest perceived increase has been in mixed annual agriculture which in the Gabayan watershed is a combination of rice, maize and vegetables. There has also been an increase in perennial agriculture which is principally coconut in the watershed as well as smaller increases in (low density) urban areas, aquaculture and idle lands.

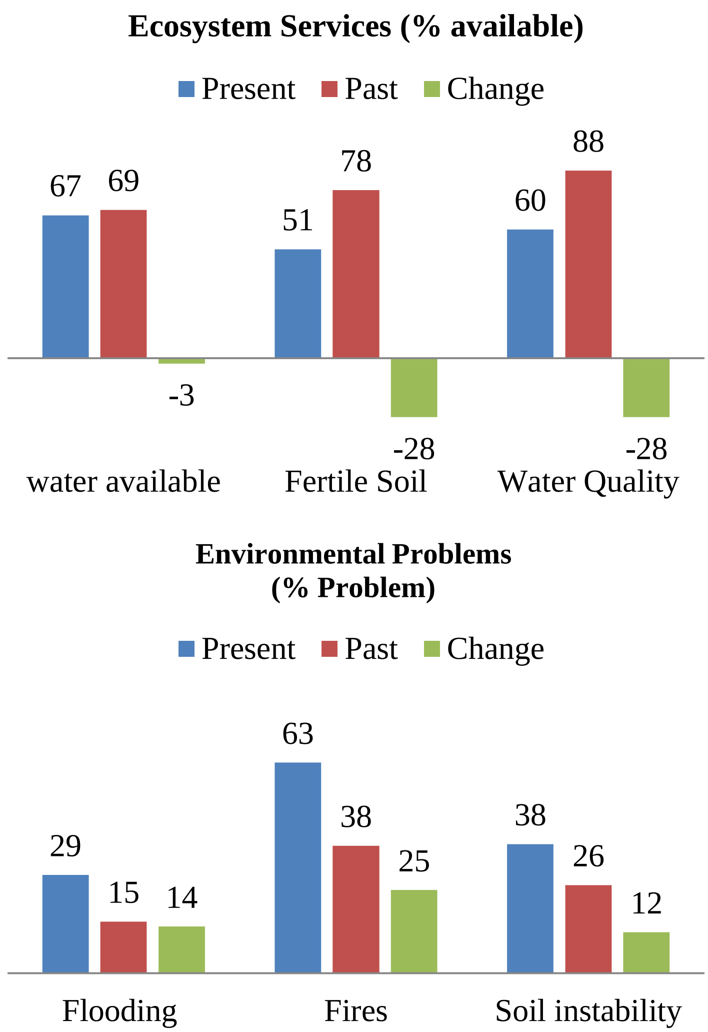


Figure 11. Perceived change in identified ecosystem services and environmental problems in the Gabayan watershed

Figure 11 provides a summary of the outputs from community perceptions about the availability of ecosystem services and the presence of environmental problems in the past and present. There is a perception that there has not been much change in water availability between the past (c. 25 years B.P) and the present. There has clearly been a perceived reduction in soil fertility and water quality, both of which are services which are provided by the watershed and could be linked to soil stability. There has been a perceived 14% increase in the incidence of flooding and fire incidence (mainly in grassland areas and linked to seasonal burning) has increased by one quarter. Perceived soil instability has increased by 12% which is consistent with a perceived reduction in soil fertility.

Land Use Change and Ecosystem Services – (MEK)

The final major component of the RHA methodology is to apply modeller's ecological knowledge (MEK). This component involves landscape scale analysis of land cover in the watershed combined with modelling of the hydrologic processes.

Land use change analysis: To be able to determine plausible drivers of environmental problems and reduction in ecosystem services which were highlighted in the PEK and LEK components, land use change analysis is required. Therefore quantification of land use change in the watershed was conducted using 30m resolution USGS Landsat satellite imagery for the period 1990 and 2010. The accuracy of this analysis was tested by comparing the output from the remote sensing analysis with data gathered during ground truthing in the field. This involved visiting randomly assigned points in the watershed and assigning a land classification to them based on visual inspection by the author. These points were then inputted into ArcGIS and the land classification compared on a pixel basis with the output from the land classification exercise using a confusion matrix (Table 19). This matrix compares the observed (field based) and remotely sensed (desk based) data by land classification and determines an overall level of accuracy. In this case the overall accuracy of 62% is considered satisfactory although ideally an accuracy level of 80% is desirable (Congalton 1996).

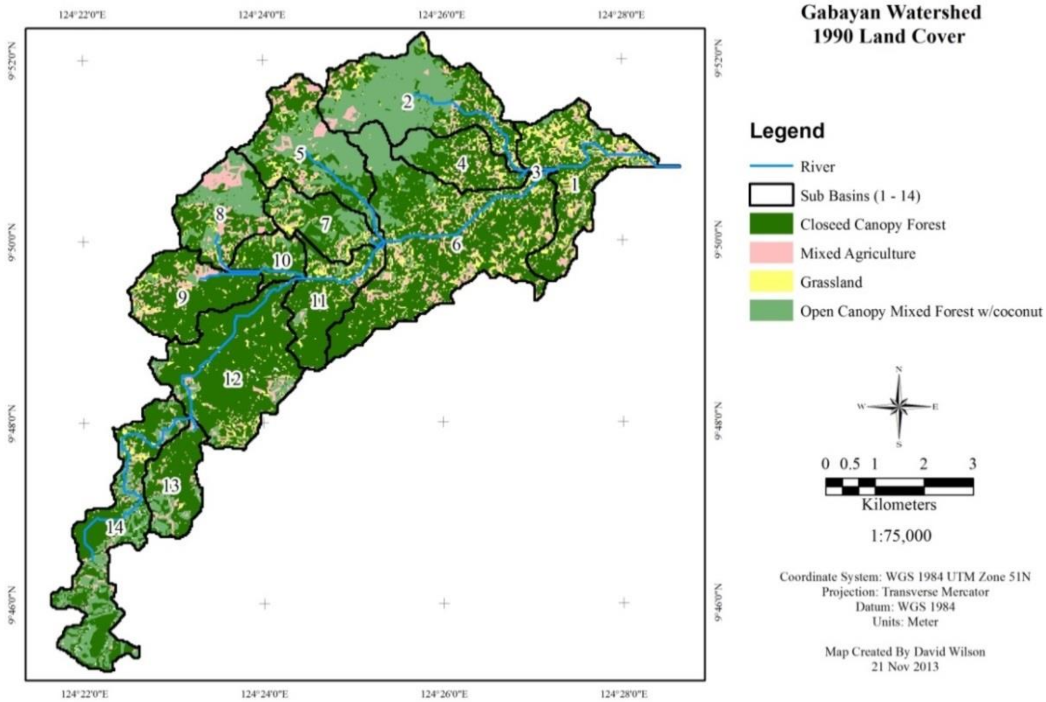
Table 19. Confusion matrix comparing observed land cover with that assigned during desk based remote sensing exercise

		OBSERVED							
	Land Classification	**Agriculture**	**Mixed Forest**	**Water**	**Other**	**Grassland**	**Closed Canopy Forest**	**Total**	**Precision**
COMPUTED	Agriculture	24	7	0	0	3	0	34	0.6
	Mixed Forest	4	3	0	0	0	2	9	0.3
	Water	0	0	1	0	0	0	1	0.0
	Other	0	0	0	1	0	0	1	0.0
	Grassland	3	1	0	0	5	1	10	0.1
	Closed Canopy Forest	0	0	0	0	0	0	0	0.0
	Total	31	11	1	1	8	3	55	1
	Overall Accuracy					**62**			

To further quantify the level of agreement between observed and computed land classification, Cohen's Kappa statistic is often used which determines the level of agreement between two raters or sets of variables. However, there is evidence to suggest that this is no longer a valid procedure for remote sensing exercises (Pontius & Millones 2011). Instead, the procedure as set out by Pontius and Millones (2011) in which two summary parameters - quantity disagreement and allocation disagreement – are used based on the matrix above was followed and produced the following results:

- Quantity Disagreement = 9
- Allocation Disagreement = 29

This suggests that the level of agreement is less than perfect but better than random ad was therefore deemed to be acceptable for the purposes of the study. It should be noted that possible reasons for lower levels of agreement and overall accuracy could be because the image used for classification is from 2010 and fieldwork was conducted in 2013 during which time agricultural practices change and indeed forest loss can occur in a short space of time. The relatively low number of field observations (55) may also influence the accuracy levels but field time constraints and access to sample points did not allow for more observations to be gathered. The changes in land cover between these two periods are shown in Table 20.and Figure 12.



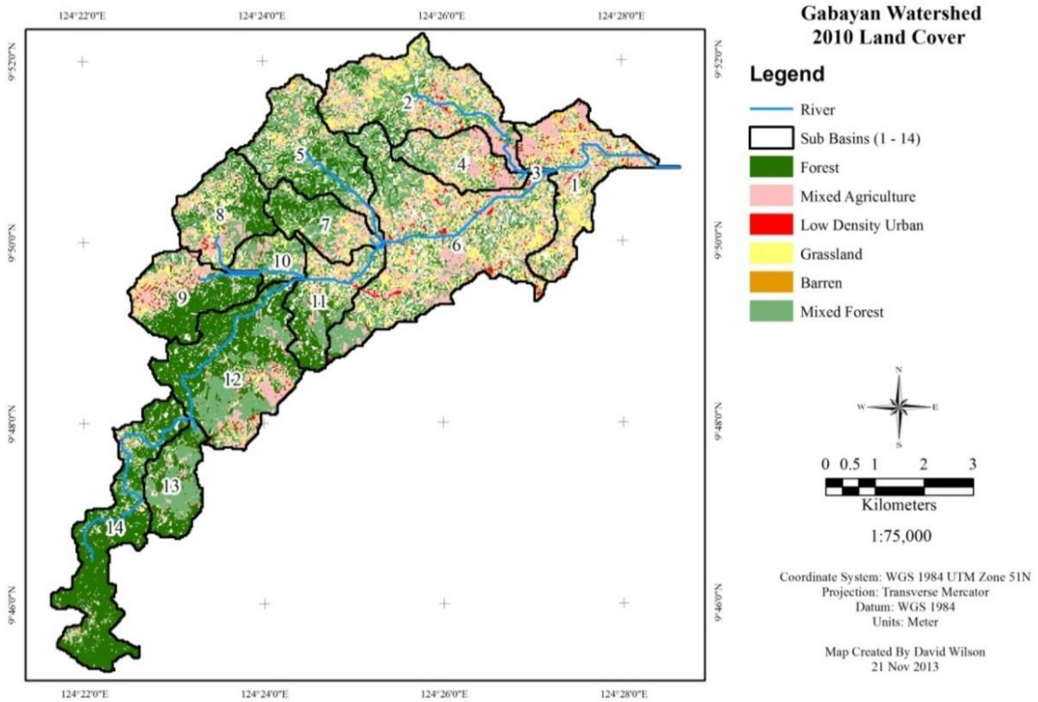


Figure 12. Results of land cover analysis of Landsat images for 1990 and 2010

Table 20. Land cover and land cover change between 1990 and 2010

LAND COVER	1990 (HA)	2010 (HA)	CHANGE (HA)	% OF TOTAL	% OF TOTAL AREA (1990)	% OF TOTAL AREA (2010)
Closed Canopy Forest	2994.09	1376.18	-1617.91	-54.04	58.11	26.71
Mixed Open Forest w/coconut	1178.01	1435.28	257.27	21.84	22.87	27.86
Mixed Agriculture	596.61	1064.74	468.13	78.46	11.58	20.67
Grassland	377.68	660.02	282.34	74.76	7.33	12.81
Low Density Urban	0.00	82.17	82.17	100%	0.00	1.59
Barren land	0.00	10.19	10.19	100%	0.00	0.20
Other (e.g. water, irrigation, roads)	6.12	523.42	517.30	>100%	0.12	10.16
Total	5152.00	5152.00	-	-	100.00	100.00

What this clearly demonstrates is a significant reduction in forests (50%) based on 1990 levels. Barren and urban areas were not visible at all in the 1990 image but account for almost 2% of total land cover by 2010. Grassland (93.41%) and mixed annual agriculture (93.41%) have almost doubled over the 20 year period between 1990 and 2010. Land cover appears to have changed most noticeably in the lower reaches of the water shed, in particular sub-basins 1, 2, 3, 4 and 6. As we will discuss later, these sub-basins could be considered critically degraded. The upper reaches of the watershed, namely sub-basins 13 and 14 appear to have remained largely intact although there seem to be some changes in forest composition between closed canopy forest and mixed open canopy forest with perennials, mainly coconut.

Land use scenarios: Given the land use change analysis described above, current (2010) land use conditions appear to represent a degraded scenario in which the natural land cover has been significantly altered from high open canopy forest cover (58% of total area) to a much more mosaicked landscape in which annual agricultural use (20%) and grasslands (12%) form a significant portion. Given what we know about the effect of different vegetation covers on the routing pathways of precipitation entering the watershed, we assume this would be reflected in the hydrologic cycle, particularly in surface run off and evapotranspiration

In order to test this using the hydrologic model, three different land cover scenarios were developed. The 1990 land cover is considered as the Baseline (S0), 2010 land cover represents Scenario 1 (S1), a degrading scenario and finally, a restoration scenario using conservation agriculture for sloping lands including agroforestry or Scenario 2 (S2).

Baseline year: 1990 (S0): The baseline year for the simulations in this study is based on the earliest available, high quality satellite imagery. Interpretation of this image shows that the majority of the watershed would have been covered in closed canopy forests, with roughly a quarter covered in mixed open canopy forest and coconut (with other woody perennials) with the remainder a combination of agricultural land concentrated in the lower elevation, more gently sloping areas and grassland. Table 21 provides an overview of the land cover based on this analysis and used in the simulation for the baseline watershed functions and processes.

Table 21. Model input land cover under the baseline scenario taken from 1990 satellite imagery.

LAND COVER	**TOTAL HECTARES**	**% OF TOTAL WATERSHED**
Closed canopy forest	2994.09	58.11
Mixed open canopy forest w/coconut	1178.02	22.86
Mixed Agriculture: 50% rice, 20% Banana, 20% vegetables, 10% corn	596.61	11.58
Grassland and pasture	377.68	7.3
Other	6.12	0.12
Total	**5152**	**100**

Scenario 1 (S1): 2010 land management practices (degraded): S1 is simulated based on the observed satellite imagery for the year 2010. As discussed earlier, the land cover during this period has changed noticeably, with forest cover decreasing by half and agricultural lands (mainly terraced rice and upland corn) almost doubling in total hectarage (Table 22). In terms of ecological integrity including delivery of ecosystem services and watershed functions (buffering peak events, sustaining seasonal low flows and regulating sediment transfer) this represents a degraded landscape when compared to the baseline land cover of 1990.

Table 22. Land cover model inputs under Scenario 1 – degraded

LAND COVER	HECTARES	% OF TOTAL
Closed canopy forest	1546.48	30.01
Mixed open canopy forest w/coconut	1588.16	30.82
Rice	557.40	10.82
Grassland	466.80	9.06
Other (e.g. water, irrigation, roads)	424.51	8.12
Mixed agriculture - (other e.g. root crops)	212.95	4.13
Bananas	169.92	3.30
Pasture	140.80	2.73
Residential-Low Density	18.59	0.36
Corn	17.82	0.35
Barren	10.19	0.20
Total	**5152.52**	**100.00**

Scenario 2 (S2): conservation agriculture with agroforestry: Certain agroforestry systems are already practiced to some extent in the watershed. Terraced rice areas are bordered by wood perennials including coconut and cacao and there have been recent efforts to incorporate contour planting and naturally vegetated strips into cogonal (*imperata cylindrica)* grasslands including the planting of coffee (*Coffea canephora*). However, these efforts remain largely nascent, sporadic and uncoordinated. There is a stated desire by farmers and active people's organisations, with some technical support from the regional and provincial office of the Department of Environment and Natural Resources (DENR), to increase the use of agroforestry systems in order to supplement diet and also as cash crops to enhance household level income. Agroforestry has also been identified by the Carood Watershed Model Forest Management Council as a

desirable intervention to help with the restoration of the watershed while at the same time providing livelihood opportunities for smallholder farmers. It is on this basis that agroforestry has been selected as the method of naturally restoring the watershed functions in this study.

Under this scenario, agroforestry species are incorporated into the existing, degraded (S1 - 2010) landscape without impinging on access to staples such as rice and corn, both of which actually increase in area coverage (Table 23). The agroforestry systems are a combination of wood perennials (mango, jackfruit and cashews) introduced into existing agricultural land; conversion of grasslands to a system combining rubber, cacao and coffee; the use of cowpea as a soil cover crop planted between row crops such as corn; and the introduction of riparian buffers. Riparian buffers are planted 15 metres either side of the streams in selected sub basins which have been identified under S2 as critical (i.e. sub basin 1,2,3,4 and 6). These buffers are designed to decrease the transport of sediments (and nutrients) to the streams and consist of a combination of Ipil Ipil (*Leucaena leucocephala*) which is fast growing, offers soil stabilisation properties and can be a source of fuelwood if sustainably managed and shrubs which act as sediment traps at the boundary between agricultural fields and streams (GIZ 1975).

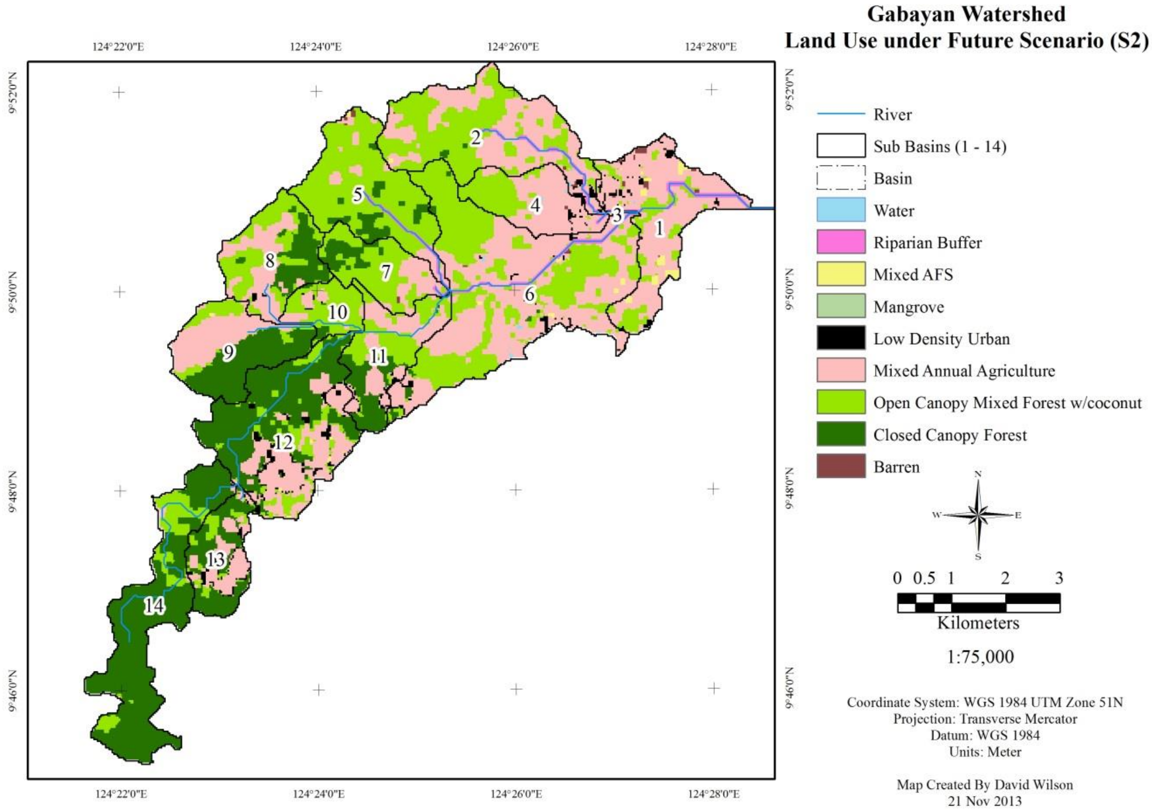
These species have been selected on the basis of their combined value in restoring the watershed functions such as stabilising soils and reducing sediment yield and transfer and as preferred, marketable products which offer livelihood diversification benefits to farmers. Overall, it is assumed that increasing the vegetative cover of the watershed will lead to changes in the hydrologic cycle, increasing infiltration and water routing pathways in turn reducing surface run off but also increasing interception and therefore possibly evapotranspiration. As far as possible, the agroforestry species have been situated in locations to which they are thought to be adapted. The clay loam soils of the watershed are somewhat acidic (pH 5.9), particularly where they have become thin and weathered under grassland conditions and these are suitable for the rubber – coffee-cacao combination simulated in this study. Table 23 and Map 6 below provide a summary of the land cover which is used to simulate the watershed functions under S2. Overall, closed leaf and mixed forest with coconut represent the majority of the land cover as with the baseline and S1 but in this scenario, much of the grassland has been converted to agroforestry which now represents around 13% of overall land cover when combined in the systems described above. This leaves significant areas still under traditional agricultural land use including terraced rice, corn and root crops meaning that access to staples would not be reduced.

Hydrologic Modelling (MEK)

During the PEK component, in which institutional stakeholders were asked to identify the most desirable watershed functions water provision, soil stability and water quality rated highly. Therefore, the hydrologic cyclic and the effect on sediment yield (soil yield in t ha^{-1} yr^{-1}) and sediment concentration (that which reaches the streams in the watershed measured in mg L^{-1}) for all three scenarios was modelled. Water quantity is analysed using a variety of measures including total discharge (water flowing from the watershed),

Table 23. Land cover model inputs under Scenario 2 - Restoration using agroforestry

LAND COVER	HECTARES	% OF TOTAL
Closed canopy forest	1252	24.3
Mixed Forest w/coconut	1828.4	35.49
Rice	929.2	18.03
Mixed Agroforestry (Cashew, mango and jackfruit)	278.8	5.41
Mixed agriculture - (other e.g. root crops)	185.8	3.61
Bananas	185.8	3.61
Corn	185.8	3.61
Cowpeas (cover crop)	92.92	1.8
Residential-Low Density	79.27	1.54
Riparian Buffer (Ipil Ipil)	46.02	0.89
Riparian Buffer (Shrub)	46.02	0.89
Barren	11.92	0.23
Grassland	10.69	0.21
Pasture	8.02	0.16
Coffee	4.01	0.08
Rubber – Cacao	4.01	0.08
Water	3.54	0.07
Total	**5152**	**100**



Map 6. Future Land Use Map showing incorporation of mixed agroforestry and riparian buffers

water transmission (total water yield per unit rainfall) and the gradual release of water (lowest monthly river discharge totals relative to mean monthly rainfall). Additionally, the overall water balance (evapotranspiration, surface runoff and base flow) for the entire watershed is presented as this may help to explain some of the changes in other variables. Precipitation has a major influence on surface runoff and sediment yield so in order to isolate the effects of land cover on these processes the same climatic data was used as model inputs for each of the 3 scenarios. In addition to rainfall, topographic and soils variables (taxonomy and texture) were also held constant as these aspects, whilst influencing the hydrologic processes and pathways at the watershed scale are unlikely to change significantly over the time period of interest. For each scenario, the model was run using the land cover in each scenario (S0 – S2) for a 25 year period in daily and monthly time steps.

Water Supply

The water balance within a basin describes the relative proportions of water (mm) for each of the hydrologic processes (Winkler et al. 2002; Brooks et al. 1991). The input to this is precipitation and the sum of each of the different processes (surface runoff, groundwater recharge, base flow and evapotranspiration) should be equal to the input, hence water balance. The water balance components were simulated for each of the different land use scenarios (S0, S1 and S2) and the mean monthly results for the 25 year simulation period are shown in Figure 13.

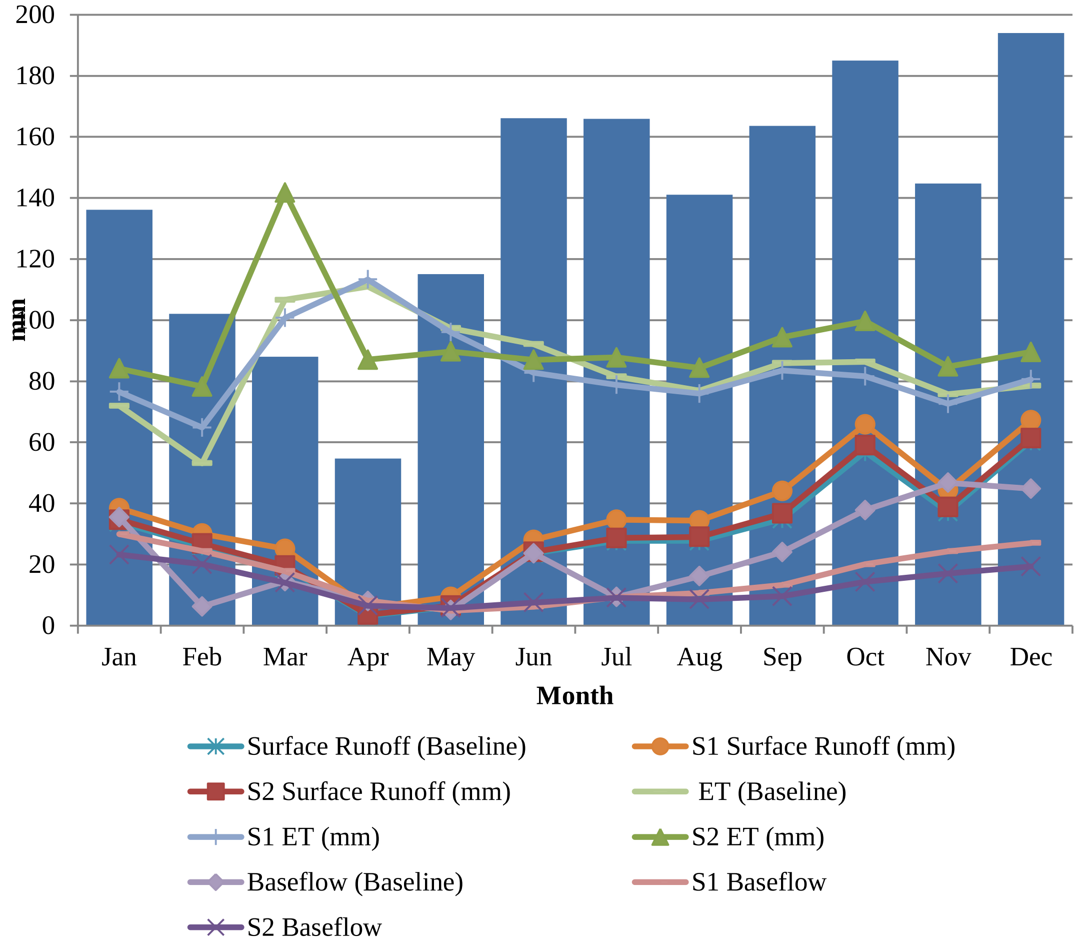


Figure 13. Simulated mean water balance for Gabayan watershed under baseline, S1 and S2 scenarios

Under S1, surface run off is consistently higher than both the baseline and S2 which are very similar throughout the simulated year. This is consistent with what we might expect in a more degraded landscape in which infiltration is limited by soil compaction and reduced vegetative cover due to more intensive agriculture practices and fallow periods. Under all scenarios, surface runoff peaks between October and December which is the wettest period of the year and corresponds with the transplanting of rice in rainfed systems and indeed irrigated systems which use water impoundments to store rainfall. This is therefore an extremely important aspect in the water balance at the watershed scale.

Evapotranspiration is highest, for both the baseline and S1 scenarios, in April and indeed these scenarios are fairly closely matched throughout the mean hydrologic year. This is somewhat surprising as the baseline scenario has significantly more permanent, closed canopy forest cover which could increase the amount of ET through leaf and stem interception (Winkler et al. 2002). However, much of the ET in S1 may come from the upper most soil layer where it is made available for plant use and exposed under a more degraded scenario. This emphasises the complexity of the hydrologic processes and watershed function. While the overall mean results may appear similar, the processes may be acting in very different ways. Under S2, ET peaks a month earlier, in April and higher than either the baseline or S1.

Baseflow, which is a combination of lateral flow through soil at shallow depths and groundwater flow or seepage into the river channels is very similar under both S1and S2, increasing only slightly towards the end of the hydrologic year after dropping to the lowest point immediately after the dry period in May. Under the baseline scenario however, baseflow fluctuates more throughout the year, peaking in November during a period of high rainfall.

Table 24 and Figure 14 summarise the relative proportions and the change in each of the processes between the 3 scenarios simulated.

Table 24. Relative proportions of each hydrologic function and changes between each scenario

	ET			SURFACE RUNOFF			BASEFLOW		
	S0	S1	S2	S0	S1	S2	S0	S1	S2
mm	1017	1007	1108	356	427	368	271	196	155
%	61	60	66	21	25	22	16	11	9
	CHANGE: ET			CHANGE: SURFACE RUNOFF			CHANGE: BASEFELOW		
	S0 vs S1	S0vs S2	S1 vs S2	S0 vs S1	S0vs S2	S1 vs S2	S0 vs S1	S0vs S2	S1 vs S2
mm	-10.07	91.27	101.34	70.61	12.25	-58.36	-75.77	-16.81	-41.04
%	-0.98	9	10	19.7	3.4	-13.6	-27.8	-42.	-20.9

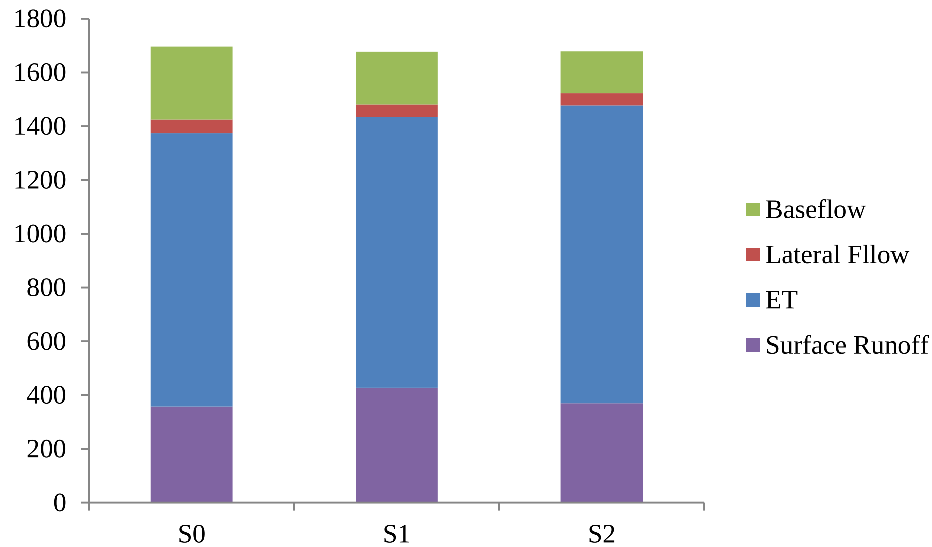


Figure 14. Relative water balance components for the three modelled scenarios; S0 - baseline, S1 - degraded and S2 - conservation agriculture

The approximate proportions are similar across each of the three scenarios with S1 having the highest proportion for surface run off. The lowest level of surface runoff other than the baseline scenario occurs under S2 which also has the lowest level of base flow. In terms of relative change in hydrologic processes for each scenario, there is an almost 9% increase in ET between the S0 and S2 and a small (0.98%) decrease between S0 and S1.

There is almost a 20% increase in surface run off between the baseline and the degraded S1 scenario with just a 3% increase under S2. There is a 13% decrease under conservation agriculture (S2) when compared to the degraded land cover (S1).

Base flow decreases across all scenarios under comparison, most significantly between the baseline (S0) and S2, agroforestry restoration. This could reflect an increase water demand by woody perennials, especially during the drier months when water is scarce. This has implications for the water available to the system and should be considered carefully if the incorporation of trees into agricultural landscapes is to be prioritised as a restoration intervention. Reduction in annual base flow could negatively impact existing agricultural activities and the water regulating services at a basin scale.

Figure 15 demonstrates that basin scale discharge is affected by the land cover scenario. There is a clearly an increased overall discharge under S1 when compared to S2. This increase in channelized discharge could be beneficial to domestic and agricultural users as more water is available in the river system. However, the peak flows appear to be higher which could be associated with negative impacts such as flooding although further analysis of single hydrologic events and buffering capacity is outside the scope of this paper.

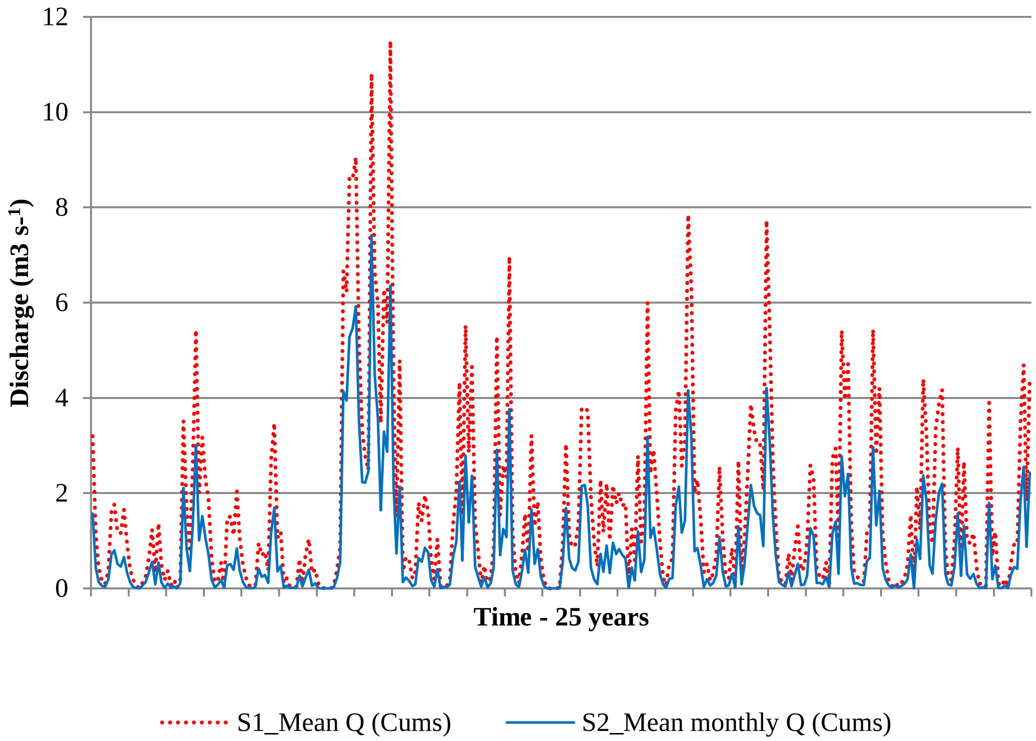


Figure 15. Mean monthly discharge for all scenarios based on 25 year time series precipitation data

To understand what influence land use has on discharge over time Figure 16 shows the total discharge per unit rainfall for both S1(degraded) and S2 (conservation agriculture) scenarios. This shows that in fact there is little difference between the two scenarios, with both increasing slightly over the 25 year simulation period. Taken together with the total monthly discharge over time it would appear that from a water quantity perspective, land use changes (observed and potential future) have little negative impact on water quantity indicators. This in turn suggests that the focus of any PES scheme should perhaps not be on overall water quantity as there appears to be no threat to this ecological function. However, as will be discussed in the next section, the timing and seasonal availability of water may be more of an issue.

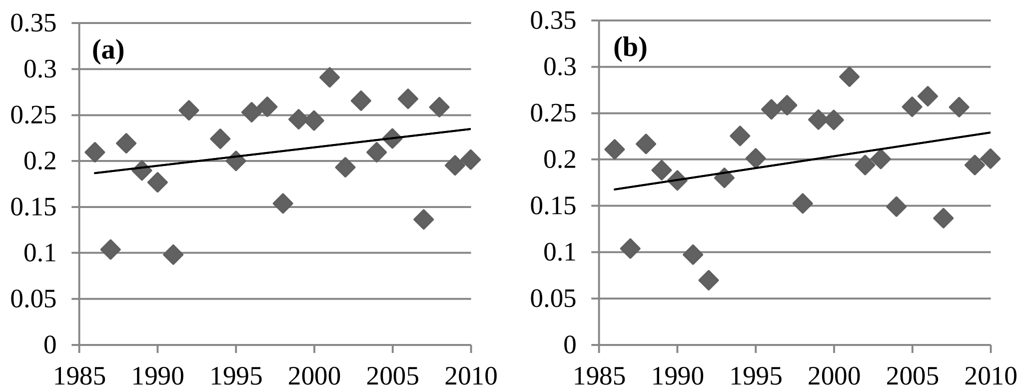


Figure 16. Total water discharge per unit rainfall (Transmission) for (a) S1 and (b) S2

Seasonal Availability and Evenness of Flow

The regulation of seasonal availability of surface water which can be used for domestic and agricultural purposes is one of the principal ecosystem services offered at a watershed scale. The presence of too much or the absence of water during the agricultural year can be extremely detrimental for farmers. An even flow of water available throughout the year, with deeper water being routed to the surface during times of low precipitation is desirable. Figure 17 plots daily rainfall against daily discharge for a mean hydrological year from the 25 year time series. This is disaggregated by quarter (seasons) where Q1 represents the dry period, Q2 is the transitional period between dry and wet and Q3 and Q4 are periods of peak annual rainfall. Under S1 (a) there is clearly some separation between seasons with very little rainfall during Q1 and Q2 correlating with very little discharge. During Q3 and Q4 there is an obvious increase in the amount of rainfall which produces corresponding response in discharge. This suggests that without significant rainfall there is relatively low channelized discharge. However, under S2 (b) it appears that the seasons are more diffuse with discharge spread fairly evenly throughout the year and less reliant on significant rainfall. This could indicate that water is released gradually throughout the year regardless of season, resulting in a more even flow under a scenario which incorporates conservation agriculture and agroforestry.

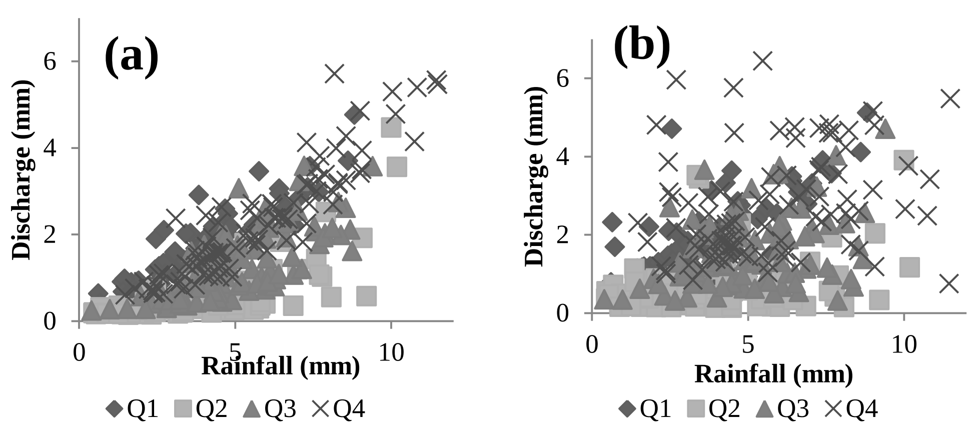


Figure 17. Seasonal (quarterly) rainfall vs discharge for (a) S1 and (b) S2 based on the mean hydrologic year from 25 year time series data

Figure 18 further illustrates the influence of different land use scenarios on the evenness of flow, this time over the full 25 year period simulated, by plotting the lowest monthly discharge as a function of mean rainfall (Jeanes et al. 2006). Under S1 there is a shallow increase in the fraction of lowest monthly discharge as a proportion of overall rainfall as shown by the fitted line in (a). However, under S2 the fraction of total water input into the system available during the periods of lowest flow increases more significantly over the simulated period illustrated by the steeper angle of the fitted line. Taken together then it appears that water is available more readily all year round under S2 when compared with S1 although this is not to say that water is available at all locations at all times under S2.

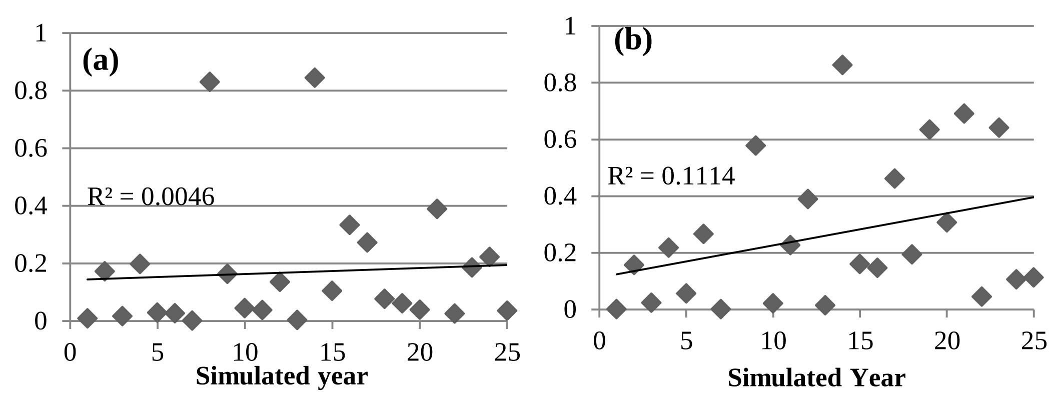


Figure 18. Lowest monthly discharge relative to mean rainfall for (a) S1 and (b) S2

Sediment Regulation

The regulation of the sediment regime is a key function at the watershed scale, supporting agricultural activities and determining the level of fertility and productivity at a farm scale. Factors influencing the loss of soil include slope, soil texture, rainfall, wind and vegetative cover.

Sediment Yield

Soil erosion in the watershed has been identified during PEK and LEK components as an environmental problem and management challenge. The model was therefore used to simulate how sediment yield and concentration is affected by land management practices under S1 and S2 when compared with S0 (baseline).

Figure 19 below shows simulated monthly mean sediment yield for the entire watershed between under S0 (baseline) and S1 (degraded) scenarios. It shows that soil erosion rates in the baseline scenario are generally lower than the range which is considered sustainable according to the Philippines National Action Plan (NAP) on soil degradation (NAP 2010) of between 10 to 12 t ha^{-1} yr^{-1}. Only sub basins 1, 3, 5, 6 and 8 exceed this and then the maximum rate is on 34 t ha^{-1} yr^{-}1. Under S1 however, almost all the sub-basins, with the exception of the upper sub-basins 12, 13 and 14 which remain under reasonable forest cover, exhibit higher than sustainable levels of soil loss with sub-basins 6 and 8 particularly high at almost 4 times the upper limit for sustainability.

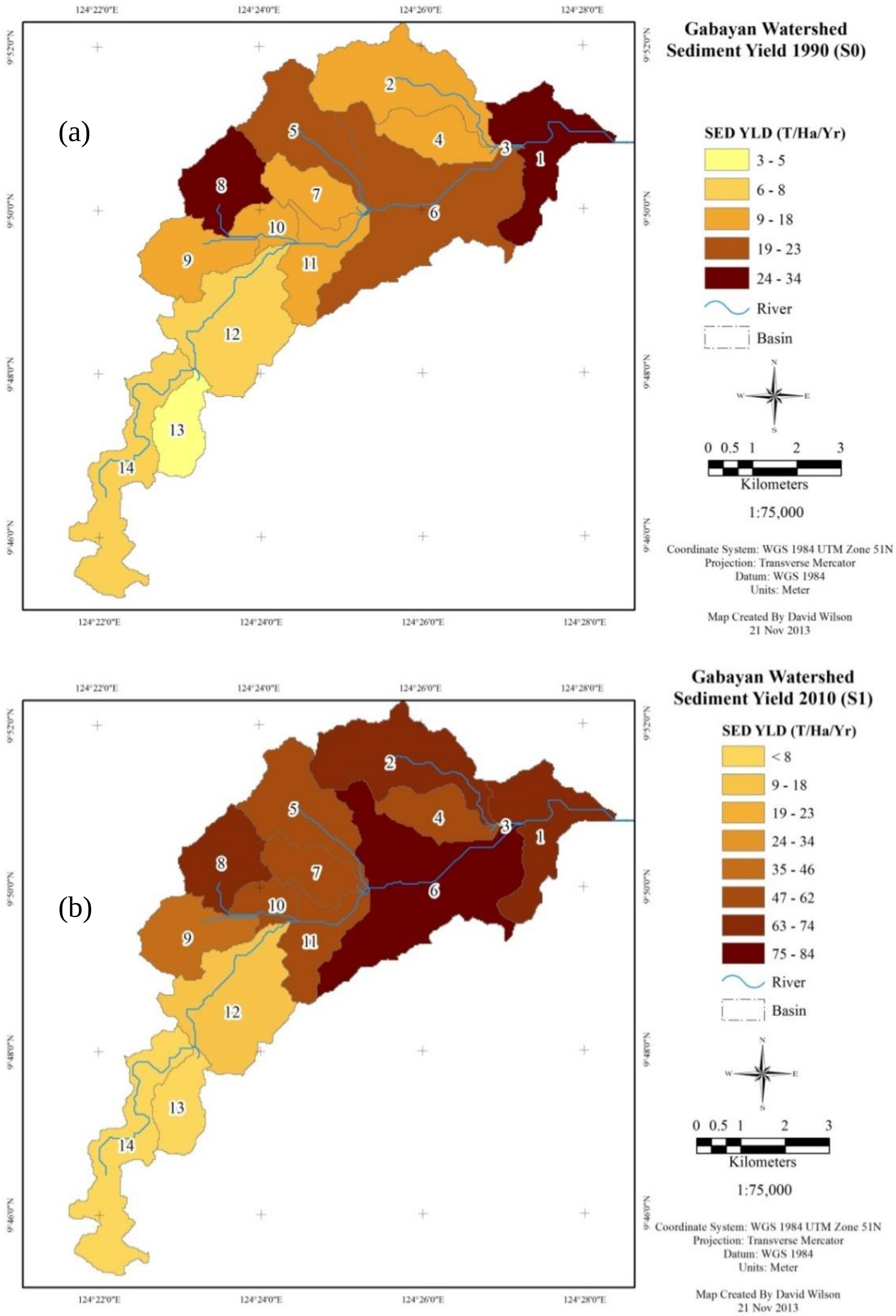


Figure 19. Simulated mean sediment yield (t ha^{-1} yr^{-1}) for (a) S0 and (b) S1 land cover

The change in land cover observed over this period has clearly affected the sediment regulation function. Figure 20 shows the simulation output for sediment yield under S2 land cover which includes improved conservation management practices and agroforestry and it can be observed that overall soil erosion rates are low, with a maximum of 21 t ha^{-1} yr^{-1} and most sub-basins showing a sustainable rate of soil loss. Indeed, the rates of soil erosion under S1 appear to improve on the rates under the baseline scenarios when more of the watershed was under closed canopy forest cover. This could provide useful evidence for the promotion of sustainable agricultural practices under a PES scheme as opposed to the reforestation of the watershed in an attempt to return it to its former state.

This evidence also suggests that there is significant spatial variation and helps to identify critical sub-basins. Under S1, we see that whilst most of the lower reaches of the watershed have elevated levels of sediment yield when compared to S0 or S2, clearly sub-basins 1,2,3,6 and 8 exhibit the highest rates. Again, this will be useful evidence when considering a geographic focus for any PES scheme and allow for the targeting of limited resources. It is also notable that the sediment loss problems appear to be occurring mainly in the lower reaches of the watershed which again could indicate grounds for negotiation between upstream stewards and downstream beneficiaries.

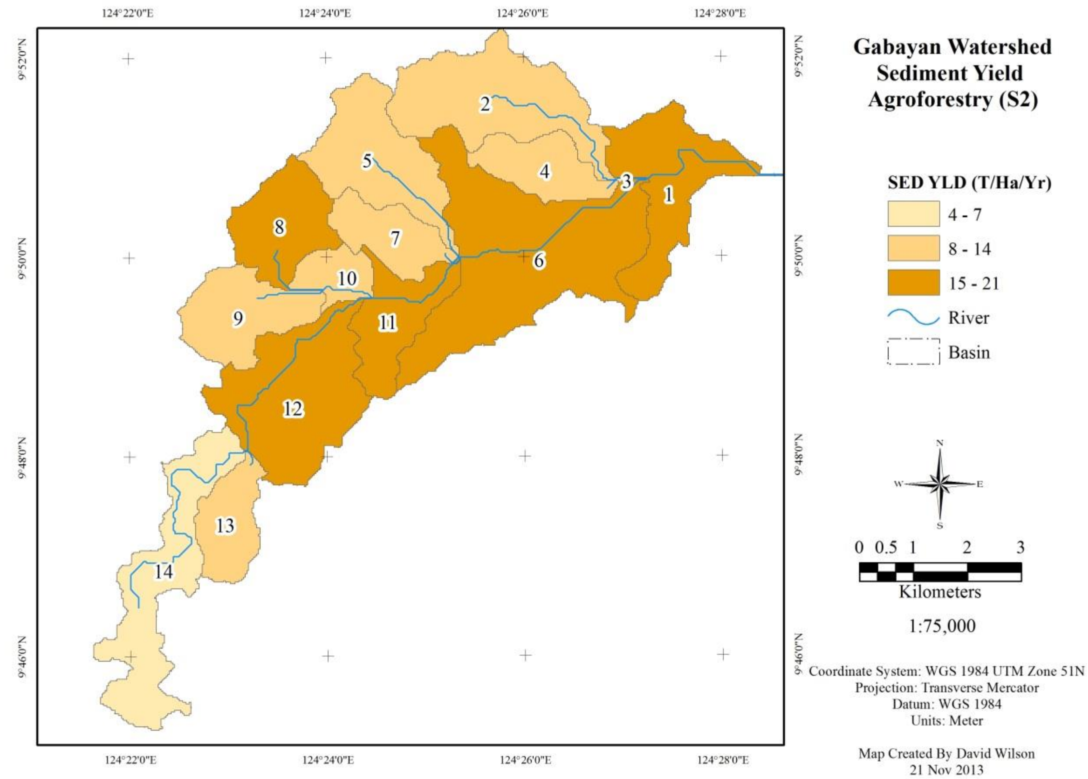


Figure 20. Soil erosion rate (t ha-1 yr-1) under S2 (conservation agriculture with agroforestry)

To analyse whether there is any temporal variation in the soil regulation regime of the watershed, Table 25 and Figure 21 show the simulated mean monthly values for sediment yield (t ha^{-1}) for the entire watershed. This shows that sediment yield is highest across all scenarios between October and February which coincides with the wettest months of the year. It also shows that the average annual sediment yield for the entire watershed based on a mean hydrologic year is 17.8 t ha^{-1} yr^{-1} under the baseline scenario, 45.5 t ha^{-1} yr^{-1} under S1 and 14.19 t ha^{-1} yr^{-1} under S2. Under S1 there is a 155% increase in sediment yield and under S2 there is a 20% reduction when compared to the baseline.

This is further evidence that the introduction of agroforestry species and associated management practices has reduced sediment yield to beyond that of the counterfactual situation in 1990.

Table 25. Simulated mean monthly and total annual sediment yield (t ha^{-1}). Figures in brackets represent percentage change compared to baseline.

MONTH	BASELINE (S0)	S1	S2
Jan	2.04	6.12	2.45
Feb	0.61	4.93	2.26
Mar	0.65	2.07	0.9
Apr	0.2	0.22	0.11
May	0.27	0.31	0.16
Jun	1.15	1.1	0.44
Jul	1.06	2.99	0.63
Aug	1.24	3.09	0.7
Sep	1.81	4.35	1.04
Oct	3.15	6.71	1.64
Nov	2.2	4.71	1.26
Dec	3.42	8.9	2.6
Total	**17.8**	**45.5**	**14.19**
		(155)	**(-20)**

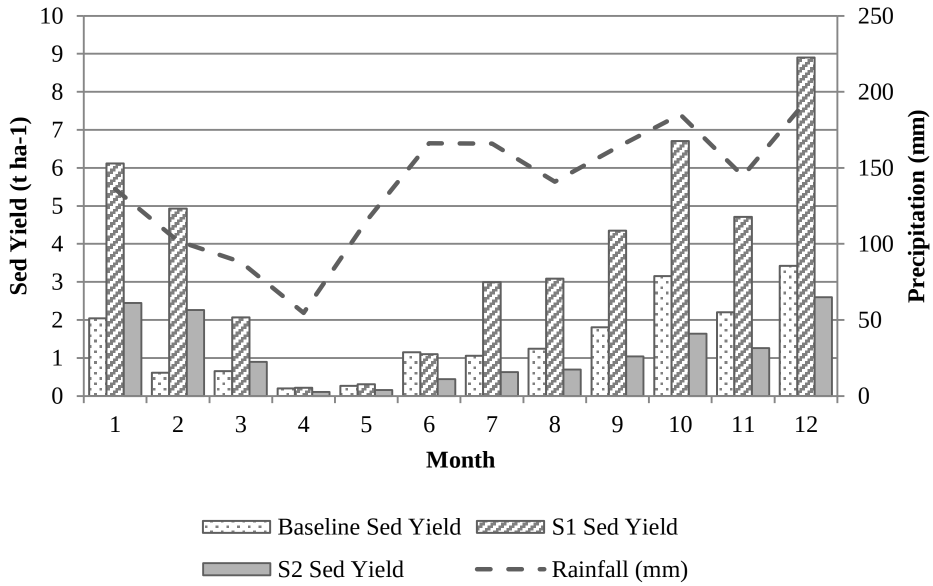


Figure 21. Mean Monthly Basin wide Sediment Yield (t ha^{-1})

To set this in context, these figures have been compared with that from literature and presented in Table 26 which reveals that the site under study has a relatively high sediment yield (t ha^{-1} yr^{-1}) under S1 but that under all scenarios the mean sediment yield is below the national and regional average.

Elevated sediment yield can be a localised impact, effecting farm or patch level soil stability and fertility (Pimentel 2006). When we consider the critical sub-basins identified in the Figure 22, we can see that S2 consistently produces the lowest mean sediment yield, in some cases less than that of the baseline and always lower than that under S1.

Table 26. Soil erosion rates for various locations

LOCATION	AVE. SEDIMENT YIELD (T HA-1 YR-1)	SOURCE
Gabayan sub-watershed	14.19 - 45.5	This study
Magat watershed, Philippines	49.99	David & Colado (1987)
Luzon	56.41 – 128.5	Asio et al. (2009)
Region VII (location of this study)	112	Asio et al. (2009)
Philippines	81	FAO (1998)
Asia	30 – 40	Pimintel et al. (1995)

However, we should express caution when interpreting these results some of the hydrological response units (HRU), the lowest unit of analysis in SWAT had values of greater than 200 t ha^{-1}.

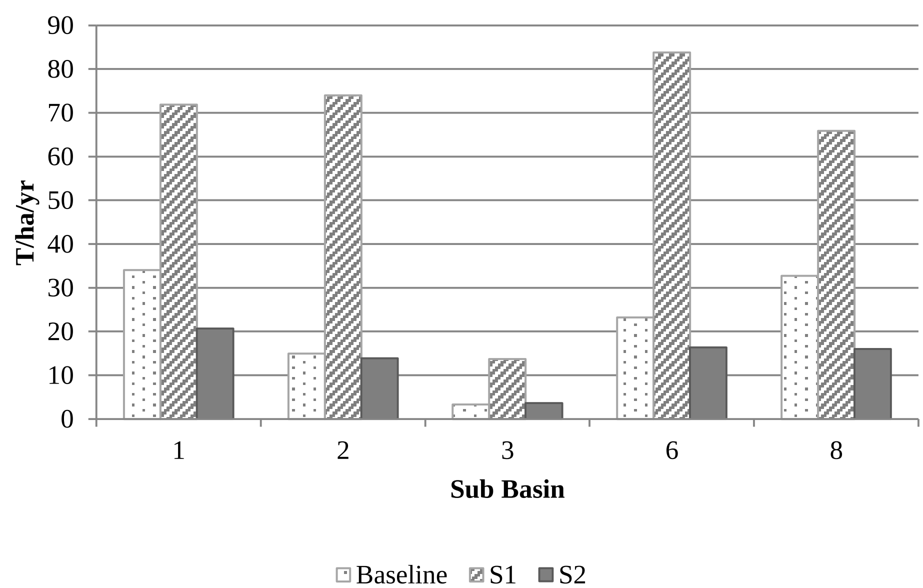


Figure 22. Sediment Yield from critical sub-basins

Nevertheless, sediment yield and soil loss are significant issues for farming communities (Asio et al. 2009; Pimentel 2006; Montgomery 2007) and without effective management, soil loss can significantly impact productivity with associated socio-economic ramifications. Offsite impacts can also be felt if sediments are delivered to the river channels this can lead to sedimentation which in turn can affect fish stocks downs stream and even in the outlet area (Palao et al. 2013). Furthermore, reducing productivity and land degradation can force farmers to look for more productive land by opening up new areas which may be forested. These are all important factors when considering whether there are grounds for a PES scheme which can address some of the environmental and socio-economic concerns within the watershed.

Sediment Concentration

Simulated sediment yield outputs discussed above represent the topsoil lost per hectare. In order to analyse the effect on water quality, which was identified as a concern during the PEK and LEK components, the sediment concentration (mg/L) in each of the streams associated with the sub basins was simulated. This is a measure of how much of the soil lost through erosion is actually delivered to the stream channels in each of the sub-basins. Figure 23 summarises the mean monthly sediment concentration in each of the 14 sub-basins within the Gabayan watershed. Sediment concentration is higher in all sub basins in the lower elevation portion of the watershed (sub basins 1 – 10) under S1. Under S2, sediment concentration is much lower, in some cases even lower than the baseline scenario and is consistently below 500 mg kg^{-1} for all sub basins. In the higher elevation sub basins (12 – 14) which are generally more forested because of their relative inaccessibility and steep slopes which would make agricultural use challenging, sediment concentration is much lower for all scenarios. Figure 24 compares sediment concentration between S0 and S1 by sub-basin.

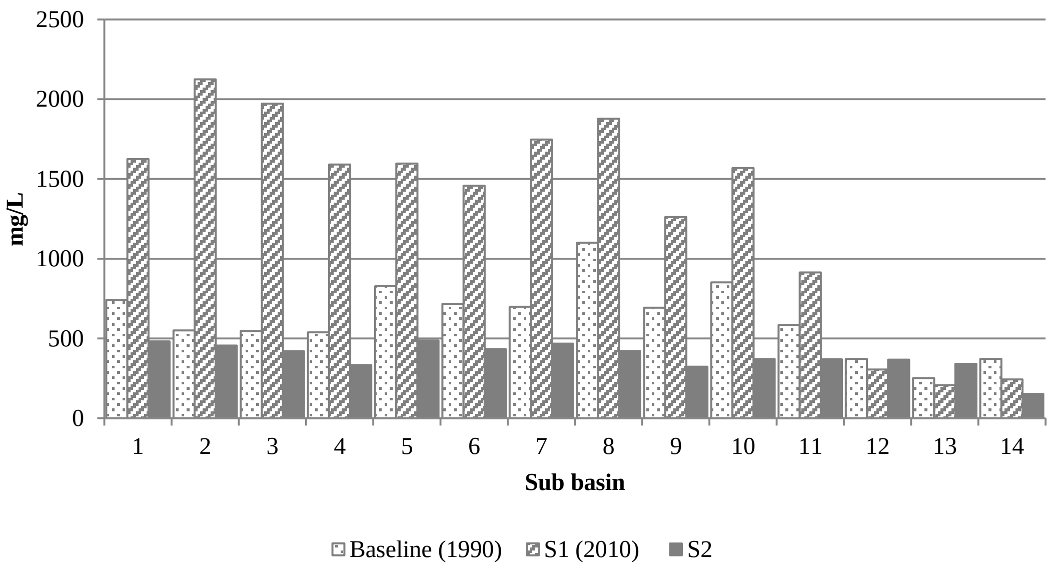


Figure 23. Mean monthly sediment concentration by sub basin for S1 and S2 based on 25 year time series data

These figures show that there is clearly more sediment delivered to the stream network under S2 as demonstrated by the majority of sub-basins having greater than 1000mg/L sediment concentration with the exception of 9, and 12 – 14 (the upper watershed). Under the baseline scenario only one sub-basin (1) exhibits greater than 1000mg/L with the majority in the 500 – 750mg/L range. Interestingly, under S2 sub-basin 13 sees a slight reduction in sediment concentration when compared to S0 but this is anomalous.

Under the S2 scenario (Figure 25), which includes the introduction of riparian buffers to the critical sub basins, there is a sizeable reduction in sediment concentration in all the sub-basins. Indeed a maximum of 488 mg/L (sub-basin 5) and most sub-basins within the 251 – 500mg/L range suggest that there the introduced management practices have been especially effective at reducing the transfer of sediments to waterways with a sizeable improvement in lower reaches where sediment concentration was highest under both S0 and S1. The introduced riparian buffers consist of fast growing trees and shrubs planted in rows, 15 metres either side of the stream in the critical sub-basins. They are designed to act as sediment traps and stabilising buffers which hold back soil transported by surface runoff while at the same time stabilising river banks to reduce in-channel erosion (GIZ 1975; DENR 2011a). It should be noted that this level of intervention where all areas, 15 metres either side of the stream channel, is probably somewhat unrealistic and is meant instead to demonstrate the potential of such management strategies.

Figure 26 summarises the simulated output from those sub-basins in which riparian buffers were added under S2 and compares them with the baseline and S0 and S1. We can clearly see that the introduction of riparian buffers has reduced the sediment concentration significantly in all critical sub-basins to below 500 mg kg $^{-1}$ when compared to both the baseline and S1 scenarios. The single largest reduction appears to be in sub basin 2.

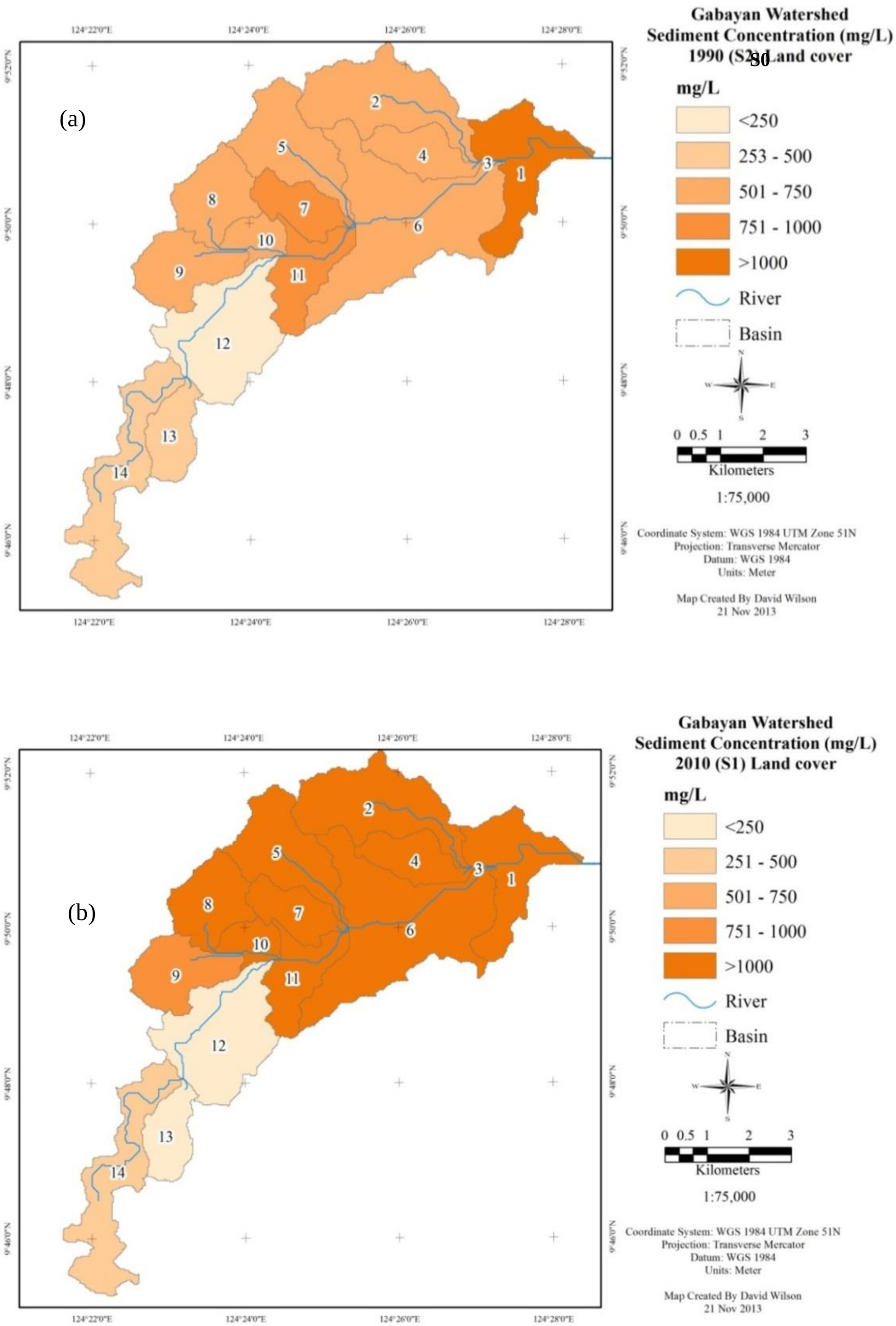


Figure 24. Mean sediment concentration (mg/L) in the Gabayan sub-basins under (a) S0 baseline and (b) 2010 land cover.

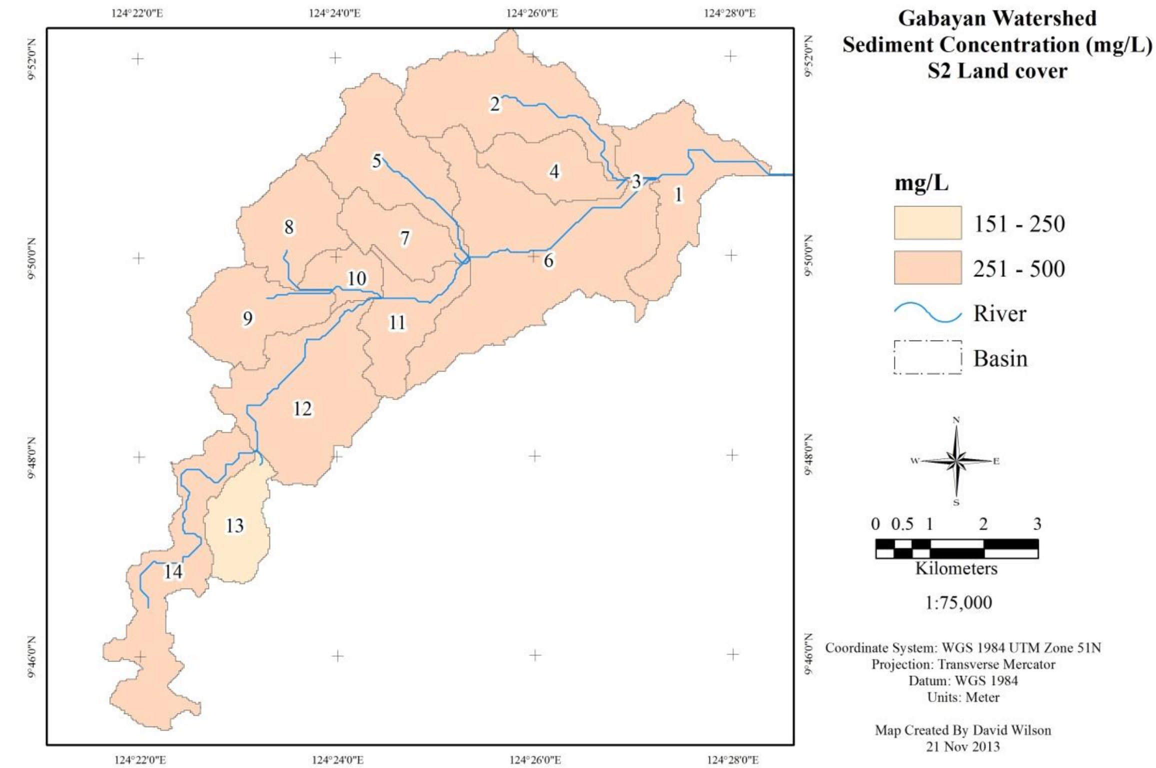


Figure 25. Mean sediment concentration in the Gabayan watershed under S2 (introduction of agroforestry and conservation agricultural practices)

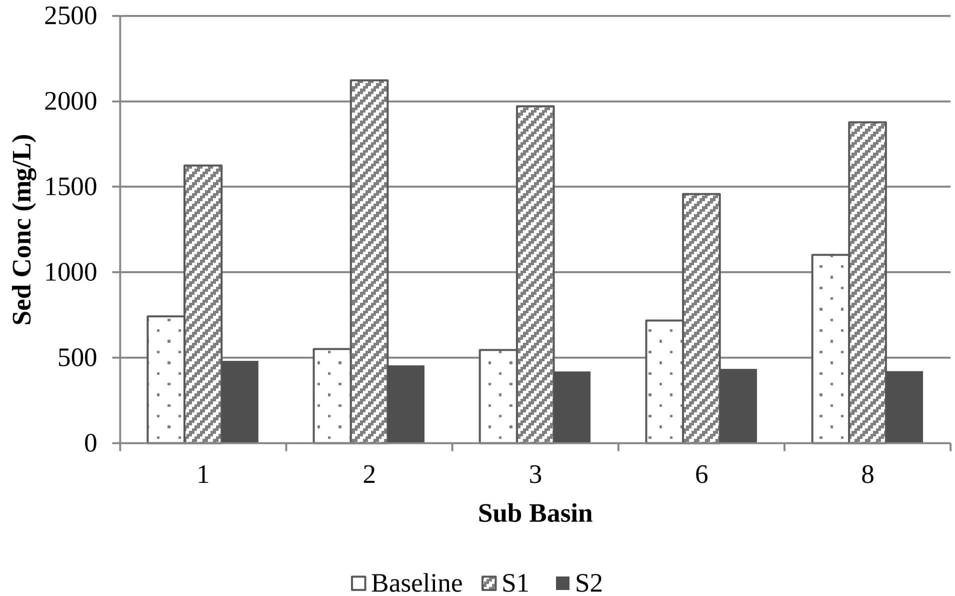


Figure 26. Mean annual Sediment concentration (mg/L) in critical sub-basins

Table 27 below summarises the change in sediment yield expressed as a percentage and shows that there is a mean increase of 165% across all critical sub basins under S1 when compared with the baseline period and a 35% reduction under S2.

Table 27. Change in sediment concentration (%) between the baseline period, S1 and S2

SUB BASIN	BASELINE VS S1	BASELINE VS S2
1	119.05	-34.95
2	286.00	-17.09
3	261.13	-23.09
6	103.22	-39.45
8	70.50	-61.72
Mean	164.99	-34.86

CHAPTER VI

DISCUSSION

Summary of Results (LEK, PEK and MEK)

The results presented in the previous section were gathered using a range of methodologies and are presented in a number of different formats. In order to interpret and discuss them effectively, the key points have been summarised in Table 28. The implication of these results and what they tell us about the central question as to whether PES could be an effective intervention in the case of the Gabayan watershed is then discussed in more detail. The table describes each of the identified ecosystem services which relate to watershed functions as perceived by local policy makers (PEK), community members (LEK) and as simulated through the hydrologic modelling exercise (MEK). Each of these domains is divided into a benefit which describes the direct benefit of the ecosystem services i.e. soil regulation is the service and soil fertility is the benefit or value, and a threat which could have a negative impact on the condition of the identified service i.e. soil regulation is perceived to be impacted by deforestation. Using the table, we can begin to analyse what level of agreement there is between the three domains or perspectives which will help to understand what, if any, grounds there are for negotiation and thus establishing a PES scheme. Negotiating an equitable scheme will require the identification of the most valuable ecosystem services as perceived by beneficiaries and stewards. This first requires a broad understanding of the ecological function at a watershed scale and was demonstrated through both the PEK and LEK consultations. However, if these services are not deemed to be under some sort of threat then a PES scheme will not be required.

For example, there is a perceived lack of water for irrigation (LEK) which has been identified as an important ecosystem service by policy makers (PEK). The results of the hydrologic modelling (MEK) suggest that there is little change in total water availability between the different past, present and future scenarios suggesting that PES scheme targeted at water supply may not be appropriate – perhaps this is more an infrastructure and distribution issue? However, when we consider the seasonal availability and variation in the timing of water flows, we see that under a conservation agriculture scenario which includes agroforestry, that there is reduced inter-seasonal variation producing a more even flow.

It appears universally agreed across all the knowledge domains that land use changes have had a negative impact on the soil regulating function of the watershed which has led to soil erosion. The perceptions of watershed stakeholders is supported by outputs from the hydrology modelling which reveals a significant intensification of soil loss when comparing current use with past and potential future land management practices. There is also a clear spatial pattern to this problem with downstream areas particularly badly affected. Perhaps then this is the most promising focus for a PES scheme?

Table 28. Summary and comparison of PEK, LEK and MEK results

COMPONENT	POLICYMAKERS ENVIRONMENTAL KNOWLEDGE (PEK)		LOCAL ENVIRONMENT KNOWLEDGE (LEK)		MODELLERS ECOLOGICAL KNOWLEDGE (MEK)	
Watershed Function	**Benefit**	**Threat/Condition**	**Benefit**	**Threat/Condition**	**Benefit (Proxy Indicator)**	**Threat/Condition**
Water supply	Mains water Irrigation Well water	Deforestation	Ground water Springs	Insufficient water for irrigation (downstream) 3% reduction in total water supply	Transmission Total discharge (Q)	Little change over time (S1 or S2) Increase total Q under S1 (Degraded)
					Water balance (ET, Surface runoff, base flow)	20% increase in surface runoff between S0 and S1 13% decrease in surface runoff between S0 and S1
Water timing (seasonal and low flow availability)	Flood Attenuation	Mangrove Loss	Dams & impoundments	Flooding (downstream) 14% increase in flooding	Low Flow	S1 – little change S2 – Low flow increases over time
					Seasonal flow	Less seasonal variability in S2

Table 28. Continued …

COMPONENT	POLICYMAKERS ENVIRONMENTAL KNOWLEDGE (PEK)		LOCAL ENVIRONMENT KNOWLEDGE (LEK)		MODELLERS ECOLOGICAL KNOWLEDGE (MEK)	
Water quality (sediment concentration)	Mains water quality	Unspecified	Domestic Water	28% reduction in water quality Poor water quality from wells Pollution from fertilisers (upland rice areas)	Sediment concentration (mg/L)	165% increase between S0 and S1 35% decrease between S0 and S2in critical sub-basins
Soil regulation	Soil Stabilisation	Deforestation Illegal Logging	Soil fertility	28% reduction in soil fertility 14% increase in soil instability Soil loss and landslides Soil erosion	Sediment Yield (t ha^{-1})	155% increase between S0 and S1 20% decrease between S0 and S2

Is a PES Scheme in the Gabayan Watershed Viable?

In addressing the central question of whether a PES framework would be an appropriate intervention to support the sustainable management of the Gabayan watershed, results from three main knowledge domains relating to the study site have been presented and discussed – Policymakers Environmental Knowledge (PEK), Local Environmental Knowledge (LEK) and Modellers Environmental Knowledge (MEK). This interdisciplinary methodology which combined social and biophysical components has produced a diverse range of outputs including: sketch maps; GIS maps and data; questionnaire responses; workshop and FGD outputs; and modelling simulation outputs in graphical and spatial format. This reflects the complexity of the subject under study which seeks to translate knowledge, perceptions and modelled biophysical information from the local to a landscape (watershed) scale.

Commonalties and differences in the analysed outputs from the different knowledge domains have been identified. In order to distil the outputs from these data gathering activities and to provide a framework for analysis, a set of indicators has been developed. This set of indicators is described below and is based on the review of literature synthesis which presented some of the key criteria and conditions to consider when designing a PES mechanism drawing on evidence from operational schemes, namely: clearly defined ecosystem services which are under threat; clearly defined beneficiaries and stewards who acknowledge and value the clearly defined ecosystem services; grounds for voluntary negotiations of rewards, payments or incentives and;

demonstrable conditionality in which there is some measure of a service being maintained or restored (Wunder et al. 2008; Tacconi 2012).

What this means for the potential of ecosystem services in the Gabayan watershed will be interpreted using a **Value-Threat-Opportunity-Trust** framework (Jeanes et al. 2006; van Noordwijk 2005).These can be considered as conditions or criteria which need to be met if a PES scheme is to be viable and are discussed in turn within the context of the findings of this study and other global and regional studies.

Clearly defined beneficiaries and stewards – Value

A PES scheme requires the negotiation of a payment, compensation or reward between clearly defined providers of an ecosystem service and a buyer of those services. These two groups must not only be identified in the landscape but they must also show some desire or willingness to participate in such a transaction. It follows that there must be recognition on the part of both parties that an ecosystem service is linked to land use practices and natural resource management practices and decisions (stewards) and that the same services are under threat (beneficiaries).

In the case of the Gabayan watershed, well defined beneficiaries and stewards of services are difficult to discern within the landscape. With no large agri-business, hydroelectric operation or water treatment facility within the watershed, a large private entity does not appear available to fill the role of buyer as in some private schemes in the Philippines (Cremaschi et al. 2012; Arocena-Francisco 2003; Lasco & Villamor 2010).

There also appears to be little hope of a government backed scheme which is a common PES typology in other countries where local or national agencies position themselves, at least initially to purchase ecosystem services, usually at a flat rate (e.g. per hectare of land managed) (Matulis 2013; FONAFIFO et al. 2012). While we observed that local and provincial government agencies acknowledge the need to restore or enhance ecosystem services, and indeed openly support such a scheme they also appear unable to play a more meaningful role in financing solutions. There is some evidence to suggest that local government units may be able to act as facilitator in this process where they are unable to directly finance which was identified by Cremaschi et al (2012) as a crucial role for such agencies in any scheme. We are therefore left with what Wunder et al (2008) define as a user led scheme in which payments are negotiated internally within the area of interest, in this case the watershed. In this case, the direct users of services will need to make payments to the perceived providers of the agreed services which must be negotiated. However, this is predicated on the clear definition of who is providing what service to whom which returns us to the problem of identifying beneficiaries and stewards in the landscape.

Perhaps the hydrologic modelling aspect of the MEK component offers the best means of identifying the beneficiaries and stewards of services within the landscape. The outputs from this component clearly identify indicators of the status of ecosystem services within the landscape. Focussing on two related services - water quality as indicated by sediment concentration and, sediment yield which is a proxy for soil stability and to a certain extent, fertility – we can see that there is a clear spatial differentiation between the upstream areas and downstream sub-basins. Sub-basins 9 – 14 in the upper reaches of the watershed consistently show lower levels of soil loss and concentration than those in lower reaches under the past (S0) and present (S1) scenarios. In addition, under a future with conservation agriculture practices which could be incentivised via a PES scheme, we see further improvements in downstream indicators. This suggests that there may be some grounds for considering those in the upstream zone to be stewards of services which have been disrupted and those in those in the lower, richer agricultural zones of the watershed as the beneficiaries. This fits with the classic upstream – downstream model in which unidirectional water based ecosystem system services flow away from upstream stewards to downstream beneficiaries (Noordwijk et al. 2006; Brauman et al. 2007; Lusiana et al. 2008b). This is more than a geographical relationship though as any reduction in watershed *function* will also be exported to downstream users manifesting as the observed environmental problems.

Clearly defined ecosystem services – Threat

Identification of relevant ecosystem services is essential. If there are many ecosystem services recognised and valued by local people then attempting to establish a scheme which delivers all these may prove too complex. Therefore, the most highly valued ecosystem services, as perceived by local people and policy makers should be targeted. However, there may be some scope for bundling (Deal & White 2012; Deal et al. 2012) ecosystem services based on a land uses which can deliver multiple benefits and this will be considered in the analysis here. Not only must these ecosystem services be defined and recognised by local stakeholders but they must be under some sort of threat which is perceived or directly observed by those affected. The results have clearly demonstrated that environmental problems are manifest in the Gabayan watershed which can be linked to the ecosystem function and in turn attributed to land use change and management practices. Based on analysis across all three knowledge domains therefore, we can discuss the perceived and modelled threat to each of the ecosystem services which fall into four main groups:

i. Water supply i.e. total water available to the system

Water supply was perceived as an important function of the watershed in both the PEK and LEK components. Insufficient water for irrigation was cited as one of the main problems in the downstream area although overall, results from the participatory land use exercises suggests there was only a perceived 3% reduction attributed to changing land management practices over time. The modelling outputs broadly support this perception indicating that there was been little change based on past (S0 - 1990) and present (S1 - 2010) land use scenarios. It appears that the introduction of conservation agriculture management practices (S2) in fact reduces total water discharge, perhaps because of higher demand from woody perennial. This evidence would suggest that water supply is not a suitable ecosystem service to target under a PES scheme as the threat to its continued provision appears to be minimal.

ii. Evenness of flow i.e. monthly low flow and seasonal availability of water

The seasonal availability of water for agricultural activities was identified by the LEK domain as being of some importance with dams and impoundments being used to store what water is available and a perceived reduction in availability of water for irrigation in the drier months. Indeed the bigger problem appears to be too much unwanted water in the form of flooding. Both these problems appear to manifest in downstream zones of the lower watershed. Outputs from the simulations for seasonal water availability shows that under current land use conditions there has been little change compared to past land use (1990) but that when we consider the conservation agriculture scenario (S2) , there is as notable increase in monthly low flow suggesting that water is available more consistently in the system. In addition, under an S2 scenario, there appears to be much less seasonal variability again pointing to a better evenness of flow with stored water being gradually released in periods of low rainfall. This ecosystem service could therefore represent a suitable target service as not only do we see that variability in seasonal availability poses a problem for downstream users who require water for irrigation, particularly in the periods of low rainfall, but also it appears that instigating a change in land use practices, can lead to a restoration or even an improvement of this service.

iii. Water quality i.e. sediment free water

Local government and other public/policymaker stakeholders (PEK) including those directly involved in water provision did not report a threat to water quality.

However, during the LEK component community members estimated that there had been a 28% reduction in water quality from surface and ground water sources between the past land use scenario and the present. They specifically noted poor quality water from wells and pumps and also polluted water from upstream fertilisers was perceived in Guindulman. Unwanted nutrients and pollutants are often transported with sediment in water channels and therefore the simulated in stream sediment concentration provides a useful indicator of water quality (Winkler et al. 2002).

Results from the MEK component indicated that there had been a 165% increase in overall sediment concentration at the watershed level with sub-basin 1, 2 and 3 in the lower reaches showing particularly high levels. The five identified critical sub-basins (1,2,3,6 & 8) all show elevated levels of sediment concentration under the current, degraded (S1) land use scenario. However, under the conservation agriculture scenario (S2), the critical sub-basins all show a reduction in sediment concentration to levels often below that of the 1990 (S0) baseline land cover and consistently below 500mg/L with the introduction of riparian buffers in these sub-basins. This appears to be an effective intervention to reduce sediment transfer throughout the watershed reducing the amount of sediment which actually reaches the stream channels. As with the evenness of flow indicators, it appears that water quality could therefore be an ecosystem service which is valued, under threat from current land management practices and could be restored if an incentive were provided to improve those practices.

iv. Sediment regulation: soil erosion and soil stability

Soil stabilisation is the only ecosystem service which is universally identified as an important service and recognised as being under threat. Under the PEK component, soil instability, including risk of landslides was highlighted as a significant problem and was linked to deforestation and illegal logging in the upland areas. During the participatory workshops (LEK) a perceived 28% reduction in soil infertility was identified and linked with a 14% increase in soil instability with soil erosion and landslides specifically highlighted. This appears to be supported by results of the modelling exercise which simulated a 155% increase in sediment yield (t ha^{-1}) between the baseline and current land cover scenarios. With the introduction of conservation agriculture including improved tillage practices, enhanced vegetative cover, terracing, contour planting and reduced soil exposure the MEK component revealed a 20% decrease in sediment yield. When considering the critical sub-basins, we see that conservation agriculture practices offer significant reduction in soil loss per hectare even when compared to the 1990 (S0) scenario which had more in-tact forest cover.

To summarise, total water yield and availability while, considered as being important, does not appear to be under threat from current land use practices when compared with a more intact watershed. Nor do simulated conservation agricultural practices appear to improve total water availability. It is therefore unlikely that targeting this as an ecosystem service restore via an incentive mechanism would be viable. However, there are common ecosystem services which are recognised by public policy makers and local communities as being of value as well as being under threat which are supported by quantitative outputs from scenario modelling (MEK). Sediment regulation appears to be both the most severe problem (across all domains) which can be improved with changes in land management practices such as conservation agriculture with an incentive via a payment for ecosystem service mechanism.

Perhaps less universally recognised but nonetheless affected by land use change are water quality as indicated by sediment concentration and seasonal availability of water. It may be possible therefore to consider sediment regulation (sediment yield or soil loss) to be the primary ecosystem service which can be quantified but that the same land management practices which deliver this service may also have additional benefits relating to water quality and evenness of flow and can therefore be bundled together. From global examples, bundling appears to be a feature of PES schemes which seek to protect or restore watershed functions in which incentivising alternative land use practices delivers multiple benefits from provisioning (water supply) to regulating (sediment regulation) and biodiversity conservation (Zheng et al. 2013; van Noordwijk et al. 2014; Ingram et al. 2014). In the case of Gabayan, if we discount overall water supply, then the remaining services relate to the regulatory function of the watershed and not provisioning services. These are less tangible than provisioning services for stakeholders and therefore are more likely to be continue to be under threat through invisibility in the market, making them potential candidates for economic instruments such as PES (Swallow et al. 2009).

Voluntarily negotiated transactions – Opportunity

Having established that there are clearly defined ecosystem services although less well defined beneficiaries and stewards within the landscape, what does this mean for the potential on negotiating a payment, reward or incentive framework which will deliver the required change in land management practices to secure that service? It appears that in this case a user financed scheme is the only potential type with no private sector or government funds available. Schemes in Cambodia which were established on this basis and led by communities have been found to deliver multiple benefits for participants including livelihood diversification and biodiversity conservation but that initial start-up funds to meet transactions costs were required (Ingram et al. 2014). In order to establish such schemes direct negotiations between the perceived stewards of ecosystem services and perceived beneficiaries are required. Negotiation between beneficiaries and stewards depends on trust, communication and the knowledge, perceptions and information available to each group (Smith & Sullivan 2014).

There is however, insufficient clarity about who these two groups are to allow for successful negotiation in the Gabayan watershed at present. Results of the MEK component suggest that there are a number of critical sub-basins which could be the focus of initial activities and that the communities within these areas could be considered the buyers of service from those communities located in the upper reaches of the watershed. Most of the critical sub-basins are located within the municipality of Candijay and the upper reaches are divided between Pilar and Guindulman. Any negotiations will therefore need to take place across different political boundaries which could add an additional degree of complexity. There is currently no legal or regulatory framework within the Philippines which could help address this and provide a sound basis for negotiation and to guide the management and distribution of any reward (Cremaschi et al. 2012). Studies in other SE Asian nations such as Vietnam, where a national PES policy is in place, have found that there is more traction in establishing schemes with a national legislative tool but that there remains the need for a local level intermediary in order to operationalise a scheme (Dam et al. 2014).

There is a multi-stakeholder, cross municipality institution already in place in the form of a watershed management council for the wider Carood basin and this could be a potential ‘honest broker’ for facilitating negotiations. It could also be the trusted organisation which receives, manages and distributes rewards or funds between beneficiaries and stewards in any future scheme. Evidence from schemes in other countries suggest that this approach could include the creation of a trust fund (Goldman-Benner et al. 2012) which is independently managed and overseen by an elected management body who would distribute funds or rewards (i.e. technical support for new agricultural practices) based on certain criteria being met and in return for a prescribed land use activity. The creation of a menu of land management activities based on the MEK output and matched to local conditions which stewards must agree to implement in return for reward or payment could be offered by the trust fund. This approach has been successful in other projects, particularly those that operate in highly complex multi-use landscapes and include agroforestry components (Hegde & Bull 2011; R. Lasco et al.

2014). The voluntary nature of any transactions means that either beneficiaries or stewards can choose either to opt out from the start or drop out once the scheme is agreed. In some schemes, a contract is used although this is not always desirable nor indeed ultimately enforceable and will only add to transaction costs of establishing a scheme.

Whether direct payments or in-kind technical support to assist with the uptake of land management practices which, lead to the delivery of ecosystem services is another key decision. Recent research suggests that total commodification of the watershed services discussed here which are accurately measured and given a precise price per unit is unlikely. Instead the concept of co-investment perhaps better describes the potential project in Gabayan in which rewards or incentives are provided for the achievement of a mutually agreed set of activities which enhances or maintains a set of ecosystem services (Namirembe et al. 2014; Swallow et al. 2009). Perhaps a more promising model for this site could be that suggested by van Noordwijk and Leimona (2010) which presents a co-investment paradigm in place of a strictly defined PES scheme. In this case, a more inclusive planning a development framework is created which the natural resource managers or stewards are provided with incentives such as secure tenure to avoid land use conflicts which may impact on ecosystem services. It also involves more general investment in infrastructure and employment opportunities which are contingent on some form of localised monitoring of ecosystem service provision (Noordwijk & Leimona 2010).

Demonstrable conditionality – Trust

Given some of the uncertainty about the negotiation of a PES scheme in the Gabayaan watershed discussed above, it is perhaps of even greater importance that there is understanding and trust that the identified services will be delivered consistently by stewards and that the beneficiaries are convinced of this i.e. demonstrable conditionality. Conditionality is often cited as a necessary component of any PES scheme. However, as we have discussed in the review of literature, is often not met in the strictest definition of the term and can be difficult to demonstrate. Ideally, positive (or negative) changes in ecosystem services which may be related to land use practices instituted and incentivised under a PES mechanism should be quantifiable and monitored. This provides assurances to the beneficiaries (who will be providing the economic incentive) that indeed the services for which they are paying are being delivered. In many schemes there is an implicit assumption which is respected by both beneficiaries and stewards, that a land use activity is delivering a service (see Kosoy et al. 2007; Vignola et al. 2012).

Via the modelling component (MEK) of this research the main watershed ecosystem services have been quantified more accurately quantified and this could perhaps be considered as a baseline against which the effects of future interventions can be measured. Whether such computationally intensive and highly technical approaches would be suitable for ongoing monitoring of a scheme is questionable given the extreme rural location of the watershed. In addition to a baseline, the hydrologic modelling has also identified critical sub-basins which should be the focus of initial activities at least and which are likely to see the most obvious benefit from an intervention to restore watershed functions. Establishing some sort of monitoring framework as part of a PES scheme though will be important to provide security for those purchasing services. Indeed Cremaschi et al. (2012) in reviewing watershed PES projects in the Philippines noted that the lack of capacity to effectively monitor schemes and the associated high costs were some of the limiting factors to their overall sustainability.

To address this persistent issue Lasco et al. (2008) offer a useful way to determine the level of monitoring required which draw on case studies in the Philippines, mimicking the IPCC's tiered approach to calculating carbon emissions in which Tier 1 is based on ecological principles; Tier 2 attempts to model the ecosystem services using best available secondary data and Tier 3 uses observed data which is monitored as part of the scheme. At least tier two of this framework has been met through this research which has employed a hydrologic modelling using local land cover data parametised to the local conditions.

Whether a tier 3 monitoring framework is possible or desirable within the watershed is uncertain and will require significant resources so is probably unlikely. In the absence of highly technical, time consuming and resource intensive monitoring mechanism, simple techniques could be employed which are monitored on a less frequent basis. A tier 1 framework could be developed which is based on the outputs of this research which suggest that for example, adopting conservation agriculture in the upland area will deliver benefits for downstream users. Therefore the adoption of these techniques can be monitored by members of the community, by municipal agricultural officers or members of the watershed council. Specific monitoring activities could include:

- More regular reading of existing stream gauges such as that at the bridge in Canawa which was erected by NIA but is no longer monitored;
- Annual or bi-annual surveying of beneficiaries of the services to determine their perception as to whether the service is being delivered;
- Annual surveying of stewards of services to determine whether and to what extent the incentivised conservation agriculture techniques have been employed at the farm level.

In summary, Table 29 provides an overview of each of the indicators of the suitability of a PES scheme in the Gabayan watershed which have been discussed above and specify whether they have been met or not. Overall, there appear to be ecological grounds for a PES scheme but question marks remain about precisely who will be the stewards and beneficiaries and how they will negotiate an appropriate mechanism. Nonetheless, there appears to be the basis for developing a scheme and there is an established baseline against which conditionality can be monitored. The Carood Watershed Model Forest Management Council (CWMFMC) has emerged as the most likely facilitator of any negotiations and potentially the overall manager of the scheme.

A note on the Rapid Hydrological Appraisal tool

The Rapid Hydrological Appraisal (RHA) method combines a number of approaches designed to extract knowledge from across a number of domains, giving equal weight to each. It is an interdisciplinary approach which produces more holistic results than for example a straightforward hydrological assessment or a participatory rural appraisal. The results are therefore richer and reflect more the complex and sometimes confounding information and socio-ecological dynamics at watershed scale. However, the approach was originally designed to be conducted by a multi-disciplinary team but was conducted in this case by a single researcher with limited time, capacity and resources. The relative strengths of a multidisciplinary team would probably make an appraisal more comprehensive and both the desk based and field time required means that this should not be recommended for an individual researcher. Ultimately, the approach was slightly adapted as described in the methods section and this more streamlined approach still seems to have produced interesting and useful results so overall the RHA model is fit for purpose at the scale used here.

Table 29. Summary of PES viability indicators including metrics or proxies where available and whether the results from this research indicate a scheme is viable

DESCRIPTION	INDICATOR	MEASURE OR PROXY	METHOD	INDICATOR MET?
Clearly defined beneficiaries and stewards (Value)	Sellers (stewards) Buyers (beneficiaries)	Location of beneficiaries and stewards in the landscape	Questionnaire Participatory Mapping Secondary data (WTP survey)	**Unclear:** There is some upstream – downstream divide and critical sub-basins but no clear source of funds
Clearly defined ecosystem services (Threat)	Watershed services and environmental problems	Ranked watershed services Outputs of hydrological modelling	Participatory and land use mapping Hydrological modelling	**Met**: Sediment regulation as the primary ecosystem service bundled with water quality and timing
Voluntary negotiated transactions (Opportunity)	Existing regulations and institutions	Recognition by local decision makers of ecosystem service threat and value	Questionnaire Secondary data	**Unclear:** no clearly defined beneficiaries and stewards therefore no grounds for negotiation

Table 29. Continued…

DESCRIPTION	INDICATOR	MEASURE OR PROXY	METHOD	INDICATOR MET?
Conditionality (Trust)	Watershed services: a. Gradual water release b. Seasonal water availability c. Total water yield d. Soil stability i. Soil erosion ii. Sediment transmission	a. Low flow as a fraction of total flow (unitless) b. Seasonal analysis c. Transmission – Total water yield per unit rainfall (mm/mm^{-3}) d. Sediment regulation i. Sediment yield (t ha^{-1}) ii. Sediment concentration (mg L^{-1})	Hydrologic modelling (SWAT)	**Met:** quantification of ecosystem service proxies seems possible using modelling or basic monitoring of soil erosion in critical sub-basins i.e. soil erosion pins.

CHAPTER VII

CONCLUSION AND RECOMMENDATIONS

Returning to the central aim of this research which is to establish the whether a PES mechanism is a viable intervention in supporting the conservation or restoration or ecosystem, services in the Gabayan watershed, we have addressed the explicit objectives of identifying, characterising and mapping the ecosystem service provision in the watershed. The causal link relationship between land use change and these ecosystem services have been established and upstream stewards and downstream beneficiaries have been highlighted albeit not specifically identified at the household level.

This research has identified significant land use changes in the Gabayan watershed over the last 20 years and that these changes have altered the state and function of the watershed leading to environmental problems such as soil erosion and reduced water quality. There is broad agreement amongst stakeholders that these same ecosystem services are of value and under threat. There appears to be some spatial division between the upstream (potential stewards) and downstream (potential beneficiaries) zones. However, grounds for negotiation without clearer definition of these beneficiaries and stewards are weak and while the internalisation of externalities within the watershed would be economically efficient, the income levels of the downstream beneficiaries are likely to prohibit direct payments being made.

A Proposed Scheme for The Gabayan Watershed

Evidence from the MEK component suggests that, hydrologically speaking, at least the watershed as a whole has entered a degraded phase which may mean that continued agricultural activities in the watershed are not sustainable. Simulations show that the introducing conservation agricultural practices within strategic locations and in biophysically appropriate areas of the watershed will improve the ecosystem service indicators. From this perspective at least, there appears to be the grounds for a mechanism which would incentivise the uptake of new or improved practices which can deliver on-site benefits at the farm level in addition to off-site downstream benefits for other users of ecosystem services.

Specifically, targeting a bundled package of services which relate to the sediment regulation and water storage and release functions of the watershed would be the most desirable both from an ecological perspective and in terms of acknowledged value of both public and community level stakeholders. The principal service would be soil stabilisation which is more readily perceptible and perhaps more easily monitored. Incentivising land management practices which deliver this service will also deliver perhaps less easily measured regulatory services including evenness of flow (i.e. seasonal availability) and water quality (as indicated by sediment concentration).

Evidence from this research suggests that adopting conservation agriculture practices with agroforestry systems in the Gabayan watershed would restore the target ecosystem services for downstream beneficiaries if adopted by upstream stewards. Therefore, a PES scheme which incentivises the uptake of practices such as reduced tillage, contour planting, maintaining soil cover and the incorporation of woody perennials into annual agricultural lands (agroforestry systems) may be effective. Instead of direct payments, from downstream to upstream users, funds could be used to provide technical and capacity building to assist farmers in the adoption of these new practices which may otherwise be deemed too risky or outside of their knowledge base. An intermediary would ideally engage stewards and beneficiaries as well as agencies with the technical skills to help build the capacity of local farmers.

A more challenging aspect of establishing a scheme in the Gabayan watershed is how to reach a point of negotiation. This is particularly difficult because clear beneficiaries and stewards of services have not emerged. It appears that the only possible type of scheme is a local user financed scheme which means that downstream users would need to pay either directly or indirectly, upstream providers for the services they receive. Figure 27 below depicts a proposed PES scheme for the Gabayan watershed in which the Carood Watershed Model Forest Management Council (CWMFMC) plays the role of facilitator, managing and monitoring the scheme and providing the link between upstream stewards and downstream beneficiaries.

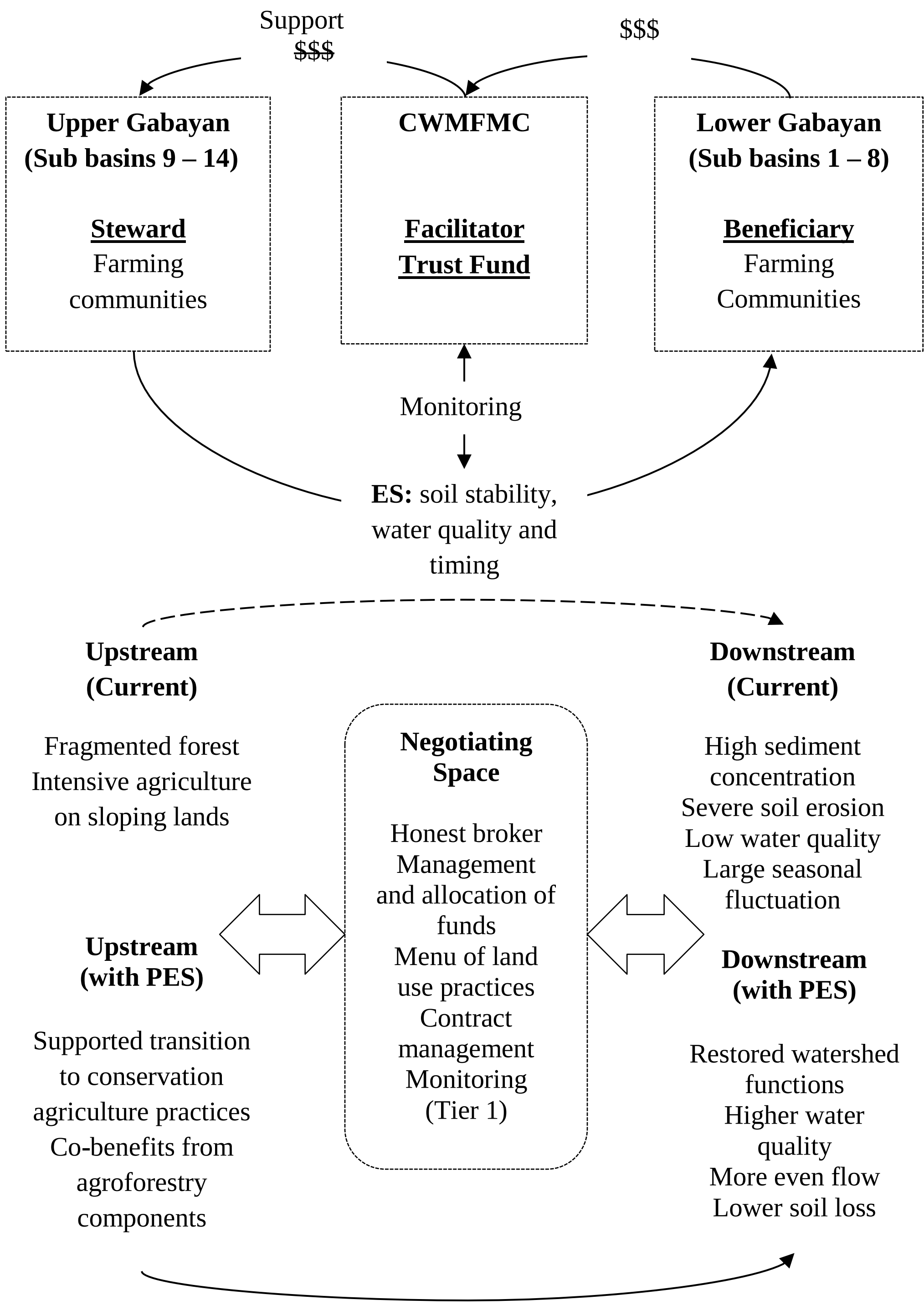


Figure 27. Proposed PES framework for the Gabayan watershed.

Recommendations

If a mechanism such as the one described in Figure 27 is to be successful the following recommended steps need to be taken:

1. Better define stewards and beneficiaries

Identifying exactly who will pay who, how much and for what is a vital step and will involve economic analysis at the household level. Understanding the motivations behind people's desire to participate is probably a logical next step in defining buyers and sellers and in ensuring that a scheme does not favour one group over another by investigating the often asymmetrical power dynamics between upstream and downstream land managers.

2. Create a space for negotiation, mediated by the watershed management council

Once those households who are willing to participate have been identified, a negotiation process will be required in which an agreed amount, schedule of payment and monitoring framework is agreed. All parties will need to be convinced that they are receiving benefits from the arrangement otherwise it is unlikely to succeed.

3. Identify seed funding

In order to stimulate the mechanism some seed funding will be required. This could come from LGUs on the basis of the avoided costs for example through soil stabilisation reducing the need for emergency response to landslides. It could also be sought from external funding agencies.

LITERATURE CITED

ABSON, D. J., & M. TERMANSEN, 2011. Valuing ecosystem services in terms of ecological risks and returns. Conservation Biology, 25(2), 250–258. doi:10.1111/j.1523-1739.2010.01623.x

ACIAR. 2012. Evaluation and adoption of improved farming practices on soil and water resources, Bohol Island, Philippines.

ANGELSEN, A. 2007. Forest Cover Change in Space and Time : Combining the von Thünen and Forest Transition (No. WPS4117) (pp. 1–43).

AROCENA-FRANCISCO, H. 2003. Environmental Service " Payments ": Experiences , Constraints and Potential in The Philippines. Southeast Asia Regional Office, Bogor, Indonesia.

ARROW, K., B. BOLIN, R.COSTANZA, P. DASGUPTA, C. FOLKE, C. S HOLLING, D. PIMENTEL 1995. Economic growth , carrying capacity , and the environment 1. Ecological Economics, 15, 91–95.

ASIO, V. B., R.JAHN, F. O PEREZ, A. IAN, & S. M. A. JR. 2009. A review of soil degradation in the Philippines. Annals of Tropical Research, 31(2), 69–94.

BAGSTAD, K. J., G. W. JOHNSON, B.VOIGT, & F.VILLA, 2012. Spatial dynamics of ecosystem service flows: A comprehensive approach to quantifying actual services. Ecosystem Services, (2007), 1–9. doi:10.1016/j.ecoser.2012.07.012

BAIOCCHI, G. 2012. On dimensions of ecological economics. Ecological Economics, 75, 1–9. doi:10.1016/j.ecolecon.2012.01.016

BALMFORD, A., A.BRUNER, P. COOPER, R.COSTANZA, S.,FARBER, R. E. GREEN, R. K. TURNER, 2002. Economic reasons for conserving wild nature. Science (New York, N.Y.), 297(5583), 950–3. doi:10.1126/science.1073947

BENNAGEN, M., A. INDAB, A.AMPONIN, R.CRUZ, R.FOLLEDO, P.VAN BEUKERING, J.DE JONG, n.d. Designing Payments for Watershed Protection Services of Philippine Upland Dwellers: Processes, Lessons Learned and Policy Insights (pp. 1–39).

BENNETT, G., N.CARROLL, & K. HAMILTON, 2013. Charting New Waters State of Watershed Payments 2012. Washington, DC.

BODIN, Ö & M. TENGÖ, 2012. Disentangling intangible social–ecological systems. Global Environmental Change, 22(2), 430–439. doi:10.1016/j.gloenvcha.2012.01.005

BOHOL PPDO, 2011. Bohol Integrated Water Supply Master Plan.

BRAUMAN, K. A., G. C. DAILY, T. K. DUARTE, & H. A MOONEY, 2007. The Nature and Value of Ecosystem Services: An Overview Highlighting Hydrologic Services. Annual Review of Environment and Resources, 32(1), 67–98. doi:10.1146/annurev.energy.32.031306.102758

BREMER, L. L., K. A FARLEY & D.LOPEZ-CARR, 2014. What factors influence participation in payment for ecosystem services programs? An evaluation of Ecuador's SocioPáramo program. Land Use Policy, 36, 122–133. doi:10.1016/j.landusepol.2013.08.002

BROOKS, K. N., P. F.FFOLLIOT, H. M.GREGERSEN, & J. L. THAMES, 1991. Hydrology and the Management of Watersheds. Iowa State University Press.

BRUIJNZEEL, L. A. ,2004. Hydrological functions of tropical forests: not seeing the soil for the trees? Agriculture, Ecosystems & Environment, 104(1), 185–228. doi:10.1016/j.agee.2004.01.015

BULTE, E. H., L.LIPPER, R.STRINGER & D. ZILBERMAN, 2008. Payments for ecosystem services and poverty reduction: concepts, issues, and empirical perspectives. Environment and Development Economics, 13(03), 245–254. doi:10.1017/S1355770X08004348

CALDERON, M. M., K.PAOLA ANIT, L.PALAO, M., & R. D.LASCO, 2013. Households ' Willingness to Pay for Improved Watershed Services of the Layawan Watershed in Oroquieta City , Philippines, 6(1), 1–18. doi:10.5539/jsd.v6n1p1

CARSAN, S., A.STROEBEL, I. DAWSON, R.KINDT, C.MBOW, J.MOWO & R. JAMNADASS, 2014. Can agroforestry option values improve the functioning of drivers of agricultural intensification in Africa? Current Opinion in Environmental Sustainability, 6, 35–40. doi:10.1016/j.cosust.2013.10.007

COASE, R. H.,1960. The Problem of Social Cost. The Journal of Law and Economics, 3, 1–44.

CONGALTON, R. G.,1996. Accuracy Assessment: A Critical Component of Land Cover Mapping. Gap Analysis. American Society for Photogrammetry and Remote Sensing, 119 – 131.

COSTANZA, R., 2003. Social goals and the valuation of natural capital. Environmental Monitoring and Assessment, 86(1-2), 19–28. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/12858996

COSTANZA, R., R ARGE, R. DE GROOT, S.FARBERK, M.GRASSO, B.HANNON, P. SUTTON, 1997. The value of the world ' s ecosystem services and natural capital, 387(May), 253–260.

CREMASCHI, D. G., R. D LASCO, & R. J. P. DELFINO, 2013. Payments for Watershed Protection Services : Emerging Lessons from the Philippines, 6(1), 90–103. doi:10.5539/jsd.v6n1p90

DAM, B. V, D. C.CATACUTAN & H. M. HA, 2014. Importance of National Policy and Local Interpretation in Designing Payment for Forest Environmental Services Scheme for the Ta Leng River Basin in Northeast Vietnam. Environment and Natural Resources Research, 4(1), 39–53. doi:10.5539/enrr.v4n1p39

DASGUPTA, P., 1996. The economics of the environment. Environment and Development Economics, 1(4), 387–428.

DAVID NIEMEIJER & R. S. DE GROOT. 2008. A conceptual framework for selecting environmental indicator sets. Ecological Indicators, 8(1), 14–25.

DAVID, W. P.,1988. SOIL AND WATER CONSERVATION PLANNING: Policy Issues and Recommendations. Journal of Philippine Development, 15(1), 47–84.

DEAL, R. L., B.COCHRAN, , & G. LAROCCO, 2012. Bundling of ecosystem services to increase forestland value and enhance sustainable forest management. Forest Policy and Economics, 17, 69–76. doi:10.1016/j.forpol.2011.12.007

DEAL, R. L., & R. WHITE, 2012. Integrating forest products with ecosystem services: A global perspective. Forest Policy and Economics, 17, 1–2. doi:10.1016/j.forpol.2012.02.014

DELGADO, M. E. M. & F.CANTERS, 2011. Modeling the impacts of agroforestry systems on the spatial patterns of soil erosion risk in three catchments of Claveria, the Philippines. Agroforestry Systems, 85(3), 411–423. doi:10.1007/s10457-011-9442-z

DENR, 2011a. Rehabilitation & Ecological Restoration R & D For Marginal & Degraded Landscapes And Seascapes: A Research Compendium for Marginal Uplands.

DENR, 2011b. Vulnerability Assessment of Carood Vulnerability Assessment of Carood: Technical Report.

DENR, 2012. Carood Watershed Forest Investment Plan (FIP).

ELMQVIST, T., E.MALTBY, T.BARKER, M. MORTIMER, C.PERRINGS, J. ARONSON, J.SALLES, 2010. Biodiversity , ecosystems and ecosystem services.

ELMQVIST, T., M. TUVENDAL, J.RISHNASWAMY & K.HYLANDER, 2011. Managing Trade-offs in Ecosystem Services.

ENGEL, S., S. PAGIOLA & S.WUNDER, 2008. Designing payments for environmental services in theory and practice: An overview of the issues. Ecological Economics, 65(4), 663–674. doi:10.1016/j.ecolecon.2008.03.011

ENGEL, S. & C. E.PALMER, 2008. Payments for environmental services as an alternative to logging under weak property rights: the case of Indonesia. Ecological Economics, 65(4), 799–809. doi:10.1016/j.ecolecon.2007.07.028

FAO. 2004. Strategic Environmental Assessment An Assessment Of The Impact Of Cassava Production And Processing On The Environment And Biodiversity. Rome.

FAO., 2010. Global Forest Resources Assessment 2010. Rome.

FARBER, S. C., R.COSTANZA & M. A. WILSON, 2002. Economic and ecological concepts for valuing ecosystem services. Ecological Economics, 41(3), 375–392. doi:10.1016/S0921-8009(02)00088-5

FARLEY, J., & R. COSTANZA, 2010. Payments for ecosystem services: From local to global. Ecological Economics, 69(11), 2060–2068. doi:10.1016/j.ecolecon.2010.06.010

FENECH, A., FOSTER, J., HAMILTON, K., & HANSELL, R., 2003. Natural capital in ecology and economics: an overview. Environmental Monitoring and Assessment, 86(1-2), 3–17. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/12858995

FISHER, B., K.KULINDWA, I.MWANYOKA, R. K.TURNER, & N. D.BURGESS, 2010. Common pool resource management and PES: Lessons and constraints for water PES in Tanzania. Ecological Economics, 69(6), 1253–1261. doi:10.1016/j.ecolecon.2009.11.008

FOLKE, C., 2006. Resilience: The emergence of a perspective for social–ecological systems analyses. Global Environmental Change, 16(3), 253–267. doi:10.1016/j.gloenvcha.2006.04.002

FONAFIFO & CONAFO, 2012. Lessons Learned for REDD + from PES and Conservation Incentive Programs (p. 164).

GARRITY, D. P., 1999. Participatory Approaches to catchment management: Some experiences to build upon. In A. R. Maglinao & R. Leslie (Eds.), Site selection and characterization: Focus on biophysical and socioeconomic inventory. Proceedings of the Managing Soil Erosion Consortium Assembly. Hanoi Vietnam.

GARRITY, D. P., 2004. Agroforestry and the achievement of the Millennium Development Goals, (August 2002), 5–17.

GASSMAN, P. W., M. R.REYES, C. H.GREEN & J. G. ARNOLD, 2007. The Soil And Water Assessment Tool: Historical Development, Applications, And Future Research Directions. American Society of Agricultural and Biological Engineers, 50(4), 1211–1250.

GIZ., 1975. Manual of reforestation and erosion control for the Philippines.

GOLDMAN-BENNER, R. L., S. BENITEZ, T.BOUCHER, A.CALVACHE, G. DAILY, P KAREIVA & A.RAMOS, 2012. Water funds and payments for ecosystem services: practice learns from theory and theory can learn from practice. Oryx, 46(01), 55–63. doi:10.1017/S0030605311001050

GÓMEZ-DELGADO, F., O.ROUPSARD, G.LE MAIRE, S TAUGOURDEAU, A.PÉREZ, M.ANOIJEN & R.MOUSSA, 2011. Modelling the hydrological behaviour of a coffee agroforestry basin in Costa Rica. Hydrology and Earth System Sciences, 15(1), 369–392. doi:10.5194/hess-15-369-2011

GROOT, R. B.DE, B. FISHER, M.CHRISTIE, J.ARONSON, L.BRAAT, J. GOWDY, S.SHMELEV, 2010. Integrating the ecological and economic dimensions in biodiversity and ecosystem service valuation.

HASKETT, J., & P. GUTMAN, 2010. Taking stock of the Global Environment Facility experience with payments for environmental service projects. In L. Tacconi, S. Mahanty, & H. Suich (Eds.), Payments for Environmental Services: Forest conservation and climate change livelihoods in the REDD? (pp. 26 – 54). Edward Elgar Publishing Ltd.

HEGDE, R., & G. Q.BULL, 2011. Performance of an agro-forestry based Payments-for-Environmental-Services project in Mozambique : A household level analysis. Ecological Economics, 71, 122–130. doi:10.1016/j.ecolecon.2011.08.014

HOLLING, C. S., 2001. Understanding the Complexity of Economic , Ecological , and Social Systems. Ecosystems, 4(5), 390–405. doi:10.1007/s10021-00

HUNTSINGER, L., & J. L. OVIEDO, 2014. Ecosystem Services are Social – ecological Services in a Traditional Pastoral System : the Case of California ' s Mediterranean Rangelands. Ecology and Society, 19(1), 8.

IFAD., 2009. Good practices in participatory mapping: A review prepared for the International Fund for Agricultural Development (IFAD).

IIAC., 2008. 80 TOOLS FOR PARTICIPATORY DEVELOPMENT (p. p218). Inter-American Institute for Cooperation on Agriculture.

INGRAM, J. C., D. WILKIE, T.CLEMENTS, R. B.MCNAB, F.NELSON, E. H.BAUR, C. A. H. FOLEY, 2014. Evidence of Payments for Ecosystem Services as a mechanism for supporting biodiversity conservation and rural livelihoods. Ecosystem Services, 1–12. doi:10.1016/j.ecoser.2013.12.003

JEANES, K., M.VAN NOORDWIJK, A. WIDAYATI FARIDA, L. JOSHI & B LEIMONA., 2006. Rapid Hydrological Appraisal. Bogor, Indonesia.

JOSE, S., 2009. Agroforestry for ecosystem services and environmental benefits: an overview. Agroforestry Systems, 76(1), 1–10. doi:10.1007/s10457-009-9229-7

KHASANAH, N., E.MULYOUTAMI, A. EKADINATA, T.ASMAWAN, Z.SAID, M. VAN NOORDWIJK, & B.LEIMONA, 2010. A Study of Rapid Hydrological Appraisal in the Krueng Peusangan Watershed , NAD , Sumatra (No. 123) (p. 53p). Bogor, Indonesia.

KOSOY, N., M.MARTINEZ-TUNA, R.MURADIAN & J.MARTINEZ-ALIER, 2007. Payments for Environmental Services in Watersheds : Insights From a Comparative Study of three Cases in Central America. Ecological Economics, 61, 446 – 455.

KRUTILLA, J. V., 1967. Conservation reconsidered. The American Economic Review, 57(4), 777 – 786.

LAMBIN, E. F., & P.MEYFROIDT, 2010. Land use transitions: Socio-ecological feedback versus socio-economic change. Land Use Policy, 27(2), 108–118. doi:10.1016/j.landusepol.2009.09.003

LASCO, R. D., R. V. O.CRUZ, J. M.PULHIN & F. B. PULHIN, 2010. Assessing Climate Change Impacts , Vulnerability and Adaptation Vulnerability and Adaptation (p. 95p).

LASCO, R. D. R. J. P.,DELFINO, D. C.CATACUTAN, E. S.SIMELTON,& D. M. WILSON, 2014. Climate risk adaptation by smallholder farmers: the roles of trees and agroforestry. Current Opinion in Environmental Sustainability, 6, 83–88. doi:10.1016/j.cosust.2013.11.013

LASCO, R. D., R. S.EVANGELISTA, & F. B. PULHIN, 2010. Potential of Community-Based Forest Management to Mitigate Climate Change in the Philippines. Small-Scale Forestry, 9, 429–443. doi:10.1007/s11842-010-9132-0

LASCO, R. D., N. A. D. MALLARI, F. B.PULHIN, A. M. FLORECE, E. L. B., RICO R. S. BALITON, & J. P. URQUIOLA, 2013.. Lessons from Early REDD + Experiences in the Philippines

LASCO, R. D., & G. B. VILLAMOR, 2010. Payments for ecological services: experiences in carbon and water payments in the Philippines. In Sustainability Science (pp. 103 – 124).

LASCO, R., F.PULHIN, A.ALFORTE & D.WILSON, 2014. Credits where credit's due: A guide to developing community level carbon forestry projects (1st ed.). World Agroforestry Centre (ICRAF).

LASCO, R., G.VILLAMOR, F.PULHIN, D CATACUTAN & M. BERTOMEU, 2008. From Principles to Numbers : Approaches in Implementing Payments for Environmental Services (PES) in the Philippines. In D. J. Snelder & R. D. Lasco (Eds.), Smallholder Tree Growing for Rural Development and Environmental Sciences (pp. 369–382). Springer Berlin Heidelberg.

LICCIARDELLO, F., C. G. ROSSI, R.SRINIVASAN, S. M. ZIMBONE, & S.BARBAGALLO, 2011. Hydrologic Evaluation Of A Mediterranean Watershed Using The Swat Model With Multiple Pet Estimation Methods. American Society of Agricultural and Biological Engineers ISSN, 54(5), 1615–1625.

LOPEZ, R. C., M. N. Q.HERRERA, & R. D. LASCO, 2011. Carbon-forestry projects in the Philippines: potential and challenges: the Quirino forest-carbon development project in Sierra Madre Biodiversity Corridor. (No. 132). doi:10.5716/WP11057.PDF

LOPEZ RC, L. R.IBAÑEZ JC, 2011. Carbon forestry projects in the Philippines: potential and challenges: the case of the Arakan Forest Corridor forest carbon project. (No. 130). doi:10.5716/WP11055.PDF

LOPEZ RC, FS, L. R.MIRASOL, 2011. Carbon-forestry projects in the Philippines: potential and challenges: the case of Mt Kitanglad Range forest-carbon development project. (No. 129). doi:10.5716/WP11054.PDF

LUSIANA, B., R.WIDODO, E.MULYOUTAMI, D. A NUGROHO & M. VAN. NOORDWIJK, 2008a. Assessing Hydrological Situation of Kapuas Hulu Basin , Kapuas Hulu Regency , West Kalimantan (p. 67p).

LUSIANA, B., R.WIDODO, E.MULYOUTAMI, D. A NUGROHO & M. VAN. NOORDWIJK, 2008b. Assessing Hydrological Situation of Talau Watershed , Belu Regency , East Nusa Tenggara (No. 58) (p. 72p).

LYNAM, T., W. DE JONG, D.SHEIL, T.KUSUMANTO & K.EVANS, 2007. A Review of Tools for Incorporating Community Knowledge , Preferences , and Values into Decision Making in Natural Resources Management. Ecology And Society, 12(1).

MA. 2005. Ecosystems and human well-being: synthesis.

MA, X., J. XU, Y LUO, S. P.AGGARWAL, J.& LI, 2009. Response of hydrological processes to land-cover and climate changes in Kejie watershed , south-west China. Hydrological Processes. doi:10.1002/hyp

MATULIS, B. S., (2013. The narrowing gap between vision and execution: Neoliberalization of PES in Costa Rica. Geoforum, 44, 253–260. doi:10.1016/j.geoforum.2012.09.001

MAXSON, M., & I. GUIJT, 2010. The " Real Book " for story evaluation methods Part I : Our journey with making sense of stories.

MBOW, C., P SMITH, D.SKOLE, L.DUGUMA & M. BUSTAMANTE, 2013. Achieving mitigation and adaptation to climate change through sustainable agroforestry practices in Africa. Current Opinion in Environmental Sustainability, 6, 8–14. doi:10.1016/j.cosust.2013.09.002

MBOW, C., M.,VAN NOORDWIJK, E.LUEDELING, H.NEUFELDT, P. A MINANG & G.KOWERO, 2014. Agroforestry solutions to address food security and climate change challenges in Africa. Current Opinion in Environmental Sustainability, 6, 61–67. doi:10.1016/j.cosust.2013.10.014

MILDER, J. C., S. J.SCHERR & C.BRACER, 2010. Trends and Future Potential of Payment for Ecosystem Alleviate Rural Poverty in Developing Countries. Ecology And Society, 15(2), 4.

MONTEITH, J. L., 1965. Evaporation and environment. Symposia of the Society for Experimental Biology, 19, 205 – 224.

MONTGOMERY, D. R., 2007. Soil erosion and agricultural sustainability. Proceedings of the National Academy of Sciences of the United States of America, 104(33), 13268–72. doi:10.1073/pnas.0611508104

MÜLLER, F & B.BURKHARD, 2012. The indicator side of ecosystem services. Ecosystem Services, 1(1), 26–30. doi:10.1016/j.ecoser.2012.06.001

MURADIAN, R., E. CORBERA, U. PASCUAL, N. KOSOY, & P. H. MAY, 2010. Reconciling theory and practice: An alternative conceptual framework for understanding payments for environmental services. Ecological Economics, 69(6), 1202–1208. doi:10.1016/j.ecolecon.2009.11.006

NAHLIK, A. M., M. E.KENTULA, M. S.FENNESSY & D. H.LANDERS, 2012. Where is the consensus? A proposed foundation for moving ecosystem service concepts into practice. Ecological Economics, 77, 27–35. doi:10.1016/j.ecolecon.2012.01.001

NAMIREMBE, S. B. LEIMONA, M.VAN NOORDWIJK, F.BERNARD & K. E.BACWAYO, 2014. Co-investment paradigms as alternatives to payments for tree-based ecosystem services in Africa. Current Opinion in Environmental Sustainability, 6, 89–97. doi:10.1016/j.cosust.2013.10.016

NAP., 2010. The Updated Philippine National Action Plan to Combat Desertification , Land Degradation and Drought (DLDD).

NEITSCH, S. L., J. G.,ARNOLD, J. R KINIRY & J. R. WILLIAMS, 2005. Soil and water assessment tool theoretical documentation. (Version 20.).

NOORDWIJK, M. VAN, & B.LEIMONA, 2010. Principles for Fairness and Efficiency in Enhancing Environmental Services in Asia : Payments , Compensation , or Co-Investment ?, 15(4).

NOORDWIJK, M. VAN, P. SAIPOTHONG, F.AGUS, K. HAIRIAH, D SUPRAYOGO & B.VERBIST, 2006. Watershed functions in productive agricultural landscapes with trees. In World Agroforestry into the Future. Nairobi: World Agroforestry Centre (ICRAF).

OSTROM, E., & COX, M., 2010. Moving beyond panaceas: A multi-tiered diagnostic approach for social–ecological analysis. Environmental Conservation, 37, 451–461.

PAGIOLA, S., A.ARCENAS & G. PLATAIS, 2005. Can Payments for Environmental Services Help Reduce Poverty? An Exploration of the Issues and the Evidence to Date from Latin America. World Development, 33(2), 237–253. doi:10.1016/j.worlddev.2004.07.011

PAGIOLA, S., E. RAMÍREZ, J.GOBBI, C.DE HAAN, M.IBRAHIM, E.,MURGUEITIO & J. P.RUÍZ., 2007. Paying for the environmental services of silvopastoral practices in Nicaragua. Ecological Economics, 64(2), 374–385. doi:10.1016/j.ecolecon.2007.04.014

PAGIOLA, S., A. R.RIOS & A.ARCENAS, 2010. Poor Household Participation in Payments for Environmental Services: Lessons from the Silvopastoral Project in Quindío, Colombia. Environmental and Resource Economics, 47(3), 371–394. Retrieved from http://www.springerlink.com/index/10.1007/s10640-010-9383-4

PALAO, L. K. M., M. M.DORADO, K. P. A.,ANIT & R. D. LASCO, 2013. Using the Soil and Water Assessment Tool (SWAT) to Assess Material Transfer in the Layawan Watershed, Mindanao, Philippines and Its Implications on Payment for Ecosystem Services. Journal of Sustainable Development, 6(6), 73–88. doi:10.5539/jsd.v6n6p73

PATTANAYAK, S. K., 2004. Valuing watershed services: concepts and empirics from southeast Asia. Agriculture, Ecosystems & Environment, 104(1), 171–184. doi:10.1016/j.agee.2004.01.016

PETHERAM, C., P. RUSTOMJI, F. H. S.CHIEW & J.VLEESHOUWER, 2012. Rainfall–runoff modelling in northern Australia: A guide to modelling strategies in the tropics. Journal of Hydrology, 462-463, 28–41. doi:10.1016/j.jhydrol.2011.12.046

PIMENTEL, D., 2006. Soil Erosion: A Food and Environmental Threat. Environment, Development and Sustainability, 8(1), 119–137. doi:10.1007/s10668-005-1262-8

PIRARD, R., 2012. Payments for Environmental Services (PES) in the public policy landscape: “Mandatory” spices in the Indonesian recipe. Forest Policy and Economics, 18, 23–29. doi:10.1016/j.forpol.2011.09.002

PIRARD, R., R. BILLÉ, & T.SEMBRÉS, 2010. Upscaling Payments for Environmental Services (PES): Critical issues. Science, 3(3), 249–261. Retrieved from http://tropicalconservationscience.mongabay.com/content/v3/10-09-27_249-261_Pirard_et_al.pdf

PONTIUS, R. G.& M.MILLONES, 2011. Death to Kappa: birth of quantity disagreement and allocation disagreement for accuracy assessment. International Journal of Remote Sensing, 32(15), 4407–4429. doi:10.1080/01431161.2011.552923

PORRAS, I., M GRIEG-GRAN & N.NEVES, 2008. All that glitters: A review of payments for watershed services in developing countries. London.

POTSCHIN, M. B., & R. H. HAINES-YOUNG, 2011. Ecosystem services: Exploring a geographical perspective. Progress in Physical Geography, 35(5), 575–594. doi:10.1177/0309133311423172

PRIMMER, E. & E.FURMAN, 2012. Operationalising ecosystem service approaches for governance: Do measuring, mapping and valuing integrate sector-specific knowledge systems? Ecosystem Services, 1(1), 85–92. doi:10.1016/j.ecoser.2012.07.008

PUHLIN, F. B.,& R. D.LASCO, 2008. Mitigation of and adapation to climate change through agroforestry systems. Readings on Climate Change and Natural Resource Management, 19–35.

ROBARDS, M. D., M. L.SCHOON, C. L.MEEK, & N. L.ENGLE, 2011. The importance of social drivers in the resilient provision of ecosystem services. Global Environmental Change, 21(2), 522–529. doi:10.1016/j.gloenvcha.2010.12.004

SACHS, J. D., & A. M. WARNER, 1995. Natural Resource Abundance and Economic Growth (No. 5398) (Vol. 3).

SAGOFF, M., 2011. The quantification and valuation of ecosystem services. Ecological Economics, 70(3), 497–502. doi:10.1016/j.ecolecon.2010.10.006

SALAS, J. C., 2004. Case Study Of The Maasin Watershed: Analyzing the Role of Institutions in a Watershed-Use Conflict.

SALLES, J.-M., 2011. Valuing biodiversity and ecosystem services: Why put economic values on Nature? Comptes Rendus Biologies, 334(5-6), 469–82. doi:10.1016/j.crvi.2011.03.008

SANTOS MARTIN, F., & M.VAN NOORDWIJK, 2011. Is native timber tree intercropping an economically feasible alternative for smallholder farmers in the Philippines? Australian Journal of Agricultural and Resource Economics, 55(2), 257–272. doi:10.1111/j.1467-8489.2011.00530.x

SMITH, H. F., & C. A.SULLIVAN, 2014. Ecosystem services within agricultural landscapes—Farmers' perceptions. Ecological Economics, 98, 72–80. doi:10.1016/j.ecolecon.2013.12.008

SORIAGA, R., & D.ANNAWI, 2010. The "No-Fire Bonus" Scheme in Mountain Province, Cordillera Administrative Region, Philippines. In L. Taccon, S. Mahanty, & H. Suich (Eds.), Payments for Environmental Services, Forest Conservation and Climate Change Livelihoods in the REDD? Edward Elgar Publishing Ltd.

SRINIVASAN, R., C. SANTHI, R. D.HARMEL & A. VAN.GRIENSVEN, 2012. Swat: Model Use, Calibration, And Validation. American Society of Agricultural and Biological Engineers, 55(4), 1491–1508.

SWALLOW, B. M., M. F.KALLESOE, U. A.IFTIKHAR, M. VAN NOORDWIJK, & C.BRACER, 2009. Compensation and Rewards for Environmental Services in the Developing World : Framing Pan-Tropical Analysis and Comparison. Ecology And Society, 14(2).

TACCONI, L., 2012. Redefining payments for environmental services. Ecological Economics, 73(4), 29–36. doi:10.1016/j.ecolecon.2011.09.028

TACCONI, L., S.MAHANTY, & H.SUICH, 2010. Forests, payments for environmental services and livelihoods. In Payments for Environmental Services: Forest conservation and climate change livelihoods in the REDD? (pp. 1 – 25). Edward Elgar Publishing Ltd.

TEEB., 2010. The Economics of Ecosystems and Biodiversity: Mainstreaming the Economics of Nature: A synthesis of the approach, conclusions and recommendations of TEEB. (Array, Ed.)Environment (p. 39). Progress Press. Retrieved from http://www.iges.or.jp/jp/news/topic/pdf/1103teeb/teeb_synthesis_j.pdf

TOMICH, T. P., D. E.THOMAS, & M. VAN NOORDWIJK, 2004. Environmental services and land use change in Southeast Asia: from recognition to regulation or reward? Agriculture, Ecosystems & Environment, 104(1), 229–244. doi:10.1016/j.agee.2004.01.017

TROY, A., & M. A.WILSON, 2006. Mapping ecosystem services: Practical challenges and opportunities in linking GIS and value transfer. Ecological Economics, 60(2), 435–449. doi:10.1016/j.ecolecon.2006.04.007

TURNER, R. K., J.PAAVOLA, P.COOPER, S.FARBER, V.JESSAMY & S. GEORGIOU, 2003. Valuing nature: lessons learned and future research directions. Ecological Economics, 46(3), 493–510. doi:10.1016/S0921-8009(03)00189-7

VAN NOORDWIJK, M. 2005. Rupes Typology Of Environmental Service Worthy Of Reward.

VAN NOORDWIJK, M., M. H.HOANG, H.NEUFELDT, I.ÖBORN, & T.YATICH, 2011. How trees and people can co-adapt to climate change Reducing vulnerability in multifunctional landscapes. (M. van Noordwijk, M. H. Hoang, H. Neufeldt, I. Öborn, & T. Yatich, Eds.). Nairobi: World Agroforestry Centre (ICRAF).

VAN NOORDWIJK, M., B.LUSIANA, B. LEIMONA, S.DEWI & D. WULANDARI,. 2013. Negotiation support toolkit for learning landcspaes (Vulme 2 Ed.). World Agroforestry Centre, Southeast asia regional Program.

VAN NOORDWIJK, M., S. NAMIREMBE, D CATACUTAN, D.WILLIAMSON & A.GEBREKIRSTOS, 2014. Pricing rainbow, green, blue and grey water: tree cover and geopolitics of climatic teleconnections. Current Opinion in Environmental Sustainability, 6, 41–47. doi:10.1016/j.cosust.2013.10.008

VATN, A., 2009. An institutional analysis of payments for environmental services. Ecological Economics, 69(6), 1245 – 1252.

VATN, A., & D. W. BROMLEY, 1997. Externalities- A Market Model Failure. Environmental and Resource Economics, 9, 135–151.

VIGNOLA, R., T. L.MCDANIELS, & R. W. SCHOLZ, 2012. Negotiation analysis for mechanisms to deliver ecosystem services: The case of soil conservation in Costa Rica. Ecological Economics, 75, 22–31. doi:10.1016/j.ecolecon.2012.01.004

VILLAMOR, G. B., & R. D.LASCO, 2009. Rewarding Upland People for Forest Conservation: Experience and Lessons Learned from Case Studies in the Philippines. Journal of Sustainable Forestry, 28(3-5), 304–321. doi:10.1080/10549810902791499

VIRA, B., B.ADAMS, C.AGARWAL, S. BADIGER, J. KRISHNASWAMY & C. KUMAR, 2012. Negotiating Trade-offs. Economic & Political Weekly, xlvii(9), 67–76.

WALLACE, K. J., 2007. Classification of ecosystem services: Problems and solutions. Biological Conservation, 139(3-4), 235–246. doi:10.1016/j.biocon.2007.07.015

WENDLAND, K. J., M. HONZÁK, R.PORTELA, B.VITALE, S.RUBINOFF & J.RANDRIANARISOA, 2010. Targeting and implementing payments for ecosystem services: Opportunities for bundling biodiversity conservation with carbon and water services in Madagascar. Ecological Economics, 69(11), 2093–2107. doi:10.1016/j.ecolecon.2009.01.002

WILSON, M. A., & J. P HOEHN,. 2006. Valuing environmental goods and services using benefit transfer: The state-of-the art and science. Ecological Economics, 60(2), 335–342. doi:10.1016/j.ecolecon.2006.08.015

WINKLER, R. D., D. D. MOORE, R. T. E.REDDING, D. L. SPITTLEHOUSE, CARLYLE- D. E.MOSES, & B. D. SMERDON, 2002. Hydrologic Processes and Watershed Response, 133–178.

WRI. no.date. Aqueduct. Retrieved March 14, 2013, from http://aqueduct.wri.org/atlas

WUNDER, S., 2005. Payments for environmental services : Some nuts and bolts. CIFOR Occasional Paper, 42(42), 32. Retrieved from http://www.cifor.cgiar.org/publications/pdf_files/OccPapers/OP-42.pdf

WUNDER, S., S.ENGEL, & S. PAGIOLA, 2008. Taking stock: A comparative analysis of payments for environmental services programs in developed and developing countries. Ecological Economics, 65(4), 834–852. doi:10.1016/j.ecolecon.2008.03.010

YIN, R., & M. ZHAO, 2012. Ecological restoration programs and payments for ecosystem services as integrated biophysical and socioeconomic processes—China's experience as an example. Ecological Economics, 73, 56–65. doi:10.1016/j.ecolecon.2011.11.003

ZHENG, H., B. E.ROBINSON, Y.-C LIANG, S.POLASKY, D.-C MA, F.-C.WANG. G. C. DAILY, 2013. Benefits, costs, and livelihood implications of a regional payment for ecosystem service program. Proceedings of the National Academy of Sciences of the United States of America, 110(41), 16681–6. doi:10.1073/pnas.1312324110

Appendix A

Baseline Watershed Environmental Services Questionnaire

1. Your Organisation

Name of Organisation: Municipality:

Number of employees at site or people active in community organisation:

Name of person completing form: Position:

Contact tel no: Contact email:

1.1 Type of Organisation

☐ Central Government Department	☐ Peoples Organisation	☐ Private sector company (Manufacture/Processing)
☐ Local Government	☐ Non-government Organisation (local)	☐ Agriculture sector organisation
☐ Health Sector – clinic/hospital	☐ Non-government organisation (nat/intl)	☐ Fisheries sector organisation
☐ Education Sector – school/university	☐ Other voluntary sector	☐ Food Processing company
☐ Other Public Sector	☐ Tourism or Leisure, incl Hotel/Restaurant/Bar	☐ Small Private Sector/ Commercial/Shop

1.2 Use of Water by Your Organisation

1.2.1 What is your current source of water?

☐ Spring

☐ Deep well

☐ Shallow well

☐ Water service provider (specify who)___________________________

☐ Direct from river

☐ Do not know

1.2.2 Are you currently paying for your water? ☐ Yes ☐ No

How much do you pay per month? ______________Pesos/month

Approximately how much water does your organisation use each month?_________m3

1.2.3 What happens to your wastewater or sewerage?

☐ Goes to septic tank or cesspit

☐ Goes to sewer

☐ Goes to river/stream

☐ Goes to land

☐ Goes to sea

☐ Do not know

1.2.4 What does your organisation use water for?

☐ Domestic use – including washing, cleaning, toilet flushing

☐ Agriculture/Fisheries/Food – irrigation, livestock**,** cleaning, processing

☐ Industry – cleaning, separating production

1.2.5 Have you heard the term 'environmental service' or 'watershed service'?

☐ Yes ☐ No

How would you describe the environmental services provided by the Carood watershed?

____

____

1. **Your Organisation and Existing Environmental Services in Carood**

   Please tell us about environmental services that you deliver.

   N.B. *Other environmental watershed services may include land or water based activities which affect the watershed catchment area: Farming; Forestry; Fishing; Aquaculture; Road building; House Building; Waste management;

Services for tourists; Manufacturing using agroforestry or mangrove products; Mineral extraction (sand, gravel, limestone);

Existing Management of Water Services in Carood Watershed	Inside Carood	Outside Carood/ Adjoin. Land	***Other existing Environmental Services in Carood Watershed**	Inside Carood	Outside Carood/ Adjoin. Land
Supplier of water – including storage, treatment or distribution.	☐	☐	Provider of other environmental watershed services.	☐	☐
User of Water – domestic or any commercial use.	☐	☐	User of other environmental watershed services.	☐	☐
Managing land for collection or storage of water.	☐	☐	Managing land for other watershed services.	☐	☐
Wastewater collection, treatment or discharge.	☐	☐	Collection or treatment of waste in watershed.	☐	☐
Provide Emergency Services, e.g. water supply or flood prevention.	☐	☐	Provide Emergency Services – landslides, fires.	☐	☐
Future Planning for water management including flood defence.	☐	☐	Future Planning for watershed management.	☐	☐
Investment in water	☐	☐	Investment in other	☐	☐

services.			watershed services.		
Data management on water or wastewater (including rainfall).	☐	☐	Data management on other watershed services.	☐	☐
Legal duty to supply, develop or protect water bodies; e.g. water abstraction permits.	☐	☐	Legal duty to supply, develop or protect other environmental watershed services.	☐	☐
Other water related service, e.g. swimming pool, tourist spring.	☐	☐	Any other environmental service	☐	☐

Depending on your answers to Question 2, only some of the following sections may apply to your organisation or company.

2. Providers of Water Related Services in Carood

3.1 **What your organisation delivers**

If your organisation is involved in delivering any of the following services in Carood please specify activities under each heading:

Land Management	Construct Water Facilities	Storage of Water	Treatment of Water	Distribution of Water	Wastewater Treatment	Flood Prevention
e.g. to help collect, supply or store water - springs, drainage, irrigation	e.g. storage, wells, distribution systems	e.g. dams, lakes, tanks, ponds.	e.g. sand filtration, chlorination or other treatment	e.g. pumping, laying pipes, controlling supply, leakage control;	e.g. sewerage, building septic tanks, treating wastewater	e.g. managing riverbanks, floodplains, mangroves, drainage.

3.2 **Capacity of any water facilities you manage.**

Any information on water facilities managed by your organisation would be much appreciated.

Water Facility/ Watershed Land Managed	**Capacity or average daily flow**	**Min. Flow** m3/day	**Max Flow** m3/day	**No of homes serviced**	**No of orgs serviced**	**Other specifics (please attach any other info)**
Area of land managed (ha)						
Spring water (m3/day)						
Water storage facilities (m3)						
Water treatment facility (m3/day)						
Water into supply network (m3/day)						

Water distribution network (km)
Water pumping stations (m3/day)
Wastewater sewerage (km)
Wastewater septic tanks (capacity m3)
Wastewater treatment (m3/day)
Flood prevention area (ha)
Drainage channels (km)
Irrigation channels for farmland (km)
Public swimming pools /other water facilities (m3)

3. **Data on Carood Water and Wastewater**

4.1 Water Quantity Data

Does your organisation hold any monthly, seasonal or annual quantitative data on water, e.g. rainfall, water in storage, water run-off, underground water or water supplied?

☐Yes ☐No

If yes please specify what information you have

____

____

Are you able and willing to share data with CWMC? ☐ Yes ☐ No

4.2 Water Quality Data – chemical or biological

Does your organisation hold any monthly, seasonal or annual qualitative data on water e.g. spring, well, mains tap, river, groundwater or coastal water? ☐Yes ☐ No

If yes please specify what information you have

____

____

Are you able and willing to share data with CWMC? ☐Yes ☐ No

4.3 Aquifer – Groundwater Zones

Does your organisation hold any data, maps or aquifer management plans on the vulnerability of groundwater? ☐Yes ☐No

If yes please specify what information you have

____

____

Are you able and willing to share data with CWMC? ☐ Yes ☐ No

4.4 Flood Risks

Does your organisation hold any data, maps or flood management plans on areas at risk of flooding?

☐Yes ☐ No

If yes please specify what information you have

____

____

Are you able and willing to share data with CWMC? ☐ Yes ☐ No

4.5 Sources of Pollution

Does your organisation hold any data on current or historic sources of pollution, e.g. household waste disposal, cemeteries, abattoirs, industrial or manufacturing waste?

☐Yes ☐ No

If yes please specify what information you have

____

____

____

Are you able and willing to share data with CWMC? ☐Yes ☐ No

4. **Priorities in Relation to Carood Watershed Management**

5.1 Has your organisation identified any concerns or problems with the management of Carood Watershed?

☐Yes ☐No

Please specify which concerns

____

____

5.2 If you have identified environmental problems who do you think is responsible for them?

____

____

5.3 Please specify your organisations **top five priorities** for improved delivery of watershed environmental services in Carood, where 1 = Highest Priority, 2= Next Highest Priority, 3= 3rd Priority, 4= 4th Priority, 5= Lowest Priority of top five priorities.

Issue	**Priority**	**Issue**	**Priority**
Mains (tap) water quality		Deforestation	
Mains (tap) water supply		Illegal Logging	
Well water quality		Grassland/forest fires	
Well water supply		Livestock management	
Spring water quality		Intensive agriculture	
Spring water supply		Harvesting non-timber products	
River water quality		Mangrove depletion	
River water supply		Illegal fishing	

Irrigation water quality		Fish farming	
Irrigation water supply		Sand and gravel extraction	
Coastal water quality		Solid waste management	
Seasonal flooding		Other sources of pollution	
Poor drainage		Loss of biodiversity	
Soil water salinity		Livelihood opportunities	
Soil erosion		Urbanisation- planning controls	
Landslides		Storms and typhoons	

Specify any other issues____

____

____

Any other comments____

____

____

For further information please contact Sally Kelling or Lilibeth Perocho at cwmc.bohol@gmail.com

Thank you for your time and valuable input to this questionnaire

Workshop Attendees (August 16th and 19th 2013)

Page 1

Republic of the Philippines
Department of Environment and Natural Resources
COMMUNITY ENVIRONMENT AND NATURAL RESOURCES OFFICE
Talibon, Bohol

ATTENDANCE SHEET

Workshop on Payment for Environmental Services Baseline & Priorities for Action

	NAME	GENDER M	GENDER F	POSITION/ DESIGNATION	ADDRESS	SIGNATURE (permission for use of photos)
1	JUANA C. ROUAL (ANNIE)		✓	CIDO (LGREAU MUNICIPALITY)	CATIGBIAN	
2	ANECITO C. MIASCO	✓		MDRRMO	ALICIA, BOHOL	
3	JAILANI P. FERNANDEZ	✓		Cartographer-I	DENR-7, ORED	
4	JOVENCIO D. TAER	✓		FSWEZMS	PENRO-BOHOL	
5	Elpidio Inlang	✓		CENRO	CENRO, Tagb.	
6	Arturo C. Ocatine	✓		FMS	TALIBON	
7	Rosvil Betos		✓	Information Officer	DENR – CENRO TALIBON	
8	MA. THERESA V. LAPESE		✓	FMS Planning	DENR-R7	
9	Fulgencio J. Ugay	✓		Agric'l Techno.	DA-USF, Lomanggog	
10	Alexis L. Suaybaguio	✓		NIA SWRFT-OIC	NIA-Ubay	
11	FELIX L. GUIOGUIO	✓		NIA SWRFT-OIC	NIA-CARMEN	
12	EVARISTO JUMAWAN	✓		DENR	CENRO, Talibon	
13	Edgar B. Osuña	✓		IDO-A	Pilar, Bohol	
14	ETTIENCIO S. HOYA	✓		HOPWODEST	PILAR, BOHOL	
15	Amelia B. Pamine		✓	MSPWASCO-Bkkeeper	San Pascual	
16	JOEL V. OTERO	✓		PANTAWID PAMILYA 4Ps.	SAN PASCUAL	
17	Estrella C. Abueva		✓	MSPWASCO	San Pascual, Ubay	
18	Reynaldo B. Cutaran	✓		MSPWASCO	San Pascual, Ubay	
19	Albarando, Bernardita		✓	P.O. CHAIR UFTPAI	San Pascual, Ubay	
20	Carmen C. Cutanan		✓	MA	Ubay, Pilar, Alicia	
21	Merlyn Senato		✓	P.O. officer	UFTPAI, Sn Pascual	MSenato
22	Concepcion Cerar		✓	P.O. "	-do-	Ccuer
23	Wilfredo Catahum	✓		Pg. Pres. Alicia	AFPAI	W.Catahum
24	Nora Montesa	✓		PO, D4D VSO	TAC CITY	
25	Sherlita Catahum		✓	Po member	AFTPAI Alicia	S.Catahum
26	DIOMEDES C. BOYLES SR.	✓		Mngr. FIPAMCO coop	BENLIW, UBAY	D.Boyles
27	Bundia B. Bagtayop			BOD " "	"	A.Bagtayop
28	Leonilo Lafuente	✓		Forestry Resource Mgt-DIV.	BEMO	
29	Sally Kelling		✓	VSO-CWMFMC	CANDIJAY	
30	RONILITA M. BUHAPO		✓	PDO-III EMS	PPDO-Tagb.	
31	Ma. Imelda Bunnag		✓	PPRD		
32	MA. TRINIDAD M. CASENAS		✓	OHM	"	
33	LYDIA C. LAJA		✓	MPDC	LGU-Alicia	
34	TEOTIMO C. BAGHUCAN			ENGR III	DPWH-B3	
35	NARCISO O. BELTRAN	✓		ARCHITECT II	DPWH-B-3	
36	DAVE WILSON	✓		ICRAF STUDENT	MANILA	
37	Teofilano C. Tuyogon	✓		BISU RDE Director	CANDIJAY	
38	Nora B. Nanggun		✓	MA	UBAY	
39	ISABELO MONTEJO	✓		RED - DENR VII	CEBU	
40						

Page 1

Republic of the Philippines
Department of Environment and Natural Resources
COMMUNITY ENVIRONMENT AND NATURAL RESOURCES OFFICE
Talibon, Bohol

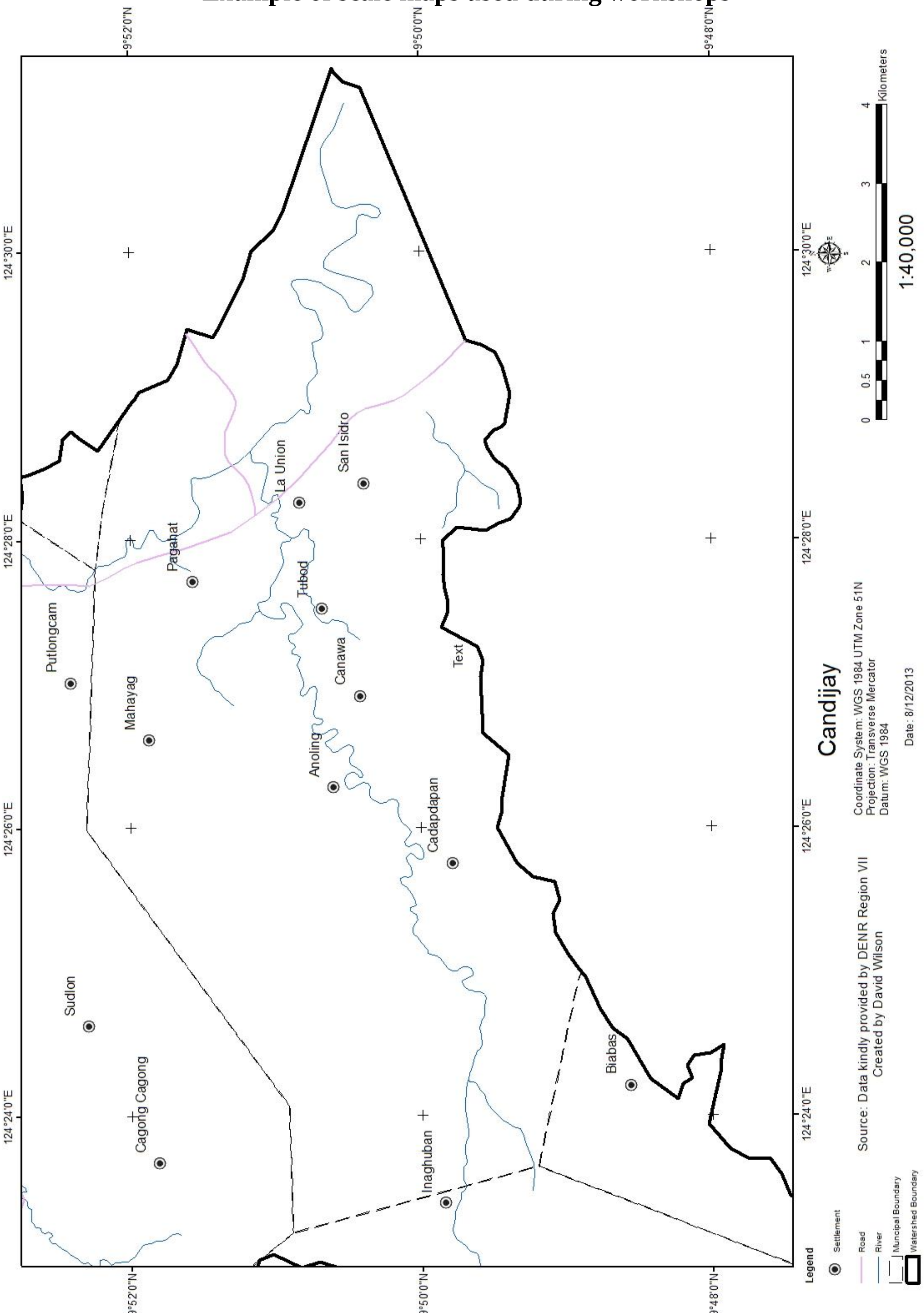
ATTENDANCE SHEET

Workshop on Payment for Environmental Services Baseline & Priorities for Action

	NAME	GENDER M	GENDER F	POSITION/ DESIGNATION	ADDRESS	SIGNATURE (permission for use of photos)
1	CASILDA N. PIQUERO		✓	BOD	BOYO-AN, CANDIJAY	[signature]
2	EDWIN D. LEDAMON	✓		FORESTER	DANAO CITY, CEBU	[signature]
3	LILIBETH PEROCHO		✓	On-site Forester, CWMF	Tubod, Candijay	[signature]
4	Restituto A. Piollo, Jr.	✓		BEMO – FRM Staff	Bilar, Bohol	[signature]
5	Petronilo P. Campoamor				@ L-daan, Candijay	[signature]
6	Ruth Rubio		✓	Carood Volunteer		[signature]
7	FLORENTINO [illegible]	✓		P.O. Pres PAMAS		[signature]
8	BIBIANO BUMAYA	✓		Treas. MCOI	CANDIJAY BOHOL	[signature]
9	FELIX P. CARIAS	✓		Brgy. Kag.	Guindulman Bohol	[signature]
10	Erminita S. [illegible]		✓	HAO	Candijay, Bohol	[signature]
11	TEOFILA G. ESTURDA		✓	Secretary - PAMAS	Panadtaran, Candijay	[signature]
12	BEDA T. GALARIDO		✓	Treas. – PAMAS	Panadtaran, Candijay	[signature]
13	Edurmita C. Buscano			Bookkeeper PAMAS	Panadtaran	[signature]
14	PRIMO E. TUTOR	✓		PO BRDS MRAI	MABINI	[signature]
15	[illegible] D. Rodriguez	✓		P.O. Pres. MCAA	Cadapdapan	[signature]
16	Hilario A. Pepero	✓		PRO: MCAA	Cadapdapan	[signature]
17	JULIET M. SALGADOS		✓	Lab. Manager, HNU Water Testing Laboratory	Tagbilaran City	[signature]
18	~~EMMANUEL BANTILAN~~					
19	EMMANUEL BANTILAN	✓	✓	SYSTEM MANAGER	GUINDULMAN	[signature]
20	RAMON CASTRO	✓		Chairman BOD GUIWASSAO		[signature]
21	Edio Calipes	✓		Brgy Capt.	Bulingit, Bayong	[signature]
22	Antonio Beefono	✓		Brgy. Kag.	Guindulman	[signature]
23	Aquinco J. Bernalia	✓		ATIMAO Rep.	Mabini	[signature]
24	Mercedes Estoreba	✓		Brgy. Kag. BOD - PAMAS	Panadtaran	[signature]
25	Alberto G. Bernaly	✓		MPDC	Tagas Candijay Bohol	[signature]
26	Geoffrey E. Gulay	✓		AT-I	LGU Guindulman	[signature]
27	RICARDO [illegible] SUMAUND	✓		P.M.		[signature]
28	SHERWIN OLAIVAR	✓		MAFWASA PRES. MABINI		[signature]
29	PABLO D. BERTUMEN	✓		MPDC - LGU GUINDULMAN		[signature]
30	Sally Kelling		✓	VSO – CWMFMC		[signature]
31	DAVE WILSON	✓		ICRAF	MANILA	[signature]
32	Rogelio Timbal	✓		Phil.	Roma	[signature]
33						

Appendix C

Example of scale maps used during workshops



Appendix D

Temporal Land use activity template